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Education and Differential Vulnerability to Natural Disasters

Butz, W.P., Lutz, W. and Sendzimir, J.

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Guest Editors: William P. Butz, Wolfgang Lutz, Jan Sendzimir
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Wittgenstein Centre
FOR DEMOGRAPHY AND GLOBAL HUMAN CAPITAL
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Special Feature Abstract

The collection of articles in this Special Feature is part of a larger project on "Forecasting Societies' Adaptive Capacity to Climate Change" (an Advanced Grant of the European Research Council to Wolfgang Lutz). In investigating how global change will affect population vulnerability to climate variability and extremes, the project aims to help develop strategies that enable societies to better cope with the consequences of climate change. In doing so, the basic hypothesis being tested is that societies can develop the most effective long-term defense against the dangers of climate change by strengthening human capacity, primarily through education. Education can directly influence risk perception, skills and knowledge and indirectly reduce poverty, improve health and promote access to information and resources. Hence, when facing natural hazards or climate risks, educated individuals, households and societies are assumed to be more empowered and more adaptive in their response to, preparation for, and recovery from disasters. Indeed the findings from eleven original empirical studies set in diverse geographic, socioeconomic, cultural and hazard contexts provide consistent and robust evidence on the positive impact of formal education on vulnerability reduction. Highly educated individuals and societies are reported to have better preparedness and response to the disasters, suffered lower negative impacts, and are able to recover faster. This suggests that public investment in empowering people and enhancing human capacity through education can have a positive externality in reducing vulnerability and strengthening adaptive capacity amidst the challenges of a changing climate.

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Is Education a Key to Reducing Vulnerability to Natural Disasters and hence Unavoidable Climate Change?

Raya Muttarak [1] *and Wolfgang Lutz* [1]

ABSTRACT. The collection of articles in this Special Feature is part of a larger project on "Forecasting Societies' Adaptive Capacity to Climate Change" (an Advanced Grant of the European Research Council to Wolfgang Lutz). In investigating how global change will affect population vulnerability to climate variability and extremes, the project aims to help develop strategies that enable societies to better cope with the consequences of climate change. In doing so, the basic hypothesis being tested is that societies can develop the most effective long-term defense against the dangers of climate change by strengthening human capacity, primarily through education. Education can directly influence risk perception, skills and knowledge and indirectly reduce poverty, improve health and promote access to information and resources. Hence, when facing natural hazards or climate risks, educated individuals, households and societies are assumed to be more empowered and more adaptive in their response to, preparation for, and recovery from disasters. Indeed the findings from eleven original empirical studies set in diverse geographic, socioeconomic, cultural and hazard contexts provide consistent and robust evidence on the positive impact of formal education on vulnerability reduction. Highly educated individuals and societies are reported to have better preparedness and response to the disasters, suffered lower negative impacts, and are able to recover faster. This suggests that public investment in empowering people and enhancing human capacity through education can have a positive externality in reducing vulnerability and strengthening adaptive capacity amidst the challenges of a changing climate.

Key Words: *adaptive capacity; climate change; differential vulnerability; education; human capital; natural disasters*

INTRODUCTION

While there is substantial ongoing research assessing the impact of future climate change on the Earth's physical systems, there are few systematic and comprehensive assessments on the likely impacts that change will have on future human well-being, given that not all people are equally vulnerable. It is admittedly very difficult if not impossible to try to assess how dangerous climate change will be in general for the future of humanity. But we still have to make policy choices today about what are priority investments that help to reduce the vulnerabilities of people in different parts of the world to already unavoidable climate change.

Given our ignorance about the extent of the overall threat, it makes sense to try to refer to things we think we know with high certainty. One is the fact that the social sciences have shown very clearly that to almost any kind of risk people are not equally vulnerable. Vulnerabilities vary by age, gender, education, level of income, location and many other factors. Hence it is plausible to assume that the future will also see differential vulnerability to the hazards associated with climate change. But from a policy perspective we also would like to know which of these differentials matter most? The set of papers in this collection will address this question with respect to empirical analysis of vulnerability to past natural disasters, since this is the only empirical evidence – assumed to be isomorphic to what we expect under climate change – that we have on the table. More specifically, the papers will contribute to testing the hypothesis that education is a key factor in reducing vulnerability as compared to other potentially relevant factors.

This collection of papers is one of the results of a larger project on "Forecasting Societies' Adaptive Capacity to Climate Change" (an Advanced Grant of the European Research Council to Wolfgang Lutz). This project is an ambitious effort to better understand what changes societies are likely to undergo over the next several decades, and determine how those changes will affect their vulnerability to a climate that is more extreme than it is today. The aim is to help develop strategies that enable societies to better cope with the consequences of climate change. The threats come most directly from increasingly intense extreme natural events, such as hurricanes, floods, forest fires and heat waves. Danger also comes from more gradual events, such as sea-level rise and changing regional temperature and humidity patterns that make agricultural production more difficult. Changing climate patterns also can increase the spread of disease.

The extent to which these events will increase human misery and death depends, in part, on the future vulnerability of the people affected. The starting assumption of the project was that a robust and resilient society will be better able to weather the storms of climate change than a society with few resources and limited coping skills. In this project those skills and capabilities are being measured and projected through the educational attainment distributions of populations by age and gender.

The basic hypothesis being tested is that societies can develop the most effective long-term defense against the dangers of climate change by strengthening human capacity, primarily through education – which helps to improve health, eradicate extreme poverty and reduce population growth. The empirical studies published in this special issue try to assess its validity under very diverse geographic, socioeconomic and cultural settings. What all the studies have in common is that they explicitly address the effects of education on disaster vulnerability and compare them to other possible relevant effects. Since the consideration of education as a possible protecting factor has so far been largely absent from the scientific literature on disaster vulnerability, this

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set of papers charts new territory. As we will see later all eleven studies confirm the important role of education for reducing different kinds of disaster vulnerabilities in very different settings and at the macro- and micro-level.

Several recent catastrophic event such as the typhoon Haiyan that hit the Philippines in 2013, the 2004 Indian Ocean tsunami, the 2005 hurricane Katrina, or the 2010 Haiti earthquake, are examples that already today more could have been done to minimize the impact of natural hazards before they occur. In fact, not all natural hazards events become a disaster and massive losses and damages are, to a certain extent, preventable. The levels of adverse impacts are determined by exposure and the vulnerability of societies and socio-ecological systems (Cardona et al. 2012). Exposure could lead to a disaster risk when the population and economic resources are exposed to potentially dangerous settings. Meanwhile, vulnerability refers to the susceptibility, sensitivity and capacities of the exposed elements to cope with and adapt to the hazard events (Schröter et al. 2005, IPCC 2007). Exposure and vulnerability are dynamic and heterogeneous depending upon various factors including demographic, economic, social, geographic, cultural, institutional, governance and environmental elements. Understanding how vulnerability is generated is crucial in disaster risk management and reduction (O'Brien et al. 2004). While there has been considerable research attention on technical aspects, biophysical vulnerability and the vulnerability of the built environment, the social aspects of vulnerability remain relatively understudied (Cutter et al. 2003).

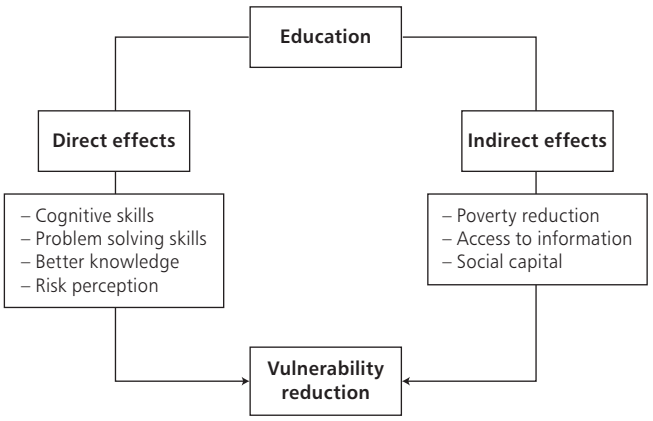
It is recognized that successful mitigation plans need to consider differential impact of hazards as a product of social vulnerability (Morrow 2008). Individuals and communities are differentially exposed, and vulnerability based on various factors such as age, gender, education, wealth, class, race/ethnicity/religion, disability and health status, which influence both the impacts and how the actors prepare for, respond to and recover from hazards and disasters. Extant social science and disasters literature reported that those with low socio-economic status, elderly, children, women, and ethnic minorities/immigrants are the most vulnerable groups (Clark et al. 1998). The elderly, children, and women typically have less physical strength and ability to escape from danger comparing to men at prime ages (Yeh 2010). The poor and people belonging to minority groups for their part are more likely to live in poor housing conditions and disaster-prone areas. Mortality and morbidity from natural disasters are much higher among these subpopulations (Neumayer and Plümper 2007, Frankenberg et al. 2011, Doocy et al. 2013). Furthermore, low-income groups generally face more obstacles during the phases of response, recovery, and reconstruction (Masozera et al. 2007). Consequently, studies on social vulnerability commonly highlight poverty/income as the main characteristic explaining differentials in all aspects of disasters (Fothergill and Peek 2004).

The emphasis on monetary aspect can also be seen in the measurement of loss and damage from disasters (Wrathall et al. 2013). Money values are more convenient to determine using market valuations. However, relying only on economic loss could mislead the estimation of the impacts of the disaster. While richer households and countries generally suffer greater monetary losses, they are likely to recover more quickly than their poorer counterparts (Noy 2009, Cavallo and Noy 2010). Furthermore, fatalities in low-income countries are generally much higher than those of higher income nations (Kahn 2005). The longer-term welfare costs of a disaster thus are greater for poorer individuals or nations. The relationship between income and disaster impacts is explained through an increase in the demand for safety as income rises (Toya and Skidmore 2007). Furthermore, with higher income, individuals have more resources to employ costly disaster precautionary measures. Accordingly, development agencies and climate change communities have put effort in mainstreaming poverty reduction in climate change adaptation programs (Eriksen et al. 2007, UNDP 2007).

VULNERABILITY, ADAPTIVE CAPACITY AND EDUCATION

While poverty is well-considered as a major cause of vulnerability and poverty reduction has recently been recognized as one key tool to enhance adaptive capacity, education both in its own right and as a means for poverty alleviation, has not yet been put on the forefront for climate change adaptation efforts. There are many sound reasons to assume that education can contribute to vulnerability reduction and enhance adaptive capacity. The relationships between education and vulnerability reduction can be both direct and indirect as presented in Figure 1.

Fig. 1. Flowchart displaying the processes through which education contributes to vulnerability reduction



Education can play an important role in reducing the negative impacts of extreme climate events in direct and indirect ways. Directly formal education is considered as a primary way individuals acquire knowledge, skills, and competencies that can influence their adaptive capacity. There is a large body of literature on the effects of education on health which is summarized in Lutz and Skirbekk (2013) who conclude that there is enough evidence to assume direct functional causality. First, there is evidence that the learning experiences associated with formal education have a lasting impact on the synoptic brain structure (Kandel 2007) and enhances cognitive skills (Neisser et al. 1996, Nisbett 2009, Reynolds et al. 2010). Literacy and numerical skills as well as general skills e.g., abstract thinking obtained through formal education imply better understanding and ability to process such risk information as weather forecast or warning messages (Mileti and Sorensen 1990, Spandorfer et al. 1995). Second, education is

associated with problem-solving skills (Moll 1994, Ishikawa and Ryan 2002, Schnell-Anzola et al. 2005). Thus, in such an emergency situation like when a disaster strikes, educated individuals might be more capable to respond and act upon the event. Third, education enhances the acquisition of knowledge, values and priorities as well as the capacity to plan for the future and improve allocation of resources (Thomas et al. 1991, Glewwe 1999). It is, for example, well documented that educated individuals have better basic practical knowledge on nutrition and health practices (Nayga 2000, Burchi 2010). Similarly, education may also enhance knowledge on disaster risks and how to respond to such risks. Fourth, education can influence risk perception. If people perceive their risks to natural disasters to be real, they are more likely to react to cope with these risks. It is found that highly educated individuals are better aware of the earthquake risk (Ainuddin et al. 2013) and are more likely to undertake disaster preparedness (Paul and Bhuiyan 2010). High risk awareness associated with education thus could contribute to vulnerability reduction behaviors.

Apart from the above mentioned direct impacts, education may indirectly reduce vulnerability through many other means. Firstly, education improves socio-economic status as evident that education generally increases earnings (Psacharopoulos 1994, Psacharopoulos and Patrinos 2002). This allows individuals to have command over resources such as purchasing costly disaster insurance, living in low risk areas and quality housing, implementing disaster preparedness measures and evacuating in time of emergencies. Secondly, highly educated individuals usually have diversified communication linkages and have better access to useful information (Cotten and Gupta 2004, Wen et al. 2011, Neuenschwander et al. 2012). The level of education is highly correlated with access to weather forecasts and warnings as well as the types of technologies used to access weather information (Rodriguez et al. 2007). Access to forecast and early warnings allow individuals to respond and prepare for the hazards appropriately. Thirdly, education is associated with greater social capital and social support and wider social networks (Department for Business Innovation & Skills 2013). Social networks are particularly useful in time of emergency. For instance, individuals who are embedded in large and well-established social networks and friendship groups have higher chance to receive informal warnings and consequently more likely to confirm warnings and engage in response (Mileti and Sorensen 1990). Furthermore, social capital and social networks increase the propensity to evacuate and facilitate relocation and recovery (Airriess et al. 2008). Through increasing socio-economic resources, facilitating access to information and enhancing social capital, education can promote vulnerability reduction and adaptive capacity.

At the societal level, it is found that better educated society enjoys greater economic growth (Lutz et al. 2008, Crespo Cuaresma et al. 2013), higher life expectancy and higher degree of democracy (Lutz et al. 2010). This implies that better educated societies have greater social, economic, and institutional capabilities necessary for successful adaptation to climatic change (KC and Lutz 2014). Consequently, it is reasonable to assume that when facing natural hazards or climate risks, educated individuals, households and societies are more empowered and hence more adaptive in their response to, preparation for, and recovery from disasters.

SPECIAL ISSUE ON EDUCATION AND DIFFERENTIAL VULNERABILITY TO NATURAL DISASTERS

Based on the assumption that education can reduce vulnerability and enhance adaptive capacity to natural disasters, this Special Issue collects empirical evidence from different societies based on analyses of various data sources from individual- and household-level data, village-level studies and national case studies to global-level time series analysis. Although different types of natural disasters and disaster outcomes are explored, all eleven research articles specifically focus on investigating the role of education on vulnerability reduction. The common research question being asked in these articles is whether education can reduce negative impacts of covariate shocks resulting from natural disasters or epidemics and whether education can enhance adaptive capacity to these emergency events.

Since disaster events differ in terms of predictability, controllability, length of forewarning, magnitude and duration of impact, different types of events may affect vulnerability and response diversely. Preparing for earthquakes, a sudden-onset hazard, for instance, is not the same as preparedness actions for drought, a slow-onset event. There has not been much comparative work that considers how special characteristics of different natural disasters can influence physical and social impacts (National Research Council 2006). Likewise, the impact of natural disaster events is not distributed evenly among countries. The extent of losses relies considerably on the level of development, policies, institutional arrangements and economic conditions (Cavallo and Noy 2010). In this Special Issue, diverse types of natural disasters are being studied including both slow and rapid onset; and geophysical, meteorological, hydrological, climatological and biological disasters. The countries covered in the Special Issue include low- and middle-income countries stretching from Asia (e.g., India, Nepal, Indonesia and Thailand), Africa (e.g., Sub-Saharan African countries, Mali, Senegal and Uganda) to Central and South America (e.g., Brazil, Cuba, Dominican Republic, El Salvador and Haiti). Different types of disaster events and the diversity of countries being investigated allow us to test the robustness of the role of education on vulnerability reduction.

A variety of disaster-related outcomes are investigated in this Special Issue ranging from pre-disaster phase, during disaster events, to the disaster aftermath. Prior to a disaster event, mitigation efforts could help reduce vulnerability to disaster impacts such as injuries and loss of life and property. Avoiding building in high-hazard areas is one effective mitigation action. The case study of households in Brazil and El Salvador reports that residents of high risk areas have on the average lower levels of education than households living in low risk areas (Wamsler et al. 2012). This might be because individuals who are literate and have higher level of education have better ability to perceive and understand existing risks and are able to act on perceived threats. Correspondingly, the study of tsunami-risk areas in southern Thailand shows that individuals and households with higher education had greater disaster preparedness e.g., stockpiling emergency supplies and having family evacuation plan (Muttarak and Pothisiri 2013). Consistent findings are reported at the country-level. Comparing to neighboring countries like Haiti and Dominican Republic, Cuba, with higher average level of education among its population, has better effecting risk-

management and risk-communication system as well as disaster preparedness (Pichler and Striessnig 2013).

During the disaster event, understanding and carrying out appropriate response to warning messages are crucial in minimizing losses. Sharma and colleagues (2013) find that the clarity of cyclone warnings increases the likelihood of evacuation in coastal zones in India and the effect is the largest among the most educated group. However, there is no evidence that highly educated individuals were more likely to evacuate voluntarily to a cyclone shelter or a relief shelter. This is explained by the fact that highly educated respondents, given their higher incomes, generally live in better quality housing. Feeling safe in their home, they were less likely to evacuate.

The post-disaster phase mainly concerns disaster impacts and recovery. Disaster impacts comprise both physical and social impacts (Lindell 2013). Physical impacts include casualties (mortality, injury and morbidity) and damage to agriculture, infrastructure and the natural environment. Social impacts consist of psychological, demographic, economic and political aspects. In this Special Issue, both disaster impacts and recovery are thoroughly investigated.

With respect to physical impacts, the cross-national time series analysis of deaths from natural disasters in 125 countries as well as the study of human lives lost from floods and landslides in 75 communities in Nepal consistently show that countries with higher proportion of women with at least secondary education and communities with higher mean year of schooling respectively suffered lower mortality from disasters (KC 2013, Striessnig et al. 2013). The above mentioned comparative study of Haiti, Dominican Republic and Cuba also reports lower disaster-related mortality in Cuba, the country with the most educated population. At the individual-level, the longitudinal study of households located in Aceh and North Sumatra, Indonesia report that men who completed senior secondary school were significantly more likely to survive the 2004 Indian Ocean tsunami as compared to those with primary education (Frankenberg et al. 2013). It is explained that education maybe a proxy for height and strength, another dimension of human capital, which can be relevant in such emergency situation like running away from tsunami waves. Frankenberg and colleagues (2013) also find that women with higher education were less likely to be caught up in the water, injured or witnessed others struggling in the water. Similarly, an analysis of malaria risk in children in 8 sub-Saharan African countries by Siri (2014) reports that maternal schooling was significantly inversely associated with the odds of malaria infection. The relationship between maternal education and lower malaria parasitemia in children is found to be independent of household wealth. This finding has an important policy implication especially since there is evidence that climate variability is associated with an increase of malaria epidemics (Zhou et al. 2004). Apart from reducing mortality, injury and morbidity, it appears that education is also associated with lower damage and losses. It is found that the number of animal losses and the number of families affected by floods and landslides in Nepal were significantly lower in the villages with higher mean years of schooling (KC 2013). These findings provide strong evidence that formal schooling can reduce vulnerability in terms of life losses, injury, morbidity and damage.

Turning to social impacts, the above mentioned study of the 2004 Indian Ocean tsunami finds that post-traumatic stress reactivity (PTSR) measured 5 years after the tsunami was substantially lower among the better educated. This indicates better resilient in terms of psychosocial well-being for those with higher schooling. It is also found that the better educated were more successful in smoothing consumption, i.e., keeping their level of consumption, after the tsunami. Likewise, the study of the impacts of floods and droughts on community welfare in Thailand shows that better educated communities did not experience income loss while communities with lower education suffered a reduction in income after being hit by droughts (Garbero and Muttarak 2013). The lower psychological and economic impacts among better educated individuals and communities imply that they might cope better with disasters and spend less time to recover.

One reason why formal education can enhance coping strategies in the aftermath of a natural disaster is that highly educated individuals or households may have greater flexibility and skills to take up a new job or have better socioeconomic resources to buffer the income loss from climatic shocks. Indeed the study of villagers in rural areas in Mali and Senegal show that the respondents with a higher level of education are less vulnerable to natural hazards because they have more diversified economic activities beyond agriculture and hence are less dependent on climatic or environmental factors (van der Land and Hummel 2013). Likewise, having a wider portfolio of coping strategies, it is found that highly educated individuals and households in Uganda, Brazil and El Salvador were likely to choose mechanisms that are more sustainable and unlikely to lead to chronic poverty and undermine future prospects (Wamsler et al. 2012, Helgeson et al. 2013). For instance, households where the household head has higher educational attainment were significantly less likely to choose taking their children out of school as a coping strategy. This signifies that more educated households are less likely to opt for a strategy that can harm human capital investment.

In terms of recovery, it seems that better educated individuals or households are faster in getting back to a normal life partially because people with higher education have better social and economic resources. Accordingly, the study of the 2004 Indian Ocean tsunami aftermath previously mentioned shows that among those who got displaced after the tsunami, the better educated were less likely to stay in temporary housing, which is typically a camp. Instead, they were more likely to move to private homes, either renting or staying with family or friends. The above mentioned study on the impacts of floods and droughts in Thailand also reports that communities with higher education were more able to secure government financial assistance for drought affected areas. This might be because highly educated communities have wider social networks and better access to resources.

The eleven empirical studies discussed above provide consistent findings on the positive impact of formal education on vulnerability reduction. The results are robust across units of analysis – be it at individual, household, community or country level – and across countries being studied. Many studies in this Special Issue also show that the effect of education remains significant after accounting for wealth/income. Moreover, in

many cases, income/wealth does not have a clear tendency nor clear correlation with vulnerability reduction (KC 2013, Muttarak and Pothisiri 2013, Sharma et al. 2013, Striessnig et al. 2013, Wamsler et al. 2012). The protective effects of education – from the pre-disaster phase, during the disaster event, to the disaster aftermath – indicates that investment in public education can have a positive externality in reducing vulnerability and enhancing adaptive capacity.

POLICY IMPLICATION

Over the next several years, billions of Euros will likely be spent on adaptation programs, primarily through the Kyoto Protocol adaption fund and national governments. Actually, the amount of 100 billion dollars has been formally pledged to be expended annually from 2020 onwards. But there is serious concern among many experts about the lack of a solid scientific basis to guide policymakers on how best to allocate the money.

The hypothesis that education is key to reducing vulnerability and strengthening adaptive capacity does indeed have massive implications for setting priorities. Should the significant funds allocated for adaptation to climate change be invested in improving existing infrastructure and agricultural practices, or should some money go instead to enhancing human empowerment through education and health? Which approach is more likely to enable people to cope with the long-term challenges posed by a climate that is becoming more violent?

Failure to wisely address these and related questions could result in ill-informed investment policies that lock countries into inflexible coping strategies that will not be effective under possible future climates. Given the significant uncertainties in place-specific climate forecasts, investments in an overall empowerment of human resources that leads to greater flexibly in reacting to the arising challenges may well be a wiser strategy.

In terms of strategies for empowerment the studies presented in this collection also show that female education is of a particular importance. Not only that there remain significant gender gaps in school enrolment and youth literacy rates, but there is also evidence that investment in female education contributes greatly to economic growth and human welfare. With respect to disaster risk reduction, the findings from this Special Issue also point to the prominent role of female education in reducing vulnerability: from increasing disaster preparedness (Muttarak and Pothisiri 2013), minimizing malaria risk (Siri 2014), lowering disaster-related mortality (Striessnig et al. 2013), to reducing disaster risk and enhancing adaptive capacity (Wamsler et al. 2012). Investing in girls' education coupling with strict enforcement on female school enrolment and completion thus should be made priority as self-evident that women educational achievements can have far-reaching effects within the family, across generations and communities.

The studies presented in this volume tried to address for the first time in a more systematic manner the important strategic question whether education should be considered a key factor in reducing disaster vulnerability and enhancing adaptive capacity to climate change. Based on the empirical evidence from many different parts of the world using very different approaches and levels of aggregation the answer turns out to be clearly on the affirmative. In particular, it is interesting to note that almost consistently education turns out to be more important than income in reducing disaster vulnerability. This implies that policies should focus less on direct monetary transfers and income generation and more on general empowerment through education and human capital formation as the most efficient strategy toward enhancing resilience. We are realistic enough to understand that the evidence presented in this set of studies will not yet turn around the priorities in the well-entrenched vulnerability and adaptation community. But we hope that we have at least put the issue visibly on a table and hence hopefully inspire many more studies on this topic which is so important for our common future.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/6476

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Climate Change, Adaptation and Formal Education: The Role of Schooling for Increasing Societies' Adaptive Capacities in El Salvador and Brazil*

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ABSTRACT: With a worldwide increase in disasters the effects of climate change are already being felt, and it is the urban poor in developing countries who are most at risk. There is an urgent need to better understand the factors that determine people's capacity to cope with and adapt to adverse climate conditions. This paper examines the influence of formal education in determining the adaptive capacity of the residents of two low-income settlements: Los Manantiales in San Salvador (El Salvador) and Rocinha in Rio de Janeiro (Brazil), where climate-related disasters are recurrent. In both case study areas, average levels of education were found to be lower for high-risk households than residents at less risk. In this context, the influence of education was identified to be twofold and due to: (a) direct effects on risk reduction; and (b) mitigating effects on factors that increase risk. The results suggest that education plays a more determinant role for women than men in relation to their capacity to adapt. Moreover, these results suggest that the limited effectiveness of institutional support may be related to the fact that the role of formal education has so far not been sufficiently explored. Promoting improved access to (better-quality) formal education is thus a way to increase adaptive capacity. This is further supported by the fact that disasters were found to have negative effects on education levels, which in turn reduces adaptive capacity, resulting in a vicious circle of increased risk.

Key Words: *adaptation; adaptive capacity; Brazil; climate change; coping capacity; disaster; education; El Salvador; flood; income; informal settlement; landslide; risk reduction*

INTRODUCTION

Climate change is on everyone's lips. With the global temperature on the rise and a worldwide increase in so-called natural disasters, the effects of climate change are already being felt, and many climate-change studies predict a continued rise in the frequency of such events, which include amongst others windstorms, heat waves, heavy rain, floods, and landslides (Intergovernmental Panel on Climate Change [IPCC] 2007). Each year, disasters trigger devastating losses in human lives and economic assets, and developing countries are most at risk (United Nations International Strategy for Disaster Reduction [UNISDR] 2002, Wisner et al. 2004).

With rapid urbanization, which increasingly exposes populations and economies to climate-related hazards, the trend is for the risk to become urban (IPCC 2007). It is predicted that in Latin America and the Caribbean, 89% of the population will live in cities by 2050 (United Nations 2009). The urban poor, who often live in informal settlements, on steep slopes, or on flood plains are particularly vulnerable (e.g. Bigio 2003, IPCC 2007, Wamsler 2009, Wisner et al. 2004).

Despite considerable research into the geological and biological impacts of climate change, little is known about their impacts on the well-being of the world's population and our ability to adapt to them. In fact, knowledge about the adaptive capacities of future societies is one of the most important missing links in predicting the effects of climate change (Lutz 2008).

Against this background, this paper's objective is to help fill the gap by providing new knowledge on the factors that shape people's capacity to adapt to changing climate conditions. Specifically, it aims to examine how the risk and adaptive capacities of the residents of two low-income settlements (*Los Manantiales* in San Salvador, El Salvador and *Rocinha* in Rio de Janeiro, Brazil) are influenced by their level of formal education. In addition, it analyses the complex reality of residents living in disaster-prone informal settlements (so-called "slums"), and illustrates the links between their precarious living conditions, social marginalization and their level of formal education. The focus on formal education is based on recent studies which

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- The wording of the article was revised to improve the comprehensibility of the concepts, methodology, results and their relevance.
- The article was edited in order to strengthen the presentation of the arguments.
- The results were related to a relevant UNICEF study to support the findings and put them into a broader perspective.
- Minor additions were included to avoid any misunderstanding by the reader (e.g. Table 1).
- Additional interview results were included (e.g. Box 1).
- Further explanations were given to support key arguments (e.g. possible biases in the statistical correlation between education and disaster risk, mentioned in the discussion section).

argue that educational attainment may improve people's ability to cope with disasters (e.g. Adger et al. 2004, Toya and Skidmore 2005, Blankespoor et al. 2010). This study is not based on the hypothesis that formal education is the only, or even the most important driver. Rather it is driven by the need for a better understanding of the influence of formal education on risk levels. Formal education refers here to studies at primary, secondary, and university level.

The next section describes the research methodology. The third section presents the conceptual framework for the study. Here, the interrelationships between concepts of disaster, risk, and adaptive capacity are identified and discussed from a holistic systems perspective of risk reduction and climate-change adaptation. Links with formal education are also highlighted. The fourth section presents the results, including the similarities, differences, and gaps between the quantitative and qualitative analyses of the two case-study areas (in El Salvador and Brazil). The conclusions are presented in the final section.

METHODOLOGY

This paper is a comparative analysis of two case studies that examine the influence of formal education on the adaptive capacity of residents of informal low-income settlements where climate-related disasters are recurrent. Both case studies form part of the "Forecasting Societies' Adaptive Capacities to Climate Change" project. The project is funded by the European Research Council and coordinated by the International Institute for Applied Systems Analysis (IIASA) (Lutz 2008).

The first case study was carried out in several phases between 2006 and 2011 and focuses on the *Los Manantiales* community in San Salvador, El Salvador. Additional analyses were conducted in two other San Salvadorian communities: *José Cecilio del Valle* and *Divina Providencia.* Flooding, landslides, windstorms and earthquakes pose the main hazards to life and livelihoods. The second case study was carried out between 2009 and 2011 in *Laboriaux* and *Cachopa*, which are two communities in an informal settlement known as *Rocinha* in central Rio de Janeiro, Brazil, where landslides and floods are frequent.

In both case studies (hereafter referred to as the San Salvador and the Rio case studies), data was collected through semi-structured and focused interviews, surveys, a literature review, and observation. Both quantitative and qualitative data analysis techniques were applied. Statistical analyses investigated the influence of formal education on local risk levels, coping strategies, and institutional support. The qualitative analyses explored the direct and secondary effects that education may have on disaster occurrence, and vice versa.

Semi-structured interviews were conducted from 2009–2011 and included 118 households in San Salvador and 94 households in Rio. Those households most at risk (the focus group) and those at lower risk (the control group) were identified by local censuses and post-disaster evaluations conducted by national authorities and aid organizations working within the respective communities. In El Salvador, this data was collected in 2005 after a season of disasters characterized by a tragic combination of Hurricane Stan, floods, landslides, small-scale earthquakes and the eruption of the Ilamatepec volcano. In Rio, local census data was updated after the 2010 landslides in *Rocinha*. Interviewees were in the main selected randomly (with the help of maps and numeration of households), although in the dangerous case study environments, this sampling procedure was sometimes difficult to follow rigorously.

In addition to the household interviews, around 90 focused interviews were conducted with various other stakeholders. These included international and national risk management experts, staff from organizations working in the case study areas, community leaders and other key informants. Observation was of great importance to explore the direct and secondary effects that education may have on disaster occurrence (and vice versa), and for crosschecking information from other sources. Consequently, the authors of this study lived for several months in the respective study areas. In the context of the San Salvador case study, institutional databases were also accessed and analysed, and data was drawn from previous research conducted during 2006. The literature review included more than 200 publications. Finally, the preliminary outcomes of both case studies were further assessed and compared during desk work in 2011.

In accordance with the research objectives, the attributes that were analysed (in both qualitative and quantitative terms) were:

- Level of formal education;
- Level of income;
- Level of risk;
- Impact of past disasters (i.e., residents' previous disaster experience);
- Local strategies used to cope with risk or disasters (i.e., residents' so-called coping strategies);
- Institutional support (received to reduce and adapt to disaster risk); and
- Other key factors or attributes.

The analyses were based on data obtained from both interviews and existing databases. For example, household members living in the case study areas were asked: if they consider themselves to be at risk; if they believe themselves to be at higher or lower risk than other community members; how their risk situation has changed; if they have experienced specific disasters; how they cope with the risk and dangers associated with living in the community; if they can name risk reduction measures that they (or others)

undertake; if they receive external assistance; and how past disasters have affected their everyday life (such as the impact on income and education).

Qualitative data analyses consisted of a combination of literal reading, grounded theory (Glaser and Strauss 1967), systems analysis (Sterman 2000) and cultural theory (Thompson et al. 1990). For the quantitative analyses, mainly cross-tabulations were used to identify potential relationships between various attributes and their significance was tested using χ^2 (Chi square) tests. In addition, a linear regression analysis was carried out to identify relationships between levels of education and income, and two log-linear analyses were conducted to examine interactions between three independent variables: previous experience of disasters, income, and risk reduction measures taken). Finally, *t*-tests assessed whether the average level of education of the focus and control groups were significantly different.

Respectively, in the San Salvador and the Rio case studies, a total of 31 and 80 quantitative tests were carried out. First, individual results that were statistically significant at a 5% confidence level were identified. Next, a Bonferroni-type adjustment was performed to adjust confidence levels, as error probability increases with the number of tests conducted. In the following text, probabilities (before and after the Bonferroni-type adjustment) are indicated after the result where applicable (e.g. $p < 0.003$; adjusted $p < 0.16$). In some cases, lower probability results are shown; this is to highlight findings that were considered to be crucial to follow up in future studies.

Various types of triangulations were used in order to obtain a good approximation of "reality" and thus reliability and to compensate for factors that might invalidate conclusions, such as bias in the selection of cases or focus areas and interviewee self-reporting. These included data, methodological, theoretical and investigator triangulation (Harvey and MacDonald 1993, Flick 2006). Other limitations of the analyses are due to statistical methods, contextual differences and approaches, a lack of historical data, and generally difficult access to information in the precarious and insecure study areas.

ADAPTATION AND EDUCATION: A CONCEPTUAL FRAMEWORK

Disasters are commonly seen as the result of an interaction between hazards (*H*) and vulnerability conditions (*V*). In other words, hazards such as floods, landslides and windstorms are not the sole cause of disasters. It is only when they are combined with vulnerability conditions (such as people or systems susceptible to damage from hazardous events) that disasters occur. In this context a disaster can be defined as, "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" (UNISDR 2009:9).

Disaster risk is conventionally expressed by the following pseudo-equation:

$$R = H \cdot V \quad (1)$$

where R stands for risk, H for hazard(s) and V for vulnerability.

Whereas a disaster is said to be the result of "insufficient capacity or measures to reduce or cope with potential negative consequences" (UNISDR 2009:9), the definition of disaster risk (as represented by Eq. 1) does not include such capacities and/or measures. Consequently, it does not link the components of risk to appropriate risk reduction measures. Moreover, recovery actions are rarely mentioned as an inherent part of risk reduction. However, preparedness for recovery is crucial for risk reduction because: (a) both spontaneous and planned early recovery begin at the moment a hazard occurs; (b) risk areas affected by a hazard are often still recovering from earlier hazards; (c) the term "hazard" includes primary and secondary hazards (e.g. landslides or cholera following earthquakes and floods) and includes both rapid- and slow-onset events that can develop over time or are successive (e.g. aftershocks) (Wamsler, unpublished manuscript).

These limitations led to the development of an extended definition of risk and risk reduction (Wamsler 2009), which directly links risk components to corresponding risk reduction measures. These include prevention measures (that reduce or avoid hazards), mitigation measures (that reduce vulnerability), response preparedness measures (that improve post-disaster response), and importantly also recovery preparedness measures (that improve post-disaster recovery). It can be expressed as:

$$R = H/P \cdot V/M \cdot LR/PP \quad (2)$$

where R stands for risk, H for hazard(s), V for vulnerability, L_R for lack of response and recovery mechanisms and structures, P for prevention, M for mitigation, and PP for preparedness for response and recovery.

This extended risk definition has both theoretical and practical implications, as how risk is defined dictates how risk reduction is addressed (Slovic 1999). In detail, the four risk-reduction measures are:

(a) Prevention (or hazard reduction). This aims (to increase the capacity) to avoid or reduce the potential intensity and frequency of current or potential hazards that threaten households, communities and/or institutions;
(b) Mitigation. This aims (to increase the capacity) to minimize the current or potential vulnerability of households, communities and/or institutions to potential hazards or disasters;

(c) Preparedness for response (or response preparedness). This aims (to increase the capacity) to establish effective response mechanisms and structures in order for households, communities, and/or institutions to react effectively during, and in the immediate aftermath of potential hazards or disasters; and
(d) Preparedness for recovery (or recovery preparedness). This aims (to increase the capacity) to ensure that appropriate mechanisms and structures are in place to enable households, communities and/or institutions to recover following a potential hazard or disaster (including risk transfer and sharing).

These definitions highlight that, for each type of measure, there are two ways to help people to cope with, or adapt to changing climate conditions. These are: (a) direct reduction of the corresponding risk component; or (b) increasing capacities to reduce the corresponding risk component, which enables communities to reduce their risk level themselves. In both cases, the active participation of institutions and at-risk communities, as well as building upon local patterns of social behaviour and existing coping strategies has been shown to be crucial for achieving sustainable change (Wamsler 2007). The latter includes evaluating local risk reduction strategies, supporting and improving effective strategies, scaling down unsustainable practices and, where necessary, offering better alternatives.

"Coping capacity" is defined by UNISDR (2009:8) as, "(t)he ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters." It includes existing and potential, but so far unused, coping strategies. The "skills and resources" mentioned in this definition translate into the four risk reduction measures, shown in Eq. 2. This means that the coping capacity of a system (or a community) is its ability to reduce overall risk by applying these measures. Although the term "adaptive capacity" is not included in the UNISDR's glossary (2009), a definition can be found in the introduction to the Intergovernmental Panel on Climate Change's Fourth Assessment Report, which states that "adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC 2007:21). Using the extended definition of risk given above, it can be assumed that adaptive and coping capacities are determined by the same attributes or factors. As far as this study is concerned, adaptive capacity and coping capacity are therefore synonymous, as are the processes by which they can be increased, namely, risk reduction and climate-change adaptation.

Against this background, what are the key factors that affect people's capacity to cope with, and adapt to disasters? Income is often considered as "the" (or one of the) key factor(s) (e.g. Cutter et al. 2003, Lindell and Perry 2004, Wisner et al. 2004, Kahn 2005, Toya and Skidmore 2005, Blankespoor et al. 2010, United Nations Human Settlement Programme [UN-HABITAT] 2010). It is argued that people who have resources (e.g. wealth, assets, insurance) are more likely to be able to safeguard their lives, property and livelihoods and recover more quickly from a disaster, although their economic losses are often greater in absolute terms (Wisner et al. 2004). In contrast, formal education is not often considered to be a key factor in people's risk levels or their capacity to cope with, and adapt to disasters. Typically, it is only linked to higher socioeconomic status and lifetime earnings (e.g. Cutter et al. 2003) or mentioned as one of many resources that people draw upon to earn their living (see models such as the Pressure and Release (PAR) Model and the "Sustainable Livelihoods" (SL) approach) (Wisner et al. 2004). In other words, these academics have argued that it is only through its correlation with income (and livelihood) that education is related to risk.

However recent studies have raised the question of whether formal education might in fact play a more central role in determining people's adaptive capacity. Three studies that combined education indicators with data from the OFDA/CRED International Disaster Database demonstrate a correlation between lower levels of formal education and a higher number of deaths or other forms of loss from disasters (independent of income). Adger et al. (2004:101) conclude that education exhibits "a strong (negative) relationship with mortality from climate related disasters." Among education proxies, the strongest indicator is the literacy rate of the population aged 15–24, followed by the literacy rate of the entire population aged over 15, and the female-to-male literacy ratio. Toya and Skidmore (2005) base their analysis on the total number of years of schooling for the population aged over 14 and demonstrate fewer disaster-related deaths and less damage per gross domestic product (GDP) in countries with more years of formal schooling. The correlation is particularly strong in developing countries, where the level of formal education proves a more significant predictor of disaster losses than income level. Using the female educational enrolment rate as an indicator, Blankespoor et al. (2010) establish that there are fewer disaster-related deaths in countries that invest in female education. In sum, these studies strongly suggest that both formal education and gender equality in education play a more determinant role in risk levels than previously thought. Nevertheless, although these studies focus on various aspects of education and risk, they do not provide a comprehensive analysis of the role of education in shaping people's risk levels. This study fills that gap.

RESULTS: FROM RISK TO CLIMATE-RELATED DISASTERS

The conceptual framework is directly linked to the research objectives of this study, which are to analyse the role of formal education in: (a) residents' risk levels, (b) their coping strategies, and (c) the institutional support they receive. According to the extended view of risk (presented in the former section), both local coping strategies and institutional support determine people's risk levels (see Eq. 2). Consequently, objectives (b) and (c) are in fact part of (a). Differences in factors that influence risk levels can also be called differential vulnerability.

Quantitative Analysis of Risk Factors: Differential Vulnerability

This section presents the results of the quantitative analyses of the factors that influence residents' differential vulnerability, specifically the relative importance of education compared to other factors, such as income. The analyses include:

- *t*-tests to compare average levels of education and income in high- and low-risk areas.
- Cross-tabulations, χ^2 tests, and linear regression to establish whether there is a direct relationship between levels of education and income.
- Cross-tabulations and χ^2 tests to analyse the factors that determine residents' risk levels, including formal education and income.

The following four data sets formed the basis for these analyses:

- Survey data from the San Salvador case study (2009–2010);
- Survey data from the Rio case study (2010–2011);
- The institutional database of the low-income settlement *Los Manantiales* in San Salvador;
- The institutional database of the low-income settlement *Divina Providencia* in San Salvador. *Divina Providencia* forms part of the San Salvador case study and was included in the 2009–2010 survey.

Average levels of education and income in high- and low-risk areas

The analysis of all four data sets show lower levels of education in high-risk households compared to residents of lower-risk areas. In other words, education and risk levels were correlated (see Tables 1 and 2). However, unlike average education levels, average income levels in the four data sets did not show any clear correlation with residents' risk levels.

Relationship between education and income

A series of cross-tabulations, χ^2 tests, and a linear regression analysis were conducted to explore the relationship between education and income. The San Salvador survey indicated no relationship between income and education. However, the 2003 *Los Manantiales* database showed a significant correlation between: (a) average educational level of residents aged over 18 and total household income ($p < 0.001$; adjusted $p < 0.05$); and (b) total household income and educational level of the head of the household ($p < 0.002$; adjusted $p < 0.10$). It was not possible to carry out a similar analysis using the information in the *Divina Providencia* database.

In the Rio case study, cross-tabulations and χ^2 tests did not show any significant correlation between education and income at the household level. However, level of education and income were significantly correlated for female residents ($p < 0.003$; adjusted $p < 0.16$). No such correlation could be found for men. In other words, it is likely that females living in this area with a higher educational level have a higher income. Although a similar analysis was not possible in San Salvador, an analysis of the data showed that the two most educated women (13 grades or more) had a higher average income (US$ 325) than men at the same educational level (US$ 207). In addition, the least-educated women earned considerably less than the least-educated men on average.

Factors influencing risk and previous disaster impact

Education and income levels were analysed in regard to the following attributes to investigate the factors that influence residents' risk levels:

- Living in a (declared) risk area;
- Self-reporting of risk (self-reporting of being at high risk);
- Impact of previous disasters;
- The use (and number) of coping strategies;
- Knowledge of existing risk factors; and
- Institutional support received.

Factors influencing risk and past disaster impact

Cross-tabulation and χ^2 analyses were applied to identify correlations between on the one hand, education and income levels, and on the other hand living in a (declared) risk area, self-reporting of high risk, and the impact of previous disasters.

An important finding was that the analysis of the 2003 *Los Manantiales* database showed a negative correlation between the educational level of the head of the household and self-evaluated disaster risk ($p < 0.015$; adjusted $p < 0.10$). Apart from this result, educational and income levels were not found to be significantly correlated with disaster risk or the impact of previous disasters. However, in Rio, the data indicated a possible correlation between lower mean educational levels of households and living in the *Laboriaux* high-risk area ($p < 0.005$; adjusted $p < 0.4$). In addition, in San Salvador a clear correlation was found between the impact of Hurricane Mitch in 1998 and the impact of Hurricane Stan in 2005 on the same households ($p < 0.001$; adjusted $p < 0.05$). No such analysis could be made in the Rio case study.

Table 1. Average education and income levels in focus and control groups (i.e., residents living in high-risk and lower-risk areas) based on recent surveys

Risk	Average education of head of household (years)	Average education of household members (years)	Average income of head of household (US$ / BRL[a])	Total income of household (US$ / BRL[a])	Household income per person (US$ / BRL[a])
San Salvador case study					
High	5.0	6.2 [b]	111	243	57
Low	5.7	7.0 [c]	71	259	59
Rio case study					
High	5.6	6.5	818 (≈US$ 485)	1258 (≈US$ 746)	442 (≈US$ 262)
Low	7.0	7.1	801 (≈US$ 475)	1478 (≈US$ 876)	568 (≈US$ 278)

[a] Brazilian Real [b] If only those who receive income are included, the average is 6.5 [c] If only those who receive income are included, the average is 7.3

Factors influencing people's way of coping

Cross-tabulations were used to assess whether coping strategies are influenced by level of education, income, and/or the impacts of past disasters.

The San Salvador case study did not show any significant correlation between education or income and (conscious) strategies adopted to cope with and adapt to disaster risk. However, there was a significant correlation between the impacts of past disasters and the use of coping strategies ($p < 0.001$; adjusted $p < 0.05$). In other words, households that had been most affected in the past were most likely to take their own risk-reduction measures (76.9% for Hurricane Mitch; 88.2% for Hurricane Stan).

Based on the assumption that risk awareness is a precondition for taking risk-reducing measures, in the Rio case study education level was tested against residents' ability to identify risks affecting the settlement. The correlation that emerged ($p < 0.00013$; adjusted $p < 0.0104$) was the most significant result from the Rio case study. This indicates that interviewees with lower levels of education were more likely to see their surroundings as risk free, whereas those with higher levels of education were more aware of existing risks. Moreover, interviewees with a higher level of education were able to name more risks affecting the settlement ($p < 0.003$; adjusted $p < 0.16$). A similar comparison could not be made with the data from the San Salvador case study.

Factors influencing institutional support

A series of cross-tabulations were used to assess whether education, income, and/or the impacts of past disasters influence the institutional support households receive to cope with and adapt to disasters. No significant correlations were found. However, the data showed that in both case studies high-risk families received more institutional help than those at lower risk. Despite this support, 36% of families in San Salvador and 63.3% in Rio stated that their current level of risk was similar or higher than before. Further analyses suggested a correlation between the ability of households to express being at risk and having received institutional support. For example, with a 40% error rate, a potential correlation was found in *Rocinha* between self-reporting of being at risk and receipt of institutional help ($p < 0.005$; adjusted $p < 0.4$).

Qualitative Analysis of Risk Factors: Differential Vulnerability

This section presents the results of the qualitative analyses of factors that influence people's differential vulnerability. They show how disasters affect residents living in informal settlements such as *Los Manantiales* and *Rocinha,* and how this relates to their level of formal education. Unlike the quantitative analyses presented in the previous section, the qualitative analyses do not investigate the relative importance of education (compared to factors such as income), but instead provide illustrative examples of how education can influence residents' level of disaster risk. This section thus provides an understanding of *how* education is linked to the conceptual framework presented earlier.

Education: direct effects on risk-reduction

In both the San Salvador and the Rio case studies, results showed that education has a direct influence on residents' risk level and associated risk reduction. A comparison of data obtained from interviews, observation and relevant literature showed that formal education can have a positive effect on:

- Awareness and understanding of existing risk;
- Access to (and provision of) information on risk reduction;
- Acceptance and adequate use of institutional support; and
- Coping strategies (i.e. improvements to residents' risk-reduction strategies).

The following sections describe these outcomes in more detail.

Table 2. Average education and income levels in focus and control groups (i.e., residents living in high-risk and lower-risk areas) based on analyses of institutional databases

Risk	Average education of head of household (years)	Average education of household members (years)	Average income of head of household (US$)	Total income of household (US$)	Household income per person (US$)
San Salvador Manantiales (2003)					
High	5.0	5.8	181	269	60
Low	5.8	6.3	171	288	74
San Salvador Divina Providencia					
High	2.1	3.0	64	143	39
Low	4.4	5.0	86	92	49

Awareness and understanding of existing risk

The quantitative analyses of the Rio case study showed a correlation between level of education and ability to perceive existing risks (see previous section). Interviews with key informants and residents confirmed this result. For example, a representative of the Rio de Janeiro Civil Defence Service stated that formal education is "directly linked to people's ability to perceive risks." As risk awareness is a necessary condition to engage in disaster risk reduction (UNISDR 2002), this demonstrates the vital role of education in increasing people's adaptive capacity.

In the San Salvador case study, upon probing, virtually all (97%) high-risk interviewees named either flooding or landslides as an imminent risk to their lives, and the majority (83% of the focus group) mentioned at least one factor that makes them more vulnerable than other, lower-risk residents (Wamsler 2007). However, and like the Rio study, the qualitative analysis of the 2006 interviews showed that it was high-risk illiterate interviewees who were unable to mention any additional risk factors.

Access to (and provision of) risk-reduction information

In both the Rio and the San Salvador case studies, observation and interviews with residents suggest that a higher level of education has a direct effect on access to information such as:

- Hazards and other threats;
- Safer places to live;
- Risk-reduction measures;
- Potential institutional support; and
- Laws and resident's rights.

As an example, Ana, a highly-educated female *Rocinha* resident, mentioned searching for risk information on the internet as one of her main coping strategies (see Box 1). Other *Rocinha* residents suggested that better-educated residents are generally better able to express themselves, which is crucial in informing others (including authorities) about their risk situation. Similarly, key informants stated that residents with higher levels of education are more likely to be successful in their contacts with authorities and emergency officials. This was confirmed in the San Salvador case study, where those residents with the lowest levels of education were also those who frequently mentioned that: (a) they have no idea how to improve their situation; and (b) they do not know of any institutions that could assist them.

Acceptance and adequate use of institutional support

Both case studies suggest that residents with higher levels of education are more likely to respond to disaster warnings and alerts (Cutter et al. 2003, Lindell and Perry 2004). The Rio de Janeiro Civil Defence Service noted that one of the

Box 1. Education and access to risk reduction information

Ana, a 40 year-old single mother with 11 years of education is taking university-entry exams to study journalism. She lives in *Cachopa*. Although she has not received any institutional support to improve her situation, she has succeeded in receiving a stipend from the renowned private language school *Cultura Inglesa* for her son to study English. When asked about how she copes with existing disaster risk, she mentions a range of strategies including:

- Looking for risk information on the internet;
- Investing in the structure of the house;
- Improving the electricity (distribution and outlets);
- Not throwing rubbish in the streets;
- Staying informed about how to prevent diseases like dengue and tuberculosis;
- Avoiding hazardous areas during emergencies (such as a nearby gas station);
- Sending her son to swimming lessons; and
- Sending her son to study outside the *favela* (slum).

When asked about her interest in moving to a more secure area, Ana states that there is a difference between *living in* a favela and *being* the favela (referring to the stigma of its residents), and then highlights that she only lives here because she does not have the opportunity to live anywhere else.

main explanations for differential vulnerability within communities is that warnings and alerts are ignored by some residents. A community worker in *Rocinha* supports this, stating that education makes residents less suspicious of authorities and more likely to accept institutional support. No such clear correlation was found in the San Salvador case study. However, interviews and observation suggest that education level (and not income) influence adequate use of institutional assistance (see Box 2). Adequate use of institutional assistance refers to the active participation of residents, long-term maintenance of physical risk-reduction measures, regular contributions to established local emergency funds and appropriate use of credits.

Improvements to coping strategies

In both study areas, after probing only around 65% of interviewees mentioned any risk-reduction strategies or improvements. However, observation and interviews with key informants show that virtually all residents of *Los Manantiales* and *Rocinha* are, as in many southern low-income settlements, actively adapting to their risk situation (Wisner et al. 2004, 2007, Jabeen et al. 2009). Strategies residents are aware of, and thus are consciously applied are mainly structural or economic (e.g. home improvements or use of credit). The study shows that it is mainly interviewees with a higher level of education who mention and actively use other strategies. These include strategies directly related to education, such as:

- Temporarily or permanently sending children to study outside the settlement (see Box 3);
- Improving access to schools (e.g. paving streets or building bridges);
- Encouraging dependents to study;
- Taking jobs outside the settlement;
- Being able to change employers (e.g. in response to demand influenced by climate variability and extremes); and
- Staying informed of existing risk (from different sources).

The data analyses suggest that it is not necessarily the number of strategies, but the use of different strategies that characterises residents with different educational levels. The use of different strategies increases the likelihood to tackle several risk components (i.e. hazards, vulnerabilities, and response and recovery mechanisms).The qualitative analysis also shows that, unlike education, increased income often leads to a greater number of, or stronger focus on, physical improvements, which does not necessarily lead to reduced risk (Wamsler 2007). Moreover, better-off households are more likely to opt out of community engagement. This can have a negative effect on social cohesion and the disaster resilience of the entire community (Wamsler 2007).

Finally, two education-related issues were identified to be particularly relevant to efficient local coping: formal employment and interest in moving to a lower-risk area (within or outside the settlement). The following subsections explain how these two issues reduce risk and how they relate to education levels.

Formal employment

Neither the San Salvador nor the Rio case study indicate a strong correlation between formal education and income. However, both studies show the importance of formal employment in coping with disasters. In fact, helping dependents to find formal employment was mentioned as a coping strategy (Wamsler 2007). Interviewees stated that formal employment allows them easier or cheaper access to:

Box 2. Education and institutional support

Francisca lives with her husband and baby in the high-risk *Laboriaux* area. She is 26 years old and has eight years of education. When asked how she copes with the imminent risk of landslides, she mentions a range of strategies, including staying at home to not miss information from the Civil Defence Service.

Maria, a female *Los Manantiales* resident with six years of education, takes an active part in the community-based work offered by the FUNDASAL institution to reduce existing risk. Although several other interviewees were reluctant to actively participate, she says: "It is true that we [meaning the poor] have to work [in order to reduce our risk], but this is how it is, we have to work hard if we really want to make a change here and have a better life."

A technical staff member working in *Rocinha* for the government-sponsored programme *Programa de Aceleração do Crescimento* describes the importance of education: "After a disaster, the affected families have a lot of issues to solve and to deal with. Those who have a better education can generally cope better with the post-disaster situation than those who have less education, [...] because education helps them to make better decisions, for instance, when they have to decide where to go to an emergency shelter, when they have to deal with authorities or other institutions which offer different types of assistance, etc. These are cases where better education will be of help. Hence, residents' education is certainly a determinant [for their level of risk]."

Box 3. Education and coping mechanisms: Education as a conscious strategy

Ana, a single mother with 11 years of education, lives in *Cachopa*. One way she deals with risk is to send her son to study outside the *favela* so that his education is not affected by problems such as natural hazards, shootings, power cuts, and teacher strikes. In contrast, Francisca, a single mother with eight years of education, living in *Laboriaux* sent her two eldest sons to the local school. However, after the devastating landslide in 2010 and the closure of the local school, she decided to send them to stay with her mother who lives in another state. For Francisca, this is an active coping strategy as she does not want her boys to miss school and she is afraid that she would not be able to save both her two boys and her baby if there was another landslide.

- Post-disaster credits;
- Life insurance;
- Retirement pension or incapacity benefit;
- A regular income (e.g. work that is not vulnerable to climate variables and extremes);
- Health insurance;
- Sick leave (e.g. following a disaster);
- Other benefits (e.g. regulated hourly rates, safe working conditions due to formal security regulations);
- Direct post-disaster assistance from employers; and
- An official address (the employer's), which is required to register children at school.

The importance of these issues is demonstrated by the case of an informal worker living in *Divina Providencia* who pays into the social security system through deals with local entrepreneurs who certify his employment, thus giving him (illegal) access to formal insurance mechanisms. In addition, residents working in the informal sector often hold several jobs and have little time for community-based risk-reduction efforts (Wamsler 2007). Finally, interviewees suggested that a certain level of education is a determinant for finding formal employment (see Box 4), and that there is less likely to be a correlation between formal education and income for male residents. This may relate to the fact that there are generally more well-paid jobs for men (than women) that do not require any formal education.

Moving to a lower-risk area

Although the quality of education in low-income settlements in San Salvador and Rio is often substandard, this study suggests that education may be key to moving to a safer area. This includes lower-risk areas within the same settlement and (to a lesser extent) moving to a formal part of the city where risk and risk reduction are less shaped by informal processes. Better-educated interviewees tended to see moving elsewhere as an option and had ideas about how to achieve it. In a study of Rio's informal settlements, Perlman (2010) found three factors that increase the likelihood of a move from the *favela* (slum) to a *bairro* (formal settlement). Those who moved tended to: (a) have better-educated fathers; (b) have a higher level of education themselves; and (c) be more knowledgeable about Brazilian politics. In contrast, no correlation was found between leaving the *favela* and income level. The same study shows that *staying* in an informal settlement is, however, correlated with other well-being indicators, such as being in formal employment, being a homeowner, and/or being active in a community organization (Perlman 2010). Interestingly, in San Salvador all interviewees with an exceptionally high level of education and a formal job (at a governmental agency) had moved to a lower-risk area within the settlement. Finally, both the San Salvador and the Rio case studies demonstrate the importance of women as the driving force behind families moving out, typically motivated by their wish to protect their children (see Box 5).

Education: mitigating effects on risk factors

Both the San Salvador and the Rio case studies found that higher levels of education can reduce underlying risk factors. Underlying risk factors include:

- Poor health;
- Organized crime;
- Teenage pregnancy and single motherhood; and
- Informal settlement growth.

The findings presented below describe: (a) the relevance of the factor in the context of the case study areas; (b) its relationship to education; and (c) its influence on disaster risk. They illustrate how education can have a mitigating effect on underlying risk factors, how this is linked to the conceptual framework presented earlier and how the various factors are mutually reinforcing.

Box 4. Education, formal employment and disaster risk

"When I was living in the *favelas* in the 1960s, parents commonly warned their children: 'If you drop out of [elementary] school, you won't be able to get a job and you'll end up collecting garbage.' Several years ago when I was in Rio, 200 vacancies opened up for garbage collectors. Over 4000 people applied, and a high-school diploma was mandatory" (Perlman 2010:231).

According to the Director of the *Rocinha* Residents' Association, education levels influence disaster risk levels in two ways: (1) less education generally leads to a greater number of children per family; and (2) it restricts access to formal employment. He states: "These [less-educated] residents may not be able to get a [formal] job, as many formal jobs require a certain level of education, degree. And we know that not having a [formal] job, or only having an [informal] job with low wages, makes residents incapable of moving out [of the risk zone] and to a better place."

In *Cecilio del Valle*, Mercedes describes her uncle who recently died leaving four children. As he had formal employment, she now receives his life insurance: "This allows us to take care of his house and the children. He left behind four small children, the oldest one will soon be 14."

Box 5. Education and moving to lower-risk areas

Esperanza, who lives in the *Los Manantiales* area, has always wanted to leave in order to protect her children. However, her husband's unwillingness to move created stress and tension, which finally led to their separation: "I can tell you that in the past, until recently, it was nearly impossible to live here [due to all the disasters occurring], and I was close to moving somewhere else, and I even escaped with my children and got separated from my husband, because he never wanted to leave this place." In the end, Esperanza stayed in *Los Manantiales* as risk levels were considerably reduced with the help of FUNDASAL's slum upgrading program.

Poor health

Context: The physical and mental health of residents in the *Los Manantiales* and *Rocinha* areas is poor compared to the surrounding formal settlements. The high number of health problems is partly caused by a lack of waste and waste-water facilities, contaminated wells, overcrowding, violence and poorly-ventilated houses (Verly 2009) as well as by informal and physically demanding work.

Education→poor health: Education levels are an important determinant of health. The number of years of schooling has been shown to be the second most influential variable on the health status of adult Brazilians (after age) (Fonseca et al. 2000). Disease is exacerbated by a failure to follow treatment regimes, which is directly related to poor education (Ferreira et al. 2005). Furthermore, interviews revealed that many of the less well-educated residents of *Los Manantiales* and *Rocinha* are forced to take informal jobs, which are often physically demanding, with unregulated working hours, little attention given to workers' health and safety and no health insurance—leading to injuries, physical wear and tear and mental stress.

Poor health→disaster risk: Good health is a key resource for disaster survival (Enarson 2000, Wisner et al. 2004), while poor health makes people more vulnerable. As Box 6 shows, poor health makes it more difficult to earn a living and can force other family members to leave school to support their family. The interviews suggest that some health conditions (for example being disabled or HIV-positive) increase vulnerability by adding to the stigma of living in a low-income area. Furthermore, health is a determinant of people's capacity to respond to disasters. Limited mobility makes it difficult to navigate steep stairways and winding alleyways in an emergency (see Box 6). Poor health is also likely to affect capacity to recover from a disaster. It is, for instance, more difficult to withstand infectious diseases that often spread in the aftermath of disasters with an already weakened immune system (Wisner et al. 2004). An illustrative example is a woman who lives in the high-risk *Laboriaux* area. Although she did not suffer directly from the landslide in 2010, her history of psychological illness meant that the landslide had a serious impact on her, and she had great difficulty returning to her previous life.

Organized crime (and corruption)

Context: The residents of *Los Manantiales* and, to a greater extent, in *Rocinha* have been abandoned by regular law enforcement agencies and rely on gangs to keep order. In the San Salvador case study, flooding and landslides are generally seen as the main risk to lives and livelihoods. These are followed by earthquakes and windstorms, a lack of job opportunities and insecurity created by *maras* (gangs). *Los Manantiales* residents are killed, harassed, violated and robbed on a daily basis (FUNDASAL 2010). In the Rio case study, the most frequently mentioned risk after landslides was being caught in crossfire during one of the police's sporadic raids in their effort to control violent gangs.

Education→organized crime: Primary and secondary education has been shown to be one of the most effective ways to sustainably reduce participation in the drug industry (Dowdney 2003). In San Salvador, community leaders explicitly mentioned the direct relationship between poor education and violent behaviour, in the form of organized crime and intra-family violence. In addition both case studies show that children who drop out of school are more easily recruited by criminal gangs (Dowdney 2003, FUNDASAL 2010), and young men with little education often see no other way to make a sustainable living than to work for traffickers (Dowdney 2003). Lack of access to the employment market for youngsters from informal settlements is another factor that contributes to the steady flow of new recruits into criminal gangs (Perlman 2010, FUNDASAL 2010).

Box 6. Education and poor health

Claudia, a less-educated female resident of *Los Manantiales* suffers from a kidney malfunction. Before falling ill, Claudia earned a living from informal cleaning work in households outside the settlement. During an interview, she described how a lack of health insurance and consequently difficulty in accessing health services caused her health to deteriorate and increased her level of disaster risk: "No, it would just be fantastic if I would have any [health] insurance. The insurance makes a big difference. Without it, I have to go to the Hospital Rosales and wait there for around 3 days in the emergency room until I can get a bed. In theory, I would have to do this every week, but [because of this situation] I do not go any more [...] and therefore my health has been getting worse." Claudia's son has just finished his third year at school. His mother's poor health and the family's resulting financial difficulties mean that he is forced to leave school to earn money for her and his family. Although his mother is not happy about this, she is proud that her son is taking responsibility: "You know, this boy is very smart. He would like to continue studying at the University, but now this is not possible. No, because he has to work. 'Since I am helping you mom', he tells me."

Ernesto is an illiterate resident of *Los Manantiales*. He has lived next to the river all his life, but now he is worried because he lost his leg in a work accident and then lost his wheelchair (which had been given to him by a church) during the floods in the aftermath of Hurricane Stan. He is now responsible for taking care of his two grandchildren: "I have always been living on the river banks, but when I could still walk this did not worry or afflict me. But now it does [...] And imagine, my daughter leaves me here with her two children." Ernesto lost not only his wheelchair, but also his house and his land during Hurricane Stan, and he is thus currently living on his neighbour's land. His own son had to leave school and is unable to work because he has to take care of his handicapped father.

Organized crime→disaster risk: Violent conflicts between gangs and the police mean that life expectancy for men is low. Many residents fear the police and see them as corrupt and brutal. This creates widespread mistrust, not only of police officers, but of any kind of authority including emergency and development planning officials. In the San Salvador case study, national and municipal governments were often seen as unhelpful and even a hindrance to local risk-reduction efforts (Wamsler 2007). In addition, organized crime, corruption and political factionalism have eroded trust and social capital within informal settlements, affecting community cohesion and community-based coping mechanisms (Wamsler 2007). They also dilute the flow of information about jobs and other opportunities, which is spread through informal community networks (Perlman 2010). This included information on potential risk-reduction measures and institutional support. In Rio, many residents' associations have been threatened or taken over by drug gangs; consequently participation in community organizations has drastically decreased (Perlman 2010). However, observations and interviews show that in both case study areas communities are highly dependent on mutual help. The loss of social capital due to organized crime therefore appears to have serious effects on risk levels. In addition, organized drug trafficking can lead to the increased availability and abuse of illegal substances and thus higher risk levels (Uchtenhagen 2004, National Institute on Drug Abuse (NIDA) 2010). Interviewees described drug trafficking, drug abuse and associated violence as a threat to both health and well-being, which results from increased mortality and psychological stress (cf Uchtenhagen 2004, Box 7).

Teenage pregnancy (and single motherhood)

Context: There is a high rate of teenage and pre-teenage pregnancies in the case study areas. In off-the-record discussions about risk, early pregnancies are mentioned almost as frequently as drug trafficking.

Teenage pregnancy and education: Teenage pregnancy is known to be more common among girls with low levels of education (Busso 2002, Stern 2002, Observatório da Educação 2006), and there are some indications that the risk is higher for teenage girls who do not attend school (Observatório da Educação 2006).

Teenage pregnancy→disaster risk: Single and teenage mothers in *Los Manantiales* and *Rocinha* face a variety of challenges that may contribute to their disaster vulnerability. These include higher expenses, difficulty in continuing education or income-earning activities, health complications during and after pregnancy, and potential rejection by their family or partner. Interviews and observations show that early and unplanned pregnancies often create vulnerable family units (e.g. single-head households) and add to the responsibilities of the parents of the young (or single) mother. Disaster literature shows that mothers (and to an even greater extent single mothers) are at particular risk in disaster situations (Enarson 2000, Cutter et al. 2003). Being responsible for a small child (or several) can affect a woman's ability to cope with and respond to disasters (see Box 8).

Informal settlement growth

Context: Amidst all the difficulties of life in *Los Manantiales* and *Rocinha*, there is great ingenuity. Materials and objects are constantly sold and repurposed for the construction of housing, microenterprises or risk reduction. Old car tyres are converted into retaining walls or embankments; plastic sheets and corrugated iron are turned into gutters. Problems such as a lack of living space are solved by the construction of another floor or expansion along river banks, a lack of electrical sockets is fixed by simply pulling another cable, and many residents work informally in various sectors. However, there is a downside

Box 7. Education, organized crime and corruption

Several interviewees describe how rivalries between groups (political parties or violent gangs) combined with corruption, has a negative influence on the institutional support available. Luis, living in *Cecilio del Valle,* states: "The retention walls were probably built in the least-affected areas, and residents in the areas most at risk were left with nothing. The local board helped in the sense that they were trying to access help from different organizations. But then, well, this is what one can often see here: After the earthquake, most residents, including the local board members, knew which families were most in need; however, in practice, things turned out differently. They barely took them into account, those that were most in need." Another resident highlights the influence of politics on not only local assistance (from the local committee), but also the municipality: "Well, this is how the political parties work [...]: it is only some few residents who really get some help [...], they give corrugated iron sheets, scantlings, cement or bricks [...], but they only give to some."

Box 8. Education and teenage pregnancy

A woman living in *Cecilio del Valle* states: "You just have the money to pay bills but not to eat. I bought a pair of shoes for my son so that he can go to school, and then I could not pay the electricity bill. The next [electricity] bill will be double to be paid next month."

A community leader from *Rocinha*'s Residents' Association links teenage pregnancy to disaster risk and education: "Residents with little education often end up having very large families, particularly in this part where the risk is highest, which is the area of *Macega*. It is perhaps due to residents' lack of formal education that the people there haven't had many opportunities to study and gain knowledge about things [...]. The number of children tie the mother to their home, and also the father. Many mothers have to quit their studies because they become pregnant at a very early age, too young; and the responsibility of caring for a child, or for two children, becomes too much of a burden, so that they cannot continue going to school."

to this rapid informal development. Overcrowding, unsafe construction, the absence of waste and water management, the permanent fear of eviction, deforestation and excavated slopes are part of daily life.

Education→informal settlement growth: Formal education may be a determining factor in improving prospects for moving to a formal part of the city, where risk and risk reduction are less shaped by informal processes. In addition, the poor quality of public education in El Salvador and Brazil particularly affects children living in informal settlements (see the following subsection), which amplifies differences and inequalities between residents living under "formal" and "informal" conditions.

Informal settlement growth→disaster risk: The impact of informal settlement growth on disaster risk relates to aspects such as stigmatization, exclusion from formal decision-making processes, insecure tenure, and inadequate housing and infrastructure. Findings from both study areas show that living in an informal settlement limits opportunities to find employment or access institutional assistance (see Box 9). Living under informal conditions often means not having an official address (Censo Domiciliar 2010) which restricts access to education (an address is required to register children at school) and participation in formal decision-making processes (Perlman 2010, UN-HABITAT 2010). Many residents of informal settlements further have to deal with constant fear of eviction, which reduces any motivation to improve their risk situation (Wamsler 2007). In addition, informal building processes result in housing and infrastructure that cannot resist hazard impacts, create additional hazards, and obstruct disaster response and recovery (see Box 10). In terms of recovery structures and mechanisms, access is problematic for residents who do not have legal tenure and informal workers who lack associated rights.

Disaster impacts on people's education

Both the San Salvador and the Rio case studies show that disasters strongly affect residents' lives and livelihoods, which includes short- and long-term impacts on their level and quality of education. In particular, in the aftermath of disasters children are often obliged to temporarily or permanently leave school. The reasons for this include:

- They have to work to support their family;
- They have to take care of injured family members (see Box 6);
- There is no money to pay school fees (due to post-disaster expenses or theft from damaged and easily accessible houses);
- The loss of belongings required to attend (or change) school (school uniforms, books, identification, etc.);
- The destruction of the local school; and
- The permanent closure of the local school due to its location in a (newly declared) high-risk zone.

Box 9. Education, informal settlement growth and stigmatization

Eugenio from *Rocinha* says that the *favela*'s reputation as a violent and lawless area creates mistrust in its residents, even though most are victims rather than the perpetrators of crime. Not only does this stigmatization make it difficult for him to find formal work, he cannot reach his job during shootouts between traffickers and the police without risking his life, adding further weight to his employers' discrimination.

In San Salvador, interviewees from *Cecilio del Valle* describe how government officials are completely unaware of their situation and do not even want to set foot in their settlement: "The government has never had the kindness to visit these remote [meaning informal] places, [...]." Consequently, governmental assistance is scarce: "No, they have not given us anything. We only see them passing by. As we are 'private' [meaning informal], as they say it. [...] They do not care about us, only for the ones that have formally accessed their land."

Stigmatization due to an address (i.e. the name of the settlement) is illustrated by Alejandro, a resident of *Los Manantiales*: "Before, this community wasn't called New Hope; it was called River Banks. This was its name. [...] Absolutely nobody wanted to provide any assistance for River Banks, no single organization wanted to help us saying that River Banks means that it is located next to the river, and this is true. But we came here because it was actually the Municipality who offered here land for housing, and if we would build construction walls, we were told that we would get legal tenure." However, it was only after many years of fearing eviction and as a result of the FUNDASAL slum upgrading project (which provided assistance land regularisation and help with physical risk-reduction improvements) that they were given legal tenure.

Box 10. Education, informal settlement growth and insecure tenure

The examples of Maria, living in *Laboriaux* (Rio), and Eugenia living in *Cecilio del Valle* (San Salvador), demonstrate the importance of legal tenure. Eugenia does not own the land she is living on and says: "But imagine, not only does one not have a secure entrance to one's own house, if in addition I would spend a lot of money on [improving] this, and perhaps the next day they come and say 'leave, go away from here' [...]." Maria, 44 years old with 10 years of education, lives with her husband and children. Her children were awarded a scholarship by the church to study. When asked about how she copes with risk, she mentions being a homeowner (as opposed to renting) as a strategy, and investing in improvements to her house and land in order to reduce disaster vulnerability. As she earns her living informally through a local catering business, she does not want to move elsewhere. In fact, she considers *Rocinha* to be the perfect place to live and run a catering business, because its central location makes it easy to attend to clients from wealthier areas (*São Conrado* and *Ipanema)*. She says that where she lives benefits from a big kitchen, natural springs with fresh water and a marvellous view. The only problem is that local disasters negatively affect her business. After the disaster-related deaths in 2010 in *Laboriaux,* residents were not in a *clima de festa* (party mood). Residents moved away from *Laboriaux* and local demand for her birthday cakes and party catering fell.

In other cases, although children do not have to leave school, they must temporarily or permanently travel to another, more distant school. This results in:

- Additional expenses for bus fares;
- Less time to do homework, take care of other responsibilities, and sleep; and
- Children going to school only every other day (as the early mornings become too stressful over time).

Sometimes families have to move to other areas where their children cannot attend the local school. This can be due to the fact that:

- The new school cannot take more pupils; or
- The parents do not (yet) have a recognized address to register their children at the new school.

Many female residents highlighted that in the aftermath of a disaster there are many factors that make it difficult for children to concentrate on their studies. Such factors are:

- Reduced or lack of space for studying as houses are damaged or destroyed;
- Electricity failure or outages, making it impossible to study in the early morning or after sunset;
- Difficult and dangerous routes to school;
- Community distress;
- Psychological distress of families;
- Pupils have increased responsibilities such as taking care of sick family members, reconstruction of houses, part-time jobs, etc.;
- Living in temporary shelter or in unsafe houses with no privacy (no doors, walls, etc.);
- Family disruption due to a permanent move of (some of the) children to other family members living in safer areas; and
- Increased health problems that have disproportionate effects on young schoolchildren.

With education being crucial to adaptive capacity, disasters and their impact on education are likely to result in a vicious circle of increased risk and deteriorating education. However, it is important to highlight that education in low-income settlements is inadequate even when disasters do not occur. Classes are often cancelled due to power cuts, shootings, and absent or striking teachers. Not many teachers want to work in a slum; not only because they consider it unsafe, but also because such places have little social value (Gonçalves 2010, Perlman 2010). Nevertheless, although the quality of education in both case study areas is obviously low (and has even declined in some parts), several interviewees mentioned that the improving access to education for their children in recent years is a reason why they feel less at risk.

DISCUSSION: TOWARD SUSTAINABLE ADAPTATION

This section discusses the influence of formal education on societies' adaptive capacity. First, the key results are summarized. This is followed by a comparative analysis of the quantitative and qualitative results of the San Salvador and Rio case studies. Finally, the findings are discussed in the light of the conceptual framework presented above.

Summary of Key Results: The Role of Education for People's Adaptive Capacities

The initial evidence suggested that education does not play a major role in disaster risk levels. All the international risk management experts interviewed suggested that education plays only a minor role for risk reduction, which is based on its potential influence on income levels. In addition, none of the international or national experts who were consulted were aware of research that specifically analysed links between education level and disaster risk, nor of any databases that would permit such analyses. Nevertheless, the in-depth comparison of the quantitative and qualitative data showed a different picture. In fact, the qualitative results of both the San Salvador and Rio case studies indicated that formal education has a positive and direct effect on:

- Awareness and understanding of existing risk;
- Access to, and provision of information on risk reduction;
- Acceptance and adequate use of institutional support; and
- Improvements in residents' coping strategies.

As regards the latter, two issues related to formal education were particularly relevant to local coping: formal employment and interest and efforts made to move to a lower-risk area within or outside the settlement. In addition, the qualitative results suggest that a higher level of education mitigates underlying risk factors. These factors include:

- Poor health;
- Organized crime;
- Teenage pregnancy and single motherhood; and
- Informal settlement growth.

The quantitative analyses support some of the qualitative results. For example, they indicated a significant correlation between:

- Level of education and ability to identify risks (Rio);
- Level of education and number of risks identified (Rio); and
- Lower (higher) average education level and living in a high (low) risk area (San Salvador and Rio).

Other important results from the 2009–2011 surveys are correlations between:

- Households affected by Hurricane Mitch in 1998 and those affected by Hurricane Stan in 2005 (San Salvador);
- The impact of past disasters and local coping strategies (San Salvador); and
- Women's level of education and income (Rio).

Finally, in the San Salvador case study, the quantitative analysis of the 2003 FUNDASAL institutional database found correlations between:

- Education level of heads of households and total household income;
- Education levels of (working adult) household members and total household income; and
- Education level of heads of households and disaster risk.

Comparative Analysis:
The Climate/Education Nexus

The above summary of the key results shows that education has both a direct and indirect influence on residents' disaster risk level. This section highlights some of the differences between the two case studies.

Education and disaster risk

The Rio case study showed a clear statistical correlation between educational levels and ability to identify risks in the settlement. This result was independently confirmed in interviews with key informants and showed that less-educated residents tend to downplay risks. Assuming this is the case, the analysis of the 2003 San Salvador database, which identified a negative correlation between education and disaster risk, becomes more significant than it first appears. In this dataset, high and low risk is self-defined (unlike more objective risk evaluations). It also reflects the situation in the settlement before the FUNDASAL slum upgrading program and related risk-awareness campaigns. Consequently, the correlation could be even stronger than it seems (assuming the positive influence of education on the adequate use of institutional support). Interestingly, a more detailed analysis of the same database showed a correlation between both education and disaster risk, and between education and income, but *not* between income and disaster risk. This demonstrates the importance of education rather than income. Likewise, the Rio case study showed no significant correlation between education and income, either for households or for men—although the situation was different for women (see below).

A comparison of the qualitative and quantitative results of the San Salvador case study suggests that there is an important link between education levels and risk-reduction coping strategies. This correlation was not significant in the quantitative analysis, and this is probably due to the fact that the analysis was only based on coping strategies mentioned by interviewees (therefore those they are aware of). However, conscious coping strategies tend to be related to structural or economic improvements (Wamsler 2007), which overlooks the numerous other strategies that were identified in the qualitative analysis.

Institutional support for risk reduction and adaptation

The case studies suggest that current levels of institutional assistance in reducing and adapting to risk are insufficient. Although in San Salvador high-risk households received more assistance than those at moderate risk they were nevertheless similarly affected by the impact of both Hurricane Mitch in 1998 and Hurricane Stan in 2005. A similar analysis could not be made in the Rio case study. However, in the Rio study, although at-risk households had received more institutional help, 63.3% of them still stated that their current level of risk is similar or even worse than before. In addition, virtually all interviewees agreed that current measures are not sufficient to cope with increasingly frequent disasters, which casts doubt on current institutional approaches.

The "gender twist"

The study found that formal education seems to have a particular impact on women's level of risk. This was confirmed by the statistical analyses of the Rio case study and the qualitative results of both case studies. The analyses show that, for women, better education is likely to lead to a higher income. No such correlation was found for male participants. The qualitative analyses suggest that this may be due to the fact that there are many male-dominated jobs that are relatively well paid, but do not require formal education, whereas this is generally not the case for female-dominated jobs. In addition, it seems that it is easier for men (rather than women) to find formal employment without a certain level of formal education. Given the importance of the influence of formal employment on adaptive capacity (as demonstrated in the "Results" section), formal education is a key determinant of women's risk levels.

The importance of formal education in determining women's risk levels becomes also obvious when analysing other qualitative outcomes. In fact, the results show an obvious "gender twist", in that correlations between education and the factors that (directly or indirectly) influence risk are more (or only) relevant to women. Obvious examples include teenage pregnancy and single motherhood. Health is another factor where women's level of education is especially determinant, and the correlation between education and HIV/AIDS in Brazil is one of many examples (Fonseca et al. 2000). With regard to organized crime and substance abuse there

Table 3. Influence of education on existing area-specific risk

Factors influencing people's level of risk	Influence of (lower levels of) education *Illustrative examples of how lower levels of education might increase risk*	
Hazard(s)	Increased exposure to existing hazards due to high and increasing numbers of residents in the same disaster-prone settlement with no option or little interest in moving to lower risk areas, resulting in: • Increased proximity of housing and infrastructure to hazards • Expansion of informal settlements into high-risk areas	Intensified hazards and creation of new ones, such as: • Floods related to extensive littering and inadequate infrastructure • Landslides due to excavation, deforestation, intensive littering, and inadequate construction • Fire due to inadequate electricity connections
Vulnerability	• Concentration of highly defenceless population groups weakened by diseases, conflict, work-related injuries, family disruptions, etc. • Organized crime and corruption affecting community cohesion and information flow on risk and risk reduction • High numbers of teenage pregnancies and vulnerable households with single mothers, numerous children, or other dependents, etc.	• High numbers of residents working in informal and physically demanding jobs with no or little social protection • Limited access to formal assistance and low influence on decision-making processes (for risk management) • Inadequate housing construction and infrastructure • Mistrust in authorities, including planning authorities and emergency organizations
Response mechanisms and structures	• Reduced mobility of residents with poor health, single mothers, and families with many children • Reduced mobility due to low income (e.g., no personal vehicle and lack of money to pay for public transportation) • Reduced mobility due to organized crime (resulting in high levels of insecurity and increased expenses for "protection" offered by criminal groups)	• Lack of emergency access and evacuation roads (due to informal living conditions) • Limited access to formal response mechanisms (due to informal living conditions) • Mistrust in authorities and thus ignorance of formal disaster warnings, alerts, evacuations, emergency shelter, etc. • Difficulties in communication and contact with emergency organizations
Recovery mechanism and structures	• Difficulty recovering quickly due to poor health conditions • No access to formal recovery credits (due to informal work, no legal tenure, no permission to use assisted housing as collateral, no official address, etc.)	• Mistrust in authorities (which might lead to refusal or inadequate use of recovery assistance offered)

is a similar "gender twist." Although it is mainly men who are directly involved, women have to bear most risk-increasing consequences.

Finally, it is important to highlight the role of women in actively reducing risk. Women are often motivated by a strong desire to protect their children or to provide them with better opportunities, including improved education.

From Current Risk Reduction to Sustainable Adaptation

The identified strong influence of formal education on risk and risk reduction can be described by linking the results to the extended risk definition presented earlier. The conceptual and practical implications are presented in the following section.

Conceptual implications of results

The conceptual framework presented earlier proved to be an appropriate tool for the analysis of the influence of formal education. Unlike the conventional view of risk, it makes it possible to carry out a comprehensive analysis of interactions between education, disaster risk, risk reduction and adaptive capacity. People's risk levels are here determined by four risk factors: existing local hazard(s), vulnerabilities, and response and recovery mechanisms. Associated measures or adaptive capacities that aim to reduce the four risk factors are: prevention, mitigation, preparedness for response, and preparedness for recovery. This study shows that education has an influence on all risk factors and the respective adaptive capacities. See Tables 3 and 4 for some illustrative examples.

Table 4. Influence of education on people's adaptive capacity.

Factors influencing people's level of risk	Influence of (high level of) education *Illustrative examples of how higher levels of education might reduce risk*	
Precondition for adequate selection of adaptation measures	• Increased risk awareness • Better access to information on risk, risk reduction, available institutional assistance, etc. • Greater ability to assess, and provide authorities with information on, own risk situation	• Increased acceptance of (adequate) institutional assistance • A certain level of community cohesion, good health, time availability, and financial resources
Prevention	• Moving out of a risk area (within own settlement or outside own settlement)	
Mitigation	• Use of an increased number of risk reduction measures, including non-structural measures • More active use of education-related coping strategies, such as sending children to study outside their own settlement	• Better use of institutional assistance (e.g., through the adequate use and maintenance of constructive measures) • Better selection of adequate risk reduction measures
Preparedness for response	• Acceptance and adequate use of institutional support such as warnings, evacuation, emergency shelter • Active use of education-related coping strategies, such as temporarily sending children to study outside their own settlement	• Increased mobility
Preparedness for recovery	• Improved access to post-disaster credits, life insurance, paid sick leave, pension, etc. (due to formal jobs)	• Better use of institutional support such as recovery credits

CONCLUSIONS

With a worldwide increase in the number and intensity of disasters and a rise in global temperature, the effects of climate change are already being felt. Among those most at risk are the poor in developing countries, who often live in informal settlements or so-called "slums". There is an urgent need to better understand the factors that determine people's capacity to cope with and adapt to adverse climate conditions in order to reduce associated risks.

This paper examines the influence of formal education on the adaptive capacity of residents of two low-income settlements: *Los Manantiales* in San Salvador (El Salvador) and *Rocinha* in Rio de Janeiro (Brazil), where climate-related disasters are frequent. The research explores the promotion of formal education as a way to increase adaptive capacity. Data was collected using interviews, surveys, a literature review and observation, and both quantitative and qualitative data analyses were applied. Statistical analyses investigate the influence of formal education on residents' risk levels, coping strategies and institutional support. The qualitative analyses explore both the direct and secondary effects that education may have on disaster risk, and vice versa.

The results indicate that formal education may have a more significant role in determining risk levels and adaptive capacity than has hitherto been acknowledged. In both case study areas, the average level of education was lower in high-risk households (as opposed to lower-risk households). The positive influence of education was identified to be twofold: (a) it has a direct effect on risk-reducing factors; and (b) it mitigates factors that increase risk. On the one hand, formal education has a positive effect on issues such as levels of awareness and understanding of risks; access to information on (the adequate use of) risk-reduction measures; opportunities to find formal employment; and interest in moving out of an at-risk area. On the other hand, formal education has the potential to reduce underlying risk factors such as poor health, organized crime, teenage pregnancy, single motherhood and informal settlement growth. The latter includes the stigmatization of slum dwellers, exclusion from formal decision-making processes, insecure tenure, and poor housing and infrastructure. The results suggest that education plays a more determinant role for women than men in terms of adaptive capacity. They indicate that the identified limited effectiveness of institutional support for risk reduction may be related to the fact that the role of formal education has not been sufficiently explored.

Although further research is needed to test the validity of the findings in different contexts, they can justify the promotion of (improved access to and quality of) formal education as a way to increase adaptive capacity—and not only because of a potential influence on income. This outcome is supported by the negative impact of disasters on education, which in turn reduces adaptive capacity, resulting in a vicious circle of increased risk. A strong testimony in this context comes from

children themselves. In a recent study interviewing more than 600 children in Africa, Asia and Latin America, education was, in fact, the most commonly occurring theme and prioritised by all children during the consultations. Common requests were for their schools to be built on higher ground, for their learning materials to be protected, and for roads and bridges to be maintained to guarantee a safe way to school also during rainy periods (UNICEF 2011).

The strength of an education-based adaptation approach lies also in the fact that formal education was shown to influence all four risk components and related adaptive capacities without predetermining, specific or inflexible risk-reduction measures. In this context, formal education was a particularly crucial factor in the capacity to recover as it helps people to bounce back from the impact of a disaster by quickly (re)establishing livelihoods. Finally, the conceptual framework proved to be an appropriate analytical and practical tool that may help strengthen current planning strategies for investment in climate change adaptation.

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Community Vulnerability to Floods and Landslides in Nepal

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ABSTRACT. We addressed the issue of differential vulnerability to natural disasters at the level of village communities in Nepal. The focus lay on the relative importance of different dimensions of socioeconomic status and in particular, we tried to differentiate between the effects of education and income/wealth, the latter being measured through the existence of permanent housing structures. We studied damage due to floods and landslides in terms of human lives lost, animals lost, and other registered damage to households. The statistical analysis was carried out through several alternative models applied separately to the Terai and the Hill and Mountain Regions, as well as all of Nepal. At all levels and under all models, the results showed consistently significant effects of more education on lowering the number of human and animal deaths as well as the number of households otherwise affected. With respect to the wealth indicator, the picture was less clear and particularly with respect to losses in human lives, the estimated coefficients tended to have the wrong signs. We concluded that the effects of education on reducing disaster vulnerability tended to be more pervasive than those of income/wealth in the case of floods and landslides in Nepal.

Key Words: *education; floods and landslides; natural disaster; Nepal; vulnerability*

INTRODUCTION

Natural disasters occur and affect people's lives and livelihoods in almost all parts of the world. Some populations are more vulnerable than others and disparity exists between nations and communities within a country. Furthermore, within communities different households may be affected differently and even within households the vulnerability of individual household members may vary. In this study, we empirically assessed the relative importance of socioeconomic factors associated with differential community vulnerability to floods and landslides in Nepal. In this context, our specific research question was to assess the relative importance of different dimensions of socioeconomic status and in particular to try to differentiate between the effects of education and income/wealth. The reason for this effort in the unpacking of socioeconomic status (SES) was that these two dimensions of SES imply quite different policy priorities for reducing household vulnerability: either investing more in education or in strengthening the economic aspects of livelihood.

Empirical analysis of vulnerability to natural disasters' drivers have been conducted at national and subnational levels (Phifer et al. 1988, Yohe and Tol 2002, UNDP 2004, Brooks et al. 2005, Pradhan et al. 2007, Toya and Skidmore 2007, Deressa et al. 2008, Makoka 2008, Shewmake 2008). Brooks et al. (2005), in their macrolevel study, found that at the national level governance, health, and education were the three main determinants of vulnerability. In a multicountry study, Toya and Skidmore (2007) found that both higher income and educational attainment were important measures of development in reducing vulnerability to disasters.

At the microlevel, many studies applied regression analysis to find income as one predictor of vulnerability to natural disaster (Phifer et al. 1988, Pradhan et al. 2007). For example, Pradhan et al. (2007) have shown that the flood related fatality rate for children was very high among families with low socioeconomic status, measured by income-generating land ownership and the type of roof. Most of these studies used community characteristics that could be used to categorize community vulnerability as listed by King (2000): these included demographic indicators, such as size of the population, population aged 0-4, 65+, living arrangements, etc.; household types and structures; and economic indicators such as, unemployed and income level. Few studies considered education as a possible predictor of vulnerability (Phifer et al. 1988, Shewmake 2008). Phifer et al. (1988) chose education as a "rough" indicator of socioeconomic status instead of income, because of the high rate of nonresponse. Shewmake (2008) showed that "years of schooling" of the best-educated person in the household was one of the highest significant explanatory variables in explaining the variation in vulnerability of South African farmers to climate change (Shewmake 2008).

There is a huge body of literature studying the positive impacts of education on a wide spectrum of desirable outcomes. A review of this literature goes far beyond the scope of this paper. It should just be mentioned that recent reviews exist on the strong impact of female education on lowering fertility and population growth (Lutz and K. C. 2011), on assessing the effects of education on economic growth (Lutz et al. 2008) and health (Baker et al. 2011), and even on its effects on the quality of institutions and democracy (Lutz et al. 2010). However, was it meaningful to assume that education also mattered directly for reducing the vulnerability to natural disasters? Deressa et al. (2008) have shown that at the household level, farmers with higher incomes were less

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vulnerable to climate change. However, because education and income tend to be strongly correlated, it was not clear what was being measured when only one of the two factors was included in the analysis. It was well established that educated people tended to have higher salaries (Lutz et al. 2008), so if educational attainment had a strong positive association with income, then education might lower vulnerability via income. Apart from this economic effect, it may be reasonable to assume that educated people were more aware or better informed of the risks as well as the ways of mitigation and adaptation in case of disasters. Because so few studies have considered education in the analysis of vulnerability, the relationship between education and vulnerability has been largely unknown.

What were the possible causal mechanisms by which education could directly influence the vulnerability to natural disasters? While there had been almost no literature on this topic in the field of natural disasters, there was a significant body of scientific studies on the effect of education on health. And there were good reasons to assume that the effects of education on health and mortality in general were isomorphic to those on mortality to natural disasters, which is just a special kind of mortality. Baker et al. (2011) recently published a comprehensive review and assessment of the causal mechanisms by which education affects human health. It showed that there was strong empirical evidence of the importance of cognitive processes that were a result of education-induced changes in behavior that were protective of the health of the individual and his/her family members. With respect to health-related behavior, it had been shown that already low levels of education resulting in basic literacy could induce significant behavioral changes in terms of avoiding risk and taking precautions based on information about the risks. This effect tended to get stronger the higher the level of education. Contrary to an older assumption that most neurological development was completed before a child entered school, recent research has found that higher-order cognitive skills could be developed by interactions with the environment well into early adulthood. It also showed that exposure to schooling was monotonically and linearly associated with enhanced higher-order cognition (Baker et al. 2011). It was also shown that at higher ages, the mental capacity and ability to learn and adapt to new situations was higher for persons who had received more education, even if this education happened in childhood, many decades ago. These findings have had significant implications for the abilities of individuals and societies to be able to learn and adjust their behaviors based on new information and insights. It put education at the heart of the capacities of societies for learning and changing behavior toward less vulnerability and higher adaptive capacity to environmental change and the associated increased risk of natural disasters.

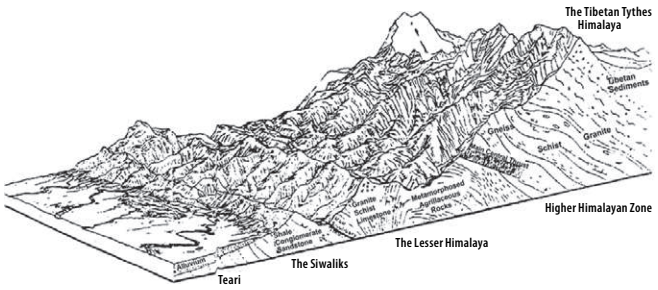
We tested community level education as a predictor of the vulnerability to floods and landslides in Nepal using two sources of data: data compiled annually by the government of Nepal (MoHA 2011) at the village level on losses due to flood and landslides, and a sample of microdata at the individual level from the 2001 census. The result of the analysis would inform us whether the educational level of a community was associated with its vulnerability to floods and landslides. Further, to explore possible causal pathways of this association, and to understand the role of education in reducing community vulnerability to floods and landslides and increasing their adaptive capacity, we conducted in-depth interviews with various stakeholders in a district of Nepal.

METHODS

Setting

Nepal is a country with varying topography starting at the relatively flat and low (80 m) Ganges Plain in the south (see Fig. 1) and steeply increasing to thousands of meters of elevation in the Himalayas. Each year during the monsoon season, massive rain events, some dropping as much as 550 mm of rainfall in 24 hours (Neupane 2008), can send huge flood pulses downstream through the steep and mountainous terrain causing flash floods and landslides in the hilly regions of Nepal. When the flood reaches the plain, known as Terai, inundation of riverbanks causes recurrent and severe flooding in Nepal, as well as in neighboring India (Dixit 2003, Khanal et al. 2007). Soil erosion is another major problem in the Terai caused by flooding. Nepal is administratively divided into 75 districts, 20 Terai and 55 non-Terai, the Hill and Mountain Regions.

Fig. 1. Physiographic regions vis-à-vis major geologic formations of the Nepal Himalaya. (DWIDP 2007)



Data

Data used in the analysis came from two sources. The main data source was a compilation of yearly disaster-related information from all over the country during the period of 2000-2009, and hereafter referred to as "disaster data" (MoHA 2011). The second source, published by the Central Bureau of Statistics of Nepal, was a microsample of the 2001 Census,

the latest available, of 2.5 million individuals. These 11% of the total population, belonging to some half a million households of Nepal, were used to obtain various individual and community level variables on population and socioeconomic status (CBS 2008).

The disaster data was compiled by the Ministry of Home Affairs (MoHA) based on reports on disaster-specific losses prepared by the district administrative offices (DAOs) on a total of 75 districts, and then sent to the ministry. Three disaster impact variables were considered in this analysis: deaths, family affected, and loss of animals due to flood and landslides. This information was collected either by the officials from the district level visiting the disaster affected site, or prepared by the Village Development Committee (VDC). In the first step of the process, households and/or livelihoods that were being flooded or hit by the landslides were listed as "family affected." In the second step, damages to the households or livelihoods, for example, deaths, loss of animal, or property damages, were calculated for the whole VDC and sent to the district administrative office. The information was available at the level of the VDC, around 4000 rural communities or urban municipalities. We combined all the data related to losses due to floods and landslides for the mentioned nine-year period. However, only the data for the periods of 2000-2001 and 2002-2006 were useful for the purpose of the regression analysis with the unit of analysis as single VDC-period.

Significant effort was invested to detect and rectify anomalies and discrepancies in the disaster data. Out of 3436 data points, 1640 (47.9%) VDC/municipality names exactly matched the standard list of names of VDCs and municipalities obtained from the Central Bureau of Statistics, Nepal. Unmatched names (1796 cases, 52.1%) were checked for spelling errors and the 1390 names (39.6%) found were corrected. The remaining 463 data points (12.7%) could not be used. The main problems were (1) many VDCs were lumped together into one group of villages or the data was reported for the whole district, (2) no matching names, and (3) names that could partially match with two or more, thereby creating "confusion" (for details see Appendix 1).

The implication of lumping the multiple records into one and the mismatched names of VDCs was significant. For example, there were 2042 deaths due to floods and landslides during the nine-year period, out of which 33% of the deaths could not be allocated to individual VDCs. These deaths were mostly concentrated in the period 2007-2009, when 22% of the deaths occurred, and in the period 2001-2002 when another 7.1% of the deaths occurred. After excluding the periods 2007-2009 and 2001-2002, the number of deaths in the dataset was reduced to 1215 (60%). Finally, problematic data points within the included periods (2000-2001 and 2002-2006) were further removed. Consequently, the final dataset (referred to as six 1-year periods: 2000-2001, 2002-2006) used in the regression analysis contained 1129 (55%) deaths with 2545 data points out of the initial 3436 data points from the 1449 VDC/ municipalities that remained.

The high number of deaths, 2042 persons in the period 2000-2009, indicated that the population was vulnerable to the risk of dying due to floods and landslides (see Table 1). Around half of the Nepalese population lived in 20 Terai districts, and 19% of the total deaths due to flood and landslides occurred in Terai districts. At the district level, the highest number of deaths, in the nine-year period, in the Terai district, occurred in Chitwan with 87 deaths, and 154 in the non-Terai district of Makwanpur, with 112 deaths in the single year 2002-2003, and 53 deaths in one VDC named Kankada. In 17 districts, the numbers of deaths were less than 10, including the district of Manang, with no deaths.

Table 1. Impact of floods and landslides in all districts of Nepal during 2000-2009 and the size of the population, mean years of schooling in 2001.

Districts	Pop (in 2000)	Mean Years of Education	Deaths	Affected Family	Animal Loss
Hills and Mountains					
Achham	231	1.4	9	1222	47
Arghakhanchi	208	3.0	26	2342	601
Baglung	269	3.7	110	1098	293
Baitadi	234	3.0	23	1333	194
Bajhang	167	1.7	11	681	195
Bajura	109	1.7	47	374	193
Bhaktapur	225	5.0	1	148	55
Bhojpur	203	2.8	23	504	283
Dadeldhura	126	2.7	38	382	122
Dailekh	225	2.6	17	310	381
Darchula	122	2.8	50	930	849
Dhading	339	2.0	59	671	399
Dhankuta	166	4.1	12	74	28
Dolakha	204	2.9	29	395	53
Dolpa	30	1.5	2	72	39
Doti	207	2.5	12	589	154
Gorkha	288	2.4	47	772	171
Gulmi	297	3.0	41	364	223
Humla	41	1.3	17	570	243
Ilam	283	4.5	21	577	240
Jajarkot	135	1.7	29	450	212
Jumla	89	1.8	7	49	9
Kabhre	386	3.6	32	1219	263
Kalikot	106	1.8	9	248	14
Kaski	381	4.7	90	1185	311
Kathmandu	1082	6.4	34	184	48
Khotang	231	2.8	56	2318	451
Lalitpur	338	5.3	14	55	119

(con'd)

Lamjung	177	3.0	30	422	292
Makwanpur	393	3.6	154	1858	556
Manang	10	3.4	0	9	5
Mugu	44	1.6	1	91	14
Mustang	15	2.6	11	37	91
Myagdi	114	2.7	46	378	156
Nuwakot	288	2.5	18	302	243
Okhaldhunga	157	2.2	42	454	247
Palpa	269	4.5	3	351	107
Panchthar	202	3.1	6	200	153
Parbat	158	3.7	2	672	205
Pyuthan	212	2.1	20	94	71
Ramechhap	212	1.6	59	1317	790
Rasuwa	45	1.5	33	148	144
Rolpa	210	1.4	21	748	79
Rukum	188	2.0	21	122	43
Salyan	214	2.6	4	132	161
Sankhuwasabha	159	3.3	31	391	182
Sindhuli	280	2.6	14	390	323
Sindhupalchok	306	1.7	23	358	279
Solukhumbu	108	2.2	22	710	168
Surkhet	289	3.7	7	549	129
Syangja	317	4.2	38	911	210
Tanahu	315	3.7	96	1389	397
Taplejung	135	3.0	46	791	346
Terhathum	113	3.8	10	153	116
Udayapur	288	2.9	24	4503	414
Non-Terai					
Banke	386	4.3	36	58588	114
Bara	559	2.8	13	163	37
Bardiya	383	2.4	5	10643	57
Chitwan	472	4.9	87	3470	525
Dang	462	3.8	20	384	427
Dhanusa	671	3.9	11	3291	220
Jhapa	688	4.6	12	3930	128
Kailali	617	3.3	24	5528	202
Kanchanpur	378	4.0	17	8447	358
Kapilbastu	482	2.6	41	56	5
Mahottari	553	2.4	14	12280	196
Morang	843	3.6	15	2989	44
Nawalparasi	563	3.0	24	9465	269
Parsa	497	2.7	6	780	139
Rautahat	545	1.9	22	7723	344
Rupandehi	708	5.0	8	3016	93
Saptari	570	3.6	4	40353	93
Sarlahi	636	2.3	20	19489	137
Siraha	572	2.5	10	11222	161
Sunsari	626	4.1	5	10478	154

In the nine-year period, there were a total of 248,891 families affected by floods and landslides. In 20 Terai districts, 212,295 (85.3%) families were affected, whereas only 36,596 (14.7%) families were affected in 55 non-Terai districts. This confirmed the general impression that in the hilly districts, flash floods and landslides were more fatal than the effects of rising water in Terai districts where the water was slow enough to give families time to avert deaths and injuries. The highest total of families affected in a non-Terai district was 4503 in Udaypur, and in a Terai district, it was 58,588 in Banke (50,200 in a single year).

A total of 15,814 animals died because of floods and landslides over the nine-year period. The number of animals lost in 20 Terai districts was 1333, and 14,481 were lost in 55 hilly districts. The highest totals, 849, occurred in the non-Terai district of Darchula, and 525 in the Terai district of Chitwan.

Model

We used the Poisson regression to test whether and how the community's vulnerability to floods and landslides was associated with socioeconomic indicators. Poisson regression was a preferred method in modeling the count data, especially when the event (dependent variable) being modeled rarely occurs or has a low probability of occurrence. The dependent variables were the disaster related losses, for example, the number of human lives lost, the number of animals lost, and the number of families affected, that could be considered events with low probability, to a greater extent the number of deaths and to a lesser extent the number of families affected. The Poisson regression was also a member of the family of general linear models (glm) where the predictors had a linear relationship with some function of the response variable; this was a logarithm of the response variable in the case of the Poisson regression.

We applied the Poisson regression model to investigate the relationship between the disaster related losses, e.g., number of human lives lost, number of animals lost, and number of families affected, and the average educational attainment of people aged 15-39 at the VDC level. In the regression analysis, we included the average education of the population aged 15-39 because this was the age in which the improvement in education progression occurred after 1991, when democracy was reinstated in Nepal after 30 years of absolute monarchy. At the same time, it was the population of young adults in this age group who brought about changes in the society faster through the assimilation of new ideas and technologies.

Three sets of models were studied for each of the response variables. Other predictors in the regression models were an income/wealth-related variable represented by the proportion of permanent housing in each VDC, and the number of times each VDC experienced the disaster (flood and landslides) during the period as a representative of exposure to the hazard of floods and landslides in each VDC. Because a VDC's population size was an important factor to consider, we included the size of the population in the regression model. Since we had no reason to believe that there was a nonlinear relationship between the population size and the number of events, we set the population variable as an offset term in the regression model so that the coefficient of the offset term was forced to be 1. Introduction of an offset term also opened a way to use the Poisson regression to model event-exposure rates (for example, death rates with numerator as number of deaths, events, among a population and denominator as total time spent by the population exposed to the event of death) with separate event and exposure variables in the model.

There was the likelihood that two neighboring VDCs might be correlated in terms of socioeconomic and demographic

status, as well as the hazards they faced. Although this was true to a large extent for the socioeconomic and demographic factors, this might not have held true for hazards of flood and landslides, which largely depended on the geographic location of the VDCs, especially in hilly districts. Although some VDCs, along certain riverbanks or situated in a river delta might have experienced similar hazards, many of the neighboring VDCs might not share the same hazards. A hazard level of VDCs would be needed to control for this, but the data for this was not available. Under these constraints, we included the hazard score in terms of number of times a VDC had experienced such an event during the study period.

In addition, we ran the analysis separately for Terai and non-Terai (Hill and Mountain Regions) because the two regions differed in terms of types and intensity of hazards and had socioeconomic differentials. It had been mentioned earlier that Nepal has a diverse geography, with Terai being a flat land and the rest being hills and mountains. As a consequence, the occurrences and impacts of floods and landslides were different in these two geographic areas. In the Hill and Mountain Regions, the disasters happened unexpectedly and with greater force of destruction, ending lives and destroying livelihoods. In Terai, in many cases, the disasters could be predicted in advance and the impact was slow, affected a larger area but with fewer deaths. Therefore, we repeated the analysis for the whole of Nepal, the Hill and Mountain Regions (55 districts), and for the Terai region (20 districts) separately.

In-depth interviews

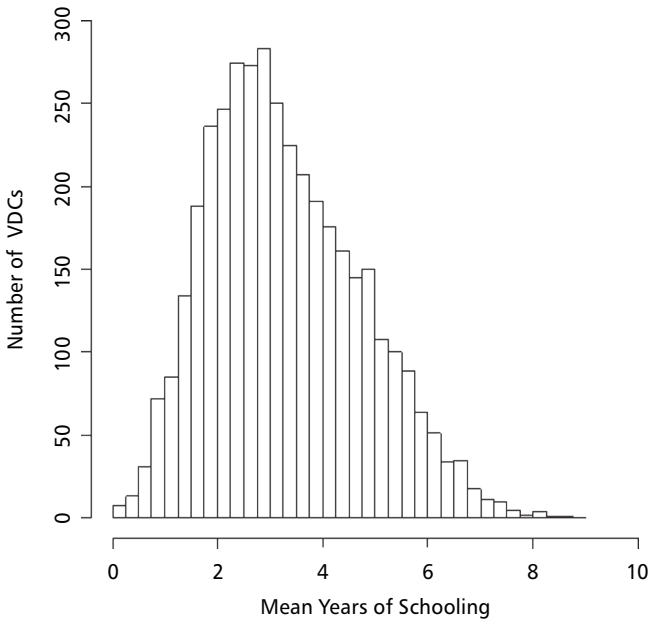
During the monsoon of 2008, to explain possible causal pathways between education and community vulnerability, and to understand the role of education in reducing community vulnerability to floods and landslides as well as increasing the adaptive capacity of these communities, the author visited a district in Nepal to conduct a few in-depth interviews with various stakeholders. District Nawalparasi was chosen because it consisted of both plains and hills associated with Terai and non-Terai districts and could be representative of most of Nepal. In-depth interviews were conducted with individuals at different places: two interviews with farmers at their residences, one interview with a local journalist, one interview with a local politician, one interview with a local Red Cross official, one interview with a government employee at the office of the district administration, and a final interview with a social worker. The interviews lasted between 10 and 50 minutes.

RESULTS

Educational distribution

The level of educational attainment was very low in Nepal (Fig. 2). In the year 2001, the mean years of schooling of the population aged 15-39 (MYS1539) was 4.55 years (3.5 years for ages 15 and over) with a relatively large standard deviation (sd) of 4.64 years (4.52 years for ages 15 and over). We found zero MYS1539 in two VDCs, Bihi VDC in Gorkha district and Bhijer VDC in Dolpa district. It was more likely that the samples from these villages did not include a single person who ever attended school. Kathmandu metropolitan city had the highest educational attainment among those aged 15-39 (8.31 years). The overall average of VDCs/municipalities was 3.3 years (sd 1.45), with 3.50 years (sd 1.49) for the Hill and Mountain Regions and 2.93 years (sd 1.29) for the Terai.

Fig. 2. Distribution of mean years of schooling among youths aged 15 to 39 years in Village Development Committees (VDC) and municipalities in Nepal, 2001 Census.



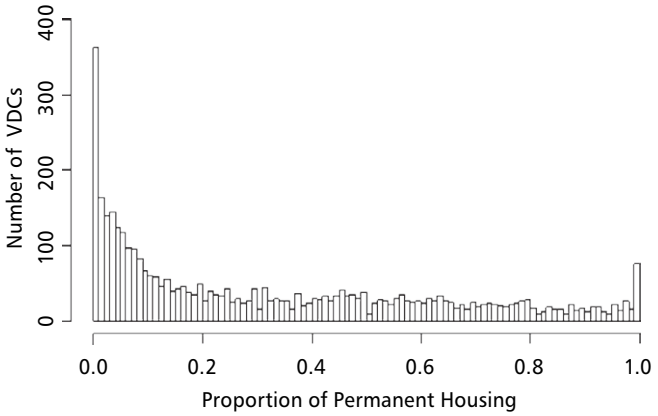
The district of Kathmandu had the highest level of MYS1539 with 7.5 years (sd 4.9), followed by other districts in the Kathmandu Valley: Lalitpur (6.4 years, sd 5.0) and Bhaktapur (6.3 years, sd 4.7, 4th place). Kaski district with Pokhara Valley, a major tourist destination, stood third with 6.3 years (sd 4.3) of MYS1539. The worst districts, in terms of educational attainment, were Humla with 1.8 years; Rolpa, Dolpa, and Achham with 2.0 years each; and Mugu and Kalikot with 2.1 years each.

Proportion of permanent housing

For each VDC/municipality, we estimated the proportion of permanent housing. In Nepal, 42.2% of all the households lived in a house with a permanent structure. In Figure 3, we show the frequency distribution of VDCs/municipalities by proportion of permanent housing. Permanent housing was a symbol of wealth and income because poor people could not afford to build a house with a permanent structure. There were

still many villages with no or low proportions of permanent housing. The correlation between the mean years of schooling (MYS1539) and proportion of permanent housing at the community level was found to be close to zero (R-square of 0.007), therefore these two factors could be considered independent.

Fig. 3. Frequency distribution of proportion of permanent housing in Village Development Committees (VDC) and municipalities in Nepal.



Village exposure to hazard

Some villages had a higher level of disaster hazards because of their geographic location and therefore experienced hazards more frequently. To control for the variation associated with the physical vulnerability of the VDCs, we calculated a village hazard index, which was estimated as the number of times in the six 1-year periods a VDC had been affected by floods and landslides. The average of the village hazard scores was 3.99 times with a standard deviation of 4.33 times. Of the VDCs that were affected at least once during this period, more than 50% had been affected less than three times, and more than 25% had been affected at least five times.

Population size of the VDCs/municipalities

The average population size of the VDCs/municipalities in the microdata (approx. 10% of the population) was about 7000 with a large standard deviation of 24,000. About 50% of the VDCs/municipalities had a population size of less than 3440, and about 10% of VDCs/municipalities had a population size of larger than 8000.

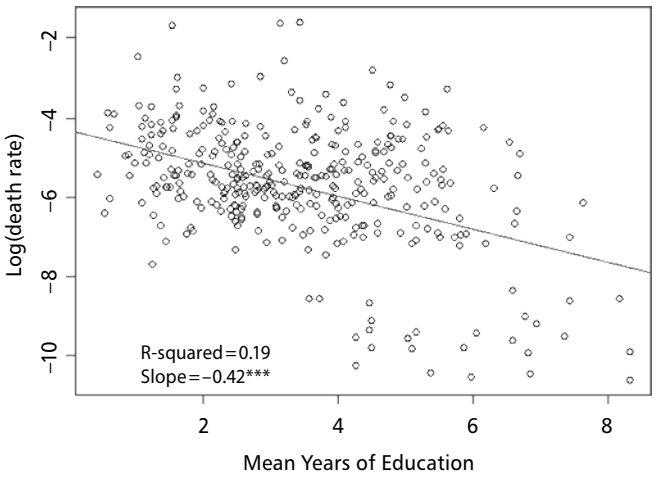
Number of lives lost

Based on the included sample of 2545 data points (VDCs with an event of a flood or a landslide) in the six 1-year periods, there were altogether 1129 deaths due to floods and landslides. In 78% of the reported cases, there were no deaths. In 254 cases, single deaths occurred in the VDCs/municipalities, followed by 106 cases with 2 deaths, 56 cases with 3 deaths, 33 cases with 4 deaths, 29 cases with 5 deaths, and so on. In terms of number of deaths, the 2 outlier maxima were 112 in one village, with 53 deaths in another village being the second largest.

In terms of recurrent deaths, over the six one-year periods, one VDC/municipality experienced deaths in three periods (total deaths = 3), 34 VDCs/municipalities experienced deaths 2 times (total deaths = 83), and 265 VDCs/municipalities experienced deaths 1 time each (total deaths = 844).

In Figure 4, we showed a bivariate plot between the VDC/municipality's specific (log of) death rate and the mean years of schooling for those VDCs that experienced at least one death. Therefore, we looked at the association between these two variables whenever death had occurred. It showed a negative association, which supported the contention that the communities with a lower level of MYS1539 had higher death rates.

Fig. 4. Log of death rate by mean years of schooling of population aged 15 to 39 at the community level.



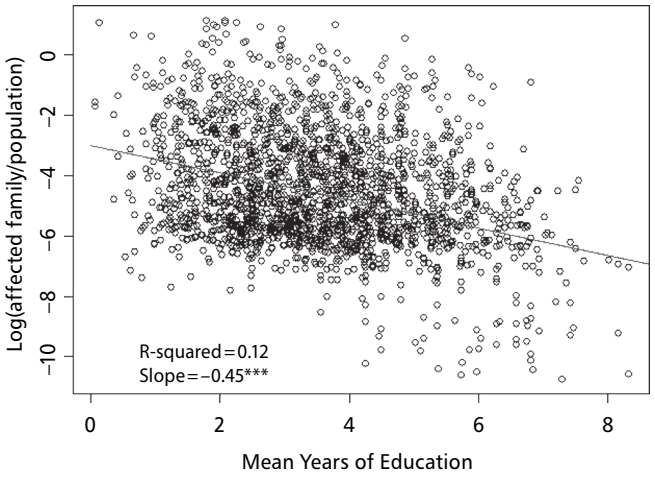
Number of families affected

During the nine-year period, in all of Nepal, a total of 248,891 families were affected by floods and landslides. In the worst year, 2007-2008, 114,668 families were affected. In the Terai region, the worst hit districts were Banke with 58,588 families affected in total and 50,200 in a single one-year period (2007-2008), and Saptari with 40,353 families affected in total and 37,290 in that same one-year period, 2007-2008. By contrast, Udayapur (4503) and Arghakhanchi (2342) were the worst hit districts in the Hill and Mountain Regions. In general, more people were affected in the Terai districts than in the non-Terai districts. However, as seen earlier, floods and landslides were far less deadly in the Terai region because the disaster was more predictable, developed more slowly with more warning, and was less hazardous in force.

At the VDC level, using data from the nine-year period with the 2001 data points, we found that an average of 26 families were affected per event per VDC/municipality with a standard deviation of 93. In 8.7% of the cases, no family was affected, and most of the times (38.1%) only one family per VDC/municipality was affected by the floods and landslides. In more than 25% of the cases, at least 10 families were affected, and the three highest observations for the number of families affected were 1209, 1651, and 1698.

Based on the data from the six 1-year periods, we showed a negative association (Fig. 5) between the fraction of the population affected by disaster (the log of the ratio of numbers of affected family and the size of the population) and educational attainment, as represented by the MYS1539 data.

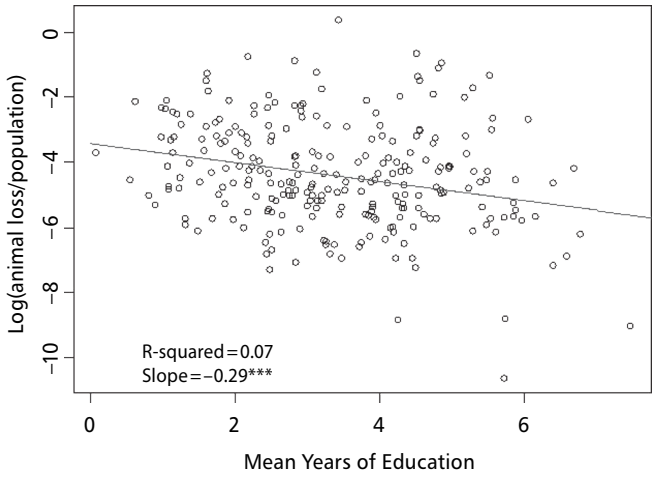
Fig. 5. Log of the ratio of number of affected families and size of the population and the mean years of education of population aged 15 to 19 at the community level.



Number of animals lost

The total number of animals lost during the nine-year period was 45,023 in the whole of Nepal. In the Terai region, the highest losses were experienced in two districts: Banke with 8563 in total in two 1-year periods during 2007-2009, and Sunsari with 6838 in total and 6799 in a 2008-2009 one-year period. Similarly, in non-Terai districts, Khotang experienced 18,027 losses in total and 17,602 in the 2007-2008 period and Makwanpur had 368. They experienced the highest losses in the list. At the VDC level, based on the availability of 4941 observations in total, an average of 1.64 animals were lost per event per VDC/municipality with a standard deviation of 12.8. In 2707 (90.2%) cases, there was no loss of animals due to the floods and landslides. In 22 cases, the number of animal losses exceeded 50, and the three highest numbers of animal losses reported were 220, 275, and 300. Based on the data from six 1-year periods, we showed a negative association (Fig. 6) between the fraction of the animals lost per population (the log of the ratio of number of animals lost and the size of the population) and educational attainment, as represented by the MYS1539. The strength of association was low (R-squared = 0.07) compared to that of the number of deaths and families affected.

Fig. 6. Log of the ratio of number of animals lost and size of the population and the mean years of schooling of the population aged 15-39 (MYS1539).



Poisson regression analysis

We ran three regression models for each of the response variables using the six 1-year data. The first model, Model 1, had only one explanatory variable, e.g., the mean years of schooling of the population aged 15-39. In the second model, Model 2, we introduced the percentage of permanent housing in the VDC, and finally in Model 3, we added the third explanatory variable representing the hazard risk of a VDC to disaster, which was the number of times the VDC had experienced a flood or landslide event over the six 1-year periods. The importance of newly added variables, in terms of explaining the variability in the response variable, could be informed by the change in the value of residual deviance, that is, the lesser the value the higher the amount of explained variation. Results from the various model runs for each of the response variables are presented in Table 2. The first four columns are the coefficients of the Poisson regression. The exponent of the coefficients is presented in parentheses and represents the relative ratio, which is the relative change in the value of dependent variables with respect to a unit change in the independent value. For example, the exponent of the coefficient exp(-0.55) = 0.58 in the case of the response variable Number of deaths - Model 3 - MYS1539 (see Table 2, first block) means a one-year increase in mean years of schooling will bring down the deaths by a factor of 0.58, or a

Table 2. Coefficients (exponents in parentheses) of the Poisson regression analysis of number of deaths, number of families affected, and number of animals lost on mean years of schooling of 15 to 39-years-old and other variables.

Response Variable (Number of)	Models†	Constant	Mean year of Schooling of aged 15 to 39	Percentage Permanent Housing	Village Vulnerability	Residual Deviance
			Nepal			
Deaths	Model1	-5.16(0.01)***	-0.72(0.49)***			6696
	Model2	-5.25(0.01)***	-0.76(0.47)***	0.01(1.01)***		6654
	Model3	-4.92(0.01)***	-0.55(0.58)***	0(1)***	-0.29(0.75)***	6183
Affected Families	Model1	-0.79(0.46)***	-0.8(0.45)***			1173
	Model2	-0.68(0.51)***	-0.64(0.53)***	-0.03(0.97)***		1128
	Model3	-0.53(0.59)***	-0.45(0.64)***	-0.03(0.97)***	-0.21(0.81)***	1020
Animal Loss	Model1	-4.06(0.02)***	-0.63(0.53)***			5301
	Model2	-4.01(0.02)***	-0.56(0.57)***	-0.01(0.99)***		5301
	Model3	-3.71(0.02)***	-0.35(0.7)***	-0.01(0.99)***	-0.28(0.76)***	4766
			Terai			
Deaths	Model1	-5.81(0)***	-0.75(0.47)***			275621
	Model2	-5.51(0)***	-1.11(0.33)***	0.04(1.04)***		255045
	Model3	-5.02(0.01)***	-0.88(0.41)***	0.04(1.04)***	-0.46(0.63)***	234551
Affected Families	Model1	-0.03(0.97)***	-0.82(0.44)***			165379
	Model2	-0.32(0.73)***	-0.53(0.59)***	-0.04(0.96)***		155976
	Model3	-0.11(0.9)***	-0.49(0.61)***	-0.04(0.96)***	-0.14(0.87)***	153260
Animal Loss	Model1	-5.29(0.01)***	-0.32(0.72)***			66830
	Model2	-5.65(0)***	-0.09(0.91)***	-0.02(0.98)***		66278
	Model3	-5.28(0.01)***	-0.07(0.93)***	-0.02(0.98)***	-0.19(0.83)***	59529
			Hills and Mountains			
Deaths	Model1	-4.87(0.01)***	-0.72(0.49)***			34586
	Model2	-4.88(0.01)***	-0.72(0.49)***	0(1)ns		34268
	Model3	-4.52(0.01)***	-0.46(0.63)***	-0.01(0.99)***	-0.28(0.75)***	32162
Affected Families	Model1	-2.17(0.11)***	-0.67(0.51)***			14229
	Model2	-2.05(0.13)***	-0.64(0.53)***	-0.01(0.99)***		14055
	Model3	-1.81(0.16)***	-0.41(0.67)***	-0.01(0.99)***	-0.2(0.82)***	13852
Animal Loss	Model1	-3.37(0.03)***	-0.84(0.43)***			19564
	Model2	-3.1(0.05)***	-0.79(0.45)***	-0.01(0.99)***		19154
	Model3	-2.87(0.06)***	-0.47(0.62)***	-0.02(0.98)***	-0.31(0.73)***	17317

†Model 1 Response Variable = MYS + Offset(log(population))
Model 2 Response Variable = MYS + Prop.Perm.Housing + Offset(log(population))
Model 3 Response Variable = MYS + Prop.Perm.Housing + Village.Vulnerability + Offset(log(population))
ns > = 0.05; * < 0.05; ** < 0.01; *** < 0.001

42% decline in the number of deaths during flooding and landslides. The last column is the residual deviance for each model, and indicates the level of unexplained variation in the dependent variable.

Number of lives lost

Based on the regression analysis, we found a significant negative association between the number of deaths due to floods and landslides and the mean years of schooling of the population aged 15-39. Adding an income/wealth-related variable increased the explanatory power of the model with a decline in the value of residual deviance (see Table 2). The residual variance declined sharply once the variable representing the village hazard score was added.

It was found that the mean years of schooling of the population, aged 15-39 years, in the communities was related to a higher degree of effectiveness in reducing the deaths in the Terai region more than in the Hill and Mountain Regions. Based on the results of Model 3 (see Table 2), in the Terai region, a one-year increase in the mean years of schooling was associated with a three-fifth (1-exp[-0.88]) decline in flood and landslide related deaths, whereas in the rest of Nepal, the decline amounted to two-fifths (1-exp[-0.46]).

Coefficients for the percentage of permanent housing in the VDC, a change in 1%, reflected mixed results. At the country level, the effect of having permanent housing was negligible, but statistically significant, on the number of deaths per event (Model 3 for deaths, first block, Table 1). However, in the

Terai, the association was positive because a 1% increase in the proportion of permanent housing was associated with more deaths, a 4% increase. The opposite pattern was observed in the Hill and Mountain Regions with a 1% decrease. The results for the Terai municipalities contradicted our hypothesis and need further explanation. A counter argument might be that the flood prone areas had a higher proportion of permanent housing in Terai and therefore resulted in the positive association, whereas in the Hill and Mountain Regions, the unexpected nature of flood and landslides with excessive force made the structure of housing irrelevant.

It was also found that in the villages where disasters were recurrent, the number of deaths was lower and hence these villages were less vulnerable than those where disasters occurred rarely. Vulnerability could be lower because people anticipated the event and were better prepared than the people in places where the events did not happen as often.

Number of families affected

Similar results were obtained for the response variable representing the number of families affected. The model's explanatory power increased significantly when the variable village hazard score was added (Table 2). "Mean years of schooling" was a significant explanatory variable in all models. Based on Model 3, in the Terai, a one-year increase in mean years of schooling was associated with a two-fifths (1-exp[-0.49]) decline in the number of families affected due to floods and landslides, whereas in the rest of Nepal, the decline would be slightly smaller, 0.67 times (Table 2).

The type of housing was important in reducing the risk of being affected, as shown by the negative coefficients (-0.03), especially in the Terai region. As stated earlier, in the Terai region, floods that were less severe and more predictable than in the Hill and Mountain Regions were the risk, hence having a permanent structure reduced the impact.

As found in the case of the number of deaths, fewer families were affected in villages experiencing recurrent events. This was true for all regions in Nepal.

Number of animal losses

In cases where the response variable represented animal loss, similar results were obtained. The associated decline in the number of animal losses with a one-year increase in the mean years of schooling was found to be small, less than one-tenth (1-exp[-0.07]) in Terai, but larger, almost up to three-fifths (1-exp[-0.47]) in the Hill and Mountain Regions.

Having more permanent housing was associated with losing fewer animals. Although the effect was very small, it was consistent over the regions. The result was similar in terms of recurrent events. Villages with recurrent events had fewer animal losses following similar arguments.

DISCUSSION

We have shown, based on the results from the regression analysis (Table 2), that the mean years of schooling of young people aged 15-39 was a statistically significant explanatory variable in explaining different indicators representing losses caused by floods and landslides in all parts of Nepal. With respect to the wealth indicator, the picture was less clear and, particularly with respect to losses in human lives, the estimated coefficients tended to have the wrong signs. We repeated the analysis separately for the Terai plain and the rest of Nepal and found similar results. We found that the increase in mean years of schooling had higher effectiveness in the Terai than in the rest of the Nepal, in the case of numbers of lives lost and numbers of families affected. The effectiveness was almost 50% higher in the Terai than in the rest of Nepal; a one-year increase in educational attainment (MYS1539) was associated with a 59% decline in number of deaths in the Terai and a 37% decline in the Hill and Mountain Regions.

One explanation for the different results in the Terai and non-Terai regions could be that the risk of deaths and injury was higher because of a higher frequency of sudden, violent disasters, e.g., flash floods and landslides. In the Terai, landslides were nonexistent, and floods developed slowly and predictably enough so that people could effectively avoid death and injury. In most cases, people suffered from an overflow of water due to inundation from the river coming to their homes and farms, or in other cases, it could be due to the erosion of the banks engulfing the land into the river. The point is, in the Terai, it was relatively easier to save one's life and livestock from death caused by a flood and a landslide than in the Hills and Mountains, and, through education even more deaths could be avoided.

In the case of the response variable representing the number of animal losses, the effectiveness of education in Hill and Mountain Regions was higher than in the Terai (0.54 vs 0.69, see Table 2). The explanation for this difference was not obvious because it seemed plausible that observations would be similar to those of other response variables. This question requires further analysis that includes more variables associated with animal losses.

A relationship between education and vulnerability was implied by an association between educational attainment and reduced losses caused by floods and landslides in Nepal. This finding was based on the results of a regression analysis. However, the practical relevance of this finding for policy required establishing clear causal relations between human capital, i.e., education, and the effect, i.e., losses due to flood and landslides.

To identify possible causal mechanisms, we used in-depth interviews with seven individuals from different walks of life in the Terai district of Nawalparasi, in Nepal. Most of them were living in an area that was regularly affected by floods.

Based on the interviews, we could infer that education could best reduce losses by increasing awareness regarding different aspects of floods and landslides, e.g., how floods and landslides occurred and what could be done to protect oneself, to mitigate the consequences, or to better adapt to the events of floods and landslides. Respondents suggested that such awareness could be raised in villagers vulnerable to disaster through adult education and literacy programs, through their children, who could be taught in school as a part of a separate awareness campaign, or by including teaching materials in school curricula. Raising this awareness would enable people to make better choices in terms of locations, safe constructions (Toya and Skidmore 2007), and choosing specific types of crops, for example, sugarcane instead of paddy, etc.

In addition to the effects of education on the individual, as highlighted by the respondents, there were two other possible ways in which education could help to reduce vulnerability. Generally, educated individuals in a household were likely to be involved in jobs that were different from the traditional jobs. This helped to diversify the household's income and at times of disaster, would be a lifeline for the regular supply of basic needs. In addition, income was invested smartly by better-educated people with local, as well as nonlocal knowledge, and hence made their lives and livelihoods less vulnerable. However, in the regression analysis we could not pinpoint this effect because a variable measuring income was not available in the data. Instead, we used types of roofs as an indicator of wealth and income in the regression model, and this resulted in a rather unclear effect on the impact of the disaster.

Furthermore, education may have contributed to community level institutions and to leadership. Raschky (2008) suggested that countries with better institutions experienced less deaths and damages from natural disaster and he defined institutions as rules/procedures that clarified how decisions were made within society (political mechanism); formal or informal rules (implementing laws, government) that influenced individual behavior; and groups of individuals that shared a common aim, for example, political parties, NGOs or clubs, companies, and authorities. The level of educational attainment in a community was most likely to affect all three types of institutions. Better-educated communities were likely to organize themselves well, identify problems collectively, find solutions, and represent themselves effectively to the higher-level authorities. This was found to be true to a larger extent in the villages where we conducted interviews, and where people, who mostly never attended school, expressed their helplessness in communicating to the higher authorities as well as stating: "who will talk for us?"

CONCLUSION

In conclusion, we have shown that at the community level, educational attainment of the young adults was a statistically significant explanatory variable in explaining different indicators that represented losses caused by floods and landslides in all parts of Nepal. At all levels and under all regression models, the results showed consistently significant effects of more education on lowering the number of human and animal deaths as well as the number of households otherwise affected.

With respect to the wealth indicator, the picture was less clear, and particularly, with respect to losses in human lives, the estimated coefficients tended to have the wrong signs. Although a clear causal relationship could not be established with the available data, some discussion of possible causal mechanisms, that were corroborated by seven in-depth interviews with different stakeholders in a flood/landslide-prone district in Nepal, suggested that at both individual and community level, education could play an important role in accessing information, in the innovation of ideas, and in the formation of effective groups (e.g., a club, volunteer organization etc.). Education could also play a part in bringing good leadership to work effectively with the local people, and to communicate with higher authorities wherein they could raise their specific concerns and participate expertly in any kind of planning related to community development, including issues related to floods and landslides. In addition, educated people could have an opportunity to diversify their income by taking nontraditional jobs that were not affected by such events.

We concluded that the effects of education on reducing disaster vulnerability tended to be more pervasive than those of income/wealth in the case of floods and landslides in Nepal. Therefore, the need for further analysis with richer data should be acknowledged. An indirect effect of investing in education today could be to lower a community's vulnerability to floods and landslides in the future, and this effect could well transcend to vulnerabilities to other forms of natural disasters, and to the adverse effect of climate change in the long run.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5095

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APPENDIX

Cleaning Disaster Data

The original reports sent by the district administrative office are in Nepali and someone at the Ministry of Home affairs entered data in EXCEL in English without any standard list of names which have caused the misspelling. Many names did not match with the official names. The reason could be the use of different names by locals for a certain VDCs. Or the disaster could have occurred in one of the ward of the VDC (out of 9 wards) and the name of the ward might have been used.

The lumping of records (for VDCs) into one might have either happened at the district level (possible reasons: due to Maoist insurgency proper assessment was not done and/or administration was not serious about the data) or could have happened at the Ministry (person who entered might have grouped multiple records into one, this however seems to be unlikely as data for some of the districts are available at the VDC level for the same year). This problem persists in later years of the study period as the data for earlier years are finer. The implication of lumping of multiple records in one and mismatched VDC names is significant. For example, regarding deaths due to flood and landslides, in total, 33% of total deaths could not be allocated to individual VDCs during the 9 years period. For example, in a one year period 2007-2008 (year 2064 Bikram Sambat in Hindu Calendar) 186 (86%) deaths were clustered in 58 (73%) such data points; followed by the year 2008-2009 with 107 (80%) deaths recorded in 41 (41%) data points; in 2001-2002 with 61% deaths in 15% of points, in 2006-2007 32% deaths in 21% data points, and for the rest of the periods, 2 to11% deaths in 8-12% data points.

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Effects of Educational Attainment on Climate Risk Vulnerability

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ABSTRACT. In the context of still uncertain specific effects of climate change in specific locations, this paper examines whether education significantly increases coping capacity with regard to particular climatic changes, and whether it improves the resilience of people to climate risks in general. Our hypothesis is that investment in universal primary and secondary education around the world is the most effective strategy for preparing to cope with the still uncertain dangers associated with future climate. The empirical evidence presented for a cross-country time series of factors associated with past natural disaster fatalities since 1980 in 125 countries confirms this overriding importance of education in reducing impacts. We also present new projections of populations by age, sex, and level of educational attainment to 2050, thus providing an appropriate tool for anticipating societies' future adaptive capacities based on alternative education scenarios associated with different policies.

Key Words: *adaptive capacity; climate change; education; natural disasters; vulnerability*

INTRODUCTION

There is little doubt that climate change is already ongoing and more change is to be expected (Solomon et al. 2007). A number of organizations have assessed the costs of adapting to these changes, with the most recent of these estimates being in the range of US$70 to 100 billion each year, and with the greatest losses being associated with increases in magnitude and frequency of extreme weather events (World Bank 2010a). However, the specific effects of climate change that will be experienced in specific locations are highly uncertain, and this creates a challenge for investments into climate-protective infrastructure (Dessai et al. 2009). An increasing number of researchers, both in academia (Agrawal and Perrin 2009, McBean and Rodgers 2010) and in the public sector (Agrawala et al. 2008, Schipper et al. 2008, World Bank 2010b), suggest that the most sensible investments in adaptation, or government interventions, may be those that focus not on directly addressing particular climatic changes, but rather on t hose that improve the resilience and reduce the vulnerability of people to climate risks in general (Eakin and Patt 2011). Here we examine the effects of one particular intervention, education, on losses from extreme weather events.

The idea that social and human development can improve resilience to climate change and extreme weather events is not new. A number of studies have compared losses from climate hazards with a number of development indicators, finding significant correlations with income, population density, access to drinking water, female fertility, and a number of indicators of good governance and public corruption (Yohe and Tol 2002, United Nations Development Programme 2004, Brooks et al. 2005, Kellenberg and Mobarak 2008, Patt et al. 2010). The most recent one of these (Patt et al. 2010) has looked explicitly at the human development index (HDI) as an indicator of disaster vulnerability. HDI is a composite indicator derived from indexes of income, life expectancy at birth, and education. This study has revealed a nonmonotonic relationship that as yet is causally unexplained: initial improvements in HDI correlate with increasing vulnerability to climatic risks, while further improvements then correlate with falling risk levels.

No detailed empirical study to date has broken down HDI into its composite elements to consider education alone, nor has any study compared the effects of different education indicators. A possible reason for this could be the lack of detailed and consistent empirical information on level of education across countries and over time. This situation has recently been improved through the reconstructions and projections of educational attainment distributions by age, sex, and four levels of educational attainment for most countries in the world (Lutz et al. 2007, KC et al. 2010). A critical feature of these data, which has allowed researchers to use them to show the effects of education on economic growth, was their disaggregation of education across age groups.

There are several reasons to expect empowerment to occur through basic literacy and subsequently through secondary education to reduce vulnerability to climate change related risks. Most directly, better education typically implies better access to relevant information, such as early warnings for tropical storms or seasonal prediction of drought (Patt et al. 2007, Moser and Ekstrom 2010). Second, there is evidence that education also enhances cognitive skills and the willingness to change risky behavior while at the same time extending the personal planning horizon (Neisser et al. 1996, Behrman and Stacey 1997, Nisbett 2009). Third, there is scientific evidence that education leads to better health and physical wellbeing at any given age, in virtually every country (Fuchs et al. 2010, KC 2010). Fourth, more education leads to higher income at the individual and household level as well as higher economic growth at the aggregate level (Becker

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1993, Schultz 1993, Lutz et al. 2008). All of these effects ought to play a role in reducing vulnerability to climate hazards.

MATERIALS AND METHODS

To investigate the link between disaster risk, development in general, and education in particular, we used data from the Emergency Events Data Base (EM-DAT) provided by the Centre for the Research of the Epidemiology of Disasters (Centre for Research on the Epidemiology of Disasters 2004). These data provide information on the number of disasters, as well as the number of deaths caused by these disasters, by country and year since 1900, with the data since 1980 being the more reliable. Although data are available for a broad range of different types of disasters, we concentrated on floods, droughts, storms, mass movements, extreme temperature events, and wildfires because they most closely resemble the kinds of disasters that are expected to increase due to climate change.

Whether a specific event is listed as a disaster in the EM-DAT database is determined by fulfillment of one of the following criteria: (1) 10 or more people were reported killed; (2) 100 or more people were reported affected; (3) a call for international assistance was issued, or; (4) a state of emergency was declared. Due to these specific criteria there is the possibility of sample selection bias. Some countries may have experienced a natural disaster, but because they were so well prepared none of the criteria necessary for being counted as a natural disaster was fulfilled. On the other extreme, in some very poorly developed regions disasters may have killed many people but due to poor information it may not even be registered and hence would not enter this database. In both cases, however, the estimated effects of development indicators on disaster deaths would only be biased downward. For a comparison of EM-DAT with other sources of disaster data, as well as a discussion of the strengths and weaknesses of these data, see Guha-Sapir and Below 2002.

Data on the level of human development and its components were taken from the United Nation's Human Development Report (United Nations Development Programme 2010). The HDI is a composite index measuring progress in the three basic dimensions: health, knowledge, and income. While the methodology of the HDI has been changed slightly in its twentieth anniversary edition, for reasons of compatibility and comparability with previous studies we used the original HDI where the knowledge component was calculated using a combination of school enrollment and rates of adult literacy.

In addition to HDI and its components we also controlled for education using data on the portion of 20 to 39-year-old women with completed secondary education or higher among the total female population aged 20 to 39. Past comprehensive research on the effects of the entire educational distribution (i.e., considering the distribution of educational attainment categories by age and sex) for a whole range of issues, going from economic growth to transition to free democracies, has shown that explicit consideration of that distribution has significant additional explanatory power compared to just taking an average measure of education such as the mean years of schooling (Lutz et al. 2008, Lutz et al. 2010). For practical purposes it is often convenient to have only one education-related variable included in the equation, so the one indicator that still reflects the inequality aspect and has the greatest discriminatory power—as shown by the above cited studies—turns out to be the proportion of younger women with junior secondary or higher education. Due to their key role in family matters, ranging from childbearing to family health to household decision making and changes in labor force participation, this group seems to be of particular importance for social as well as economic development. The data on educational attainment by age and sex was taken from the IIASA/VID data set (Lutz et al. 2007) which offers full education details by age and sex for most countries of the world from 1970 onwards in 5-year intervals.

For the regression analysis we aggregated the data into 5-year and 10-year periods in order to limit the influence of extreme outlier years when certain countries experienced particularly severe disasters with exceptionally high death counts and because some of the social variables were available only for 5-year intervals. We then estimated a number of multivariate models for the given panel of national time series. In all models we used the natural logarithm of the total number of deaths per thousand of population by country and period as our dependent variable. This probability of dying from disaster was then explained by different sets of development indicators—including education—after controlling for some of the usual background variables: real GDP per capita was taken from the Penn World Tables (Heston et al. 2009); data on the degree of democracy were taken from the Polity IV database (Marshall and Jaggers 2002); and data on population size, population density, as well as on infant mortality (IMR) stemmed from the 2008 revision of the World Population Prospects (United Nations Secretariat 2009).

$$deaths_{i,t} = \beta_0 + \beta_1 * hdi_{i,t} + General \quad (1)$$

$$deaths_{i,t} = \beta_0 + \beta_2 * hdi_{i,t}^{GDP} + \beta_3 * hdi_{i,t}^{EDU} + \beta_4 * hdi_{i,t}^{LEX} + General \quad (2)$$

$$deaths_{i,t} = \beta_0 + \beta_2 * hdi_{i,t}^{GDP} + \beta_3 * hdi_{i,t}^{EDU} + \beta_5 * eduF_{i,t} + General \quad (3)$$

$$General = \beta_6 * polity2_{i,t} + \beta_7 * nodis_{i,t} + \beta_8 * density_{i,t} + \beta_9 * coastal_i + \beta_{10-28} * region_i \quad (4)$$

Model 1 recurs to earlier findings by Patt et al. (2010) who had used the HDI as an indicator of disaster vulnerability. HDI is a very comprehensive indicator of development outcomes, which in itself neither identifies the primary causes of vulnerability nor suggests a particular policy priority. Hence, in Model 2 we decomposed the HDI into its three constituent subindices, one based on purchasing-power-adjusted per capita income, another one combining school enrollment and literacy rates, and finally an index derived from average life expectancy at birth. Including these three individual components of HDI separately in Model 2 yielded estimates for the relative importance of the three dimensions on the number of deaths from natural disasters. Yet, as discussed above, the education component of the old HDI does not explicitly measure education by the gender and age groups that matter most for vulnerability to disaster. Model 3 therefore uses our alternative education variable ($eduF_{i,t}$) to account for human capital.

All three models also considered the effect of income. Whereas GDP was implicitly included in the HDI in Model 1, Models 2 and 3 controlled for income explicitly by using the GDP component of the HDI ($hdi^{GDP}_{i,t}$). This can help us to address an important question for setting policy priorities, namely whether income matters more than education in reducing a country's disaster death counts.

Furthermore, we assumed that the quality of a country's health system should play a significant role in minimizing human losses from natural disasters. Model 1 includes life expectancy at birth implicitly in the HDI, while Models 2 and 3 included it as a separate index ($hdi^{LEX}_{i,t}$). Because disaster deaths in a given year are also reflected in the life table and hence life expectancy of that year, as a sensitivity analysis we also used the log of the infant mortality rate ($imr_{i,t}$) as an alternative indicator of health system quality. While infant mortality is not necessarily less affected by this possible endogeneity, it would be differently affected (unless the infant deaths as a proportion of all deaths are exactly the same in disasters and under normal conditions). Furthermore, infant mortality is often considered to be more closely related to the quality of the health care system than adult mortality which also includes many life-style-related factors (Fuchs et al. 2010). In any case, as can be seen in Appendix 1, our results were not affected.

In addition to these different development indicators all three models controlled for a set of other variables which are labeled "*General*" in the equations above. The exposure to climate-related risk was accounted for in our models as the log of the total number of disasters in the given period normalized by the total population size in 1000s ($nodis_{i,t}$). We also controlled for population density ($density_{i,t}$), which has been found significant in explaining casualty numbers by Yohe and Tol (2002) and more recently by Patt et al. (2010). In terms of the political system of the country we included the polity score ($polity2_{i,t}$) which has the highest values for modern free democracies. We also control for the geophysical fact of whether a country is landlocked or has a coastline ($coastal_i$), which may affect its expose to tropical storms and flooding. Finally, we controlled for possible regional particularities ($region_i$) in the form of regional fixed effects that could also account for other still-uncontrolled factors in our models.

Due to the availability of population projections by age, sex, and education (KC et al. 2010), we were also able to forecast adaptive capacity based on different education scenarios under the assumption of constant hazard levels.

RESULTS

Our analysis covers 130 countries over the time period 1980 to 2010. In the regression analysis we have complete data for 125 countries. Fig. 1 depicts the bivariate relationship between the log of disaster deaths per 1000 (on the vertical axis) and the proportion of women with completed junior secondary or higher education in the age group 20 to 39. The hump shape observed in Patt et al. (2010), who have examined the relationship between disaster risk and aggregate HDI, is present when one examines the full sample of countries (left side), but then disappears when we exclude countries that experience very few climate disasters. For all countries that experienced at least 30 disasters over the 30-year period, i.e., one or more disasters on average per year, it shows a clearly negative and almost linear association. As can be seen in Appendix 1, the picture looks the same when using HDI instead of our education variable.

Fig. 1. Relationship between the log of disaster deaths (per 1000 of 1980 population) and the mean of female education (proportion with secondary and higher education among women aged 20 to 39) over the period 1980 to 2010 for all 130 countries (left side) and 63 countries with one or more disasters on average per year (right side).

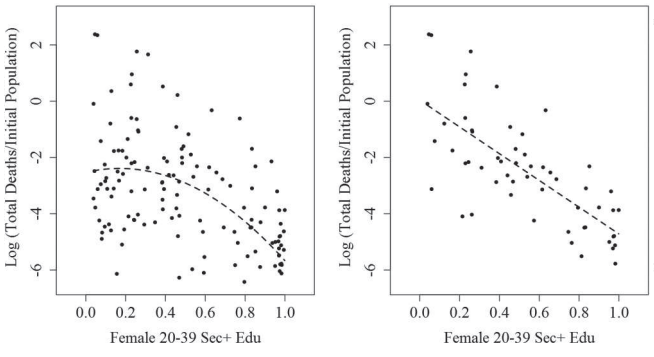


Table 1. Determinants of national death from natural disaster. Panel regression for 125 countries over 5-year and 10-year intervals between 1980 and 2010 using time fixed effects. The dependent variable is the log of deaths per capita. Numbers in parentheses are standard errors based on the heteroskedasticity-reistant and autocorrelation-resistant covariance matrix. HDI = human development index. LEX = life expectancy at birth. EDU = education. Other independent variables not reported here are dummy variables for 17 world regions. Significance codes: 0.01 = ***; 0.05 = **; 0.1 = *.

	5-yr	10-yr	5-yr	10-yr	5-yr	10-yr
Log (disasters/pop., in 1000s)	0.695*** (–0.075)	0.698*** (–0.115)	0.699*** (–0.075)	0.678*** (–0.114)	0.729*** (–0.075)	0.725*** (–0.115)
Log (density)	0.123* (–0.067)	0.159* (–0.096)	0.141** (–0.068)	0.156 (–0.098)	0.118* (–0.069)	0.136 (–0.1)
Polity score	0.296** (–0.137)	0.364* (–0.206)	0.290** (–0.135)	0.347* (–0.203)	0.279** (–0.136)	0.322 (–0.206)
Coastal country	1.211*** (–0.189)	1.027*** (–0.272)	1.174*** (–0.188)	0.952*** (–0.269)	1.054*** (–0.19)	0.826*** (–0.275)
HDI	–5.943*** (–0.818)	–6.658*** (–1.176)				
LEX component of HDI			–2.818** (–1.135)	–1.321 (–1.633)	–3.274*** (–1.113)	–2.346 (–1.629)
GDP component of HDI			–0.522 (–0.762)	–0.955 (–1.103)	–0.904 (–0.763)	–1.413 (–1.118)
EDU component of HDI			–3.626*** (–0.741)	–5.125*** (–1.076)		
Females, age 20 to 39 yr, > secondary education					–1.912*** (–0.423)	–2.239*** (–0.625)
F-statistic	15.67	8.8	15.49	8.89	14.96	8.21
N	706	355	706	355	706	355

For the given panel of national time series we specified various multivariate models in which the probability of dying from natural disasters is related to various indicators of risk as well as social and economic background factors. Results of three of them are displayed in Table 1, where two neighboring columns always belong to one model specification. As can be seen from the number of observations, the left column of each model corresponds to 5-year intervals and the right column to 10-year intervals.

Model 1 shows the well-known negative relationship between the HDI and human disaster losses. The linear effect of HDI is highly significant for both panels (representing the 5-year and 10-year intervals). We also tested for nonlinear effects from HDI on disaster losses (results of which are shown in Appendix 1) but they turn out to be insignificant. While the results from Model 1 lend support to earlier findings that negatively related development and disaster death counts, they do not tell us which of the individual components of the HDI are responsible for this decrease. Model 2 reveals that the only truly significant component of the HDI is the education index. The life expectancy component is significant with the 5-year intervals but not with the 10-year intervals, whereas the GDP component shows no significant additional explanatory power whatsoever. Model 3 uses our alternative indicator of educational attainment, yet the results turn out to convey the same story. Female education is most significant in reducing vulnerability to natural disasters.

Most of the parameters for the control variables have the expected signs, while their significance varies among the models. The frequency of disasters as the key variable measuring the exposure of countries to disasters independent of the number of fatalities is, as expected, consistently positive and highly significant under all models. Similarly, the fact that a country has a coastline turns out to have a consistently positive effect on the number of fatalities, and is significant under all models. Also, not surprisingly, a country with higher population density on average seems to have experienced a higher number of casualties. What is rather surprising at first glance, however, is the positive relationship between vulnerability and the democracy score. While the effect is not significant in all model specifications, it still seems to imply that in more authoritarian countries, *ceteris paribus*, the

vulnerability to natural disasters is reduced. This may in part be true for cases such as Cuba, Iran, Singapore, and other countries that have efficient disaster control systems, although they are not free democracies. There are also countries labeled as democracies—such as India and Bangladesh— that have serious problems in handling disasters. But there clearly remains a selectivity issue. Democratic governments may be more ready to report disaster deaths than authoritarian ones. Contrary to Costa (2012), we did not find a significant effect when controlling for possible nonlinearity in the relationship between the democracy score and deaths from natural disasters (see Appendix 1). Clearly, this issue warrants further in depth research.

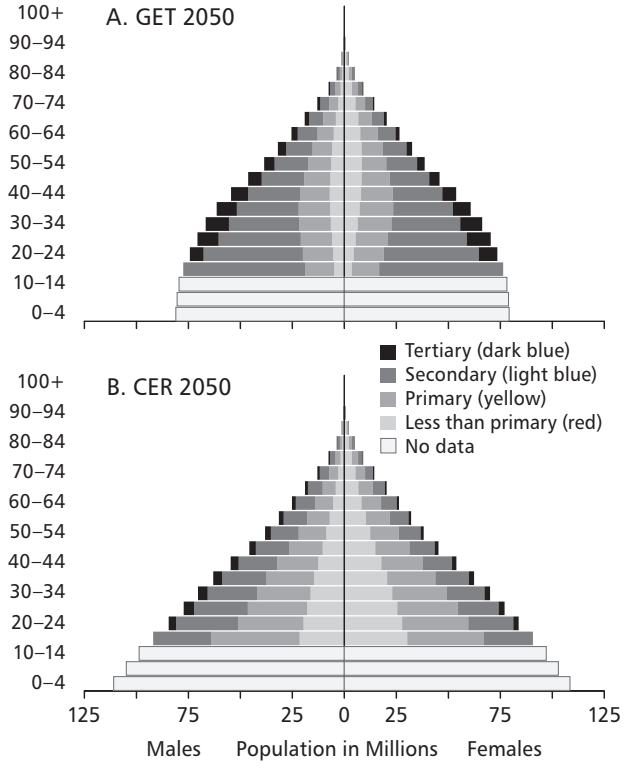
In sum, the results presented in Table 1 clearly show that education (and in particular female education) is the single most important social and economic factor associated with a reduction in vulnerability to natural disasters. Both in the form of the education component of the HDI and as measured by the proportion of the female population aged 20 to 39 with junior secondary and higher education, education has the most significant and consistently positive effects under all models and also when considering 5-year as well as 10-year intervals. In terms of setting policy priorities and in linking this to economic studies of vulnerability, which often uncritically start from the assumption that higher income is the key determinant for reducing vulnerability, it is important to note that in none of the models did income (whether in the form of the income component of the HDI or as conventional GDP per capita or its growth rate) turn out to be significant if education is being considered at the same time. This robust aggregate level finding now needs to be complemented by further microlevel evidence.

DISCUSSION

It is likely that over the next years, large amounts of money will be spent on adaptation programs through the Kyoto Protocol adaptation fund, national governments, or other donors. But there is not enough of a scientific basis to guide these funds into directions that are meaningful under a long-term perspective. There is serious concern that significant funds might be channeled into "investments" that (given the strong path dependence of, e.g., agricultural policies) lock countries into certain paths that are not tenable under future climates. Alternatively, given the uncertainty about the precise manifestations of climate change in specific areas, it may be better to increase the general flexibility and enhance the human and social capital through massive new investments in universal basic education in order to empower the populations to better cope with climate change in a way that will be to their best long-term benefit. Our results reveal the degree to which climate vulnerability is sensitive to differences in education at the national level.

Given this, new projections of populations by age and level of education (KC et al. 2010) can also be used to anticipate the future adaptive capacities of societies. Fig. 2 shows the population pyramid for Sub-Saharan Africa in 2050 with the colors indicating the level of education. Men and women without any formal education are marked in red, those with some primary education in yellow, those with completed junior secondary education in light blue, and those with tertiary education in dark blue. Today, more than half of young adult women in Africa are still without secondary education. For 2050, Fig. 2-A depicts the results of projections in which age-specific school enrollment rates at all levels are kept constant at their current levels, which means that schools are only expanding in parallel with the growth of the school-age population (CER, constant enrollment rates scenario). In contrast, Fig. 2-B shows a scenario in which school enrollment rates over the coming years increase following the path of other countries that had been at the same level earlier (GET, global education trends scenario). In both cases the 2050 population sizes (1.9 billion in CER and 1.7 in GET) will be a lot bigger than today (0.8 billion), with the difference between CER and GET resulting from the fact that more educated women have lower birth rates. Under the CER scenario the number of young adults (in particular women) will increase dramatically while under the GET scenario most of the added population will be men and women with secondary or higher education (in blue).

Fig. 2. Age pyramids by level of education for Sub-Saharan Africa, for 2050. A – under the global education trends (GET) scenario. B – under the constant enrollment rates (CER) scenario.



These are two very different societies projected for 2050. In light of the empirical analysis presented here, the first one would be highly vulnerable to possible increases in natural disasters due to climate change, while the second one would likely have considerably more adaptive capacity to cope with whatever changes the future will bring. While calculating the exact number of lives that can be saved by increasing investments into education is impossible because of the high uncertainty around future risk levels, we can use the upper and lower bounds of past disaster-risk levels to calculate the number of deaths under the CER and the GET scenarios. A first back-of-the-envelope calculation combining the projections shown in Fig. 2 with our regression results from Model 3 in Table 1 reveals that in the time period 2040 to 2050 the number of deaths due to natural extreme events in Sub-Saharan Africa under the CER scenario will be in the range of 7900 to 180,000 while under the GET scenario the predicted number of deaths ranges from 3200 to 72,200. Regardless of the risk level the ratio between the scenarios is relatively stable and important. It can account for between 4700 and 107,800 additional lives saved or lost, which corresponds to a reduction of roughly 60%. Note that this tremendous effect is not only due to the direct effect of education. The portion of women aged 20 to 39 that have completed at least secondary education will have reached almost 70% under the GET scenario, compared to just 30% under the more pessimistic outlook. But the difference between the two scenarios also has indirect effects by means of reducing the affected population size as well as population density in the GET scenario. If in the future there are more disasters than in the past, the effects from education—direct and indirect—would be even stronger.

Which scenario will actually be more likely depends on education policies in the near future. If nothing happens and school expansion does not even keep pace with population growth, the outcome would be even worse than under the CER scenario. There are of course many other important reasons for expanding school enrollment (and at the same time also enhancing the quality of schooling) in terms of positive effects on health and poverty reduction, which has led to the inclusion of universal primary education as a Millennium Development Goal (United Nations 2010). But viewing education as an investment in the adaptive capacity to climate change would be an important new policy focus.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5252

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1 Controlling for non-linearities

Since previous studies have found significant evidence for deaths from natural catastrophes to be non-linearly related to different measures of development (Brooks et al. 2005, Kellenberg and Mobarak 2008, Patt et al. 2010, Costa 2012), Table A presents the results of our panel regression analysis controlling for quadratic effects. Two neighboring columns always belong to one model specification. As can be seen from the number of observations, the left column corresponds to 5-year intervals and the right column to 10-year intervals. The dependent variable is the logged value of the number of people killed per 1000 of national population.

Model (4) reproduces Model (1) from Table 1 in the main article. As an additional control it includes HDI squared. While the squared term does not turn out to be significant, the linear effect remains unchanged for both panels (the 5-year and 10-year intervals). Model (5) corresponds to Model (2) from Table 1 in the main article and it shows a similar result controlling for the three squared components of the HDI. While there is no additional explanatory power coming from the GDP component of the HDI - neither in linear, nor in non-linear form - there seems to be some evidence for the relationship between life expectancy and death counts to be u-shaped. The education index, however, remains the strongest and most significant component of the HDI in explaining variation in the number of deaths from natural catastrophes and again, there doesn't appear to be a non-linear relationship.

Since we find an unexpected positive relationship between the polity score and our measure of vulnerability, in Model (6) of Table A we also test for non-linearities in democratization. But even in this specification, we find no evidence of a u-shaped pattern.

Finally, Figure A corresponds to Figure 1 in the article showing the bivariate relationship between deaths from natural catastrophes and the share of women aged 20-39 with at least secondary education. As can be seen, we find the same pattern when plotting the total number of deaths against the average HDI-value for each country between 1980 and 2010.

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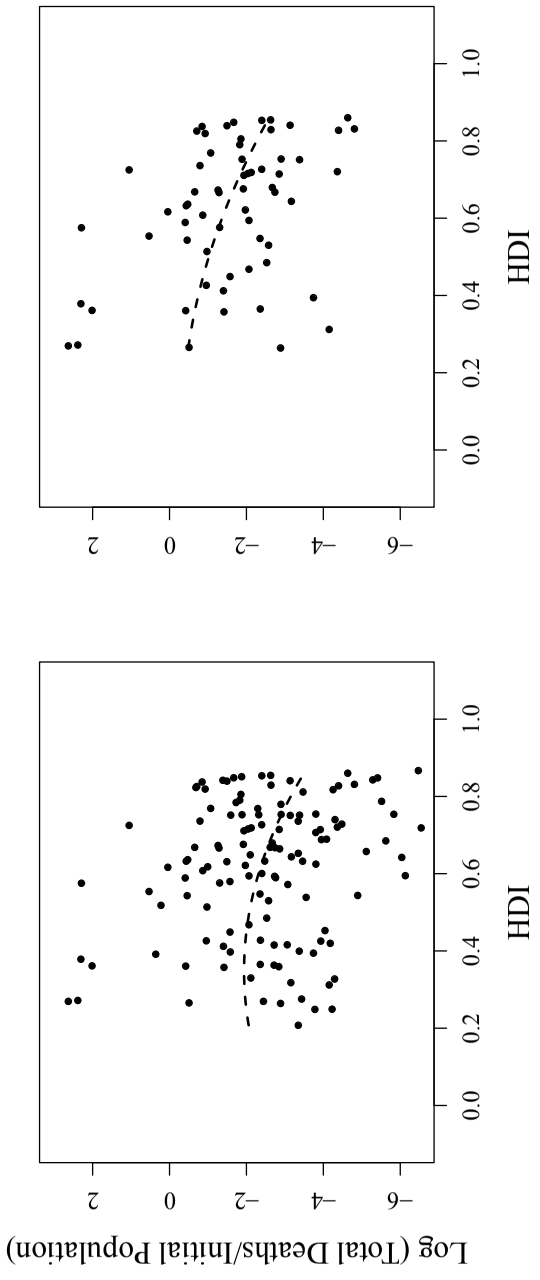

Figure A: Relationship between the log of disaster deaths (per 1000 of 1980 population) and the 1980-2010 mean value of HDI for all 130 countries (left side) and 63 countries with one or more disasters on average per year (right side).

Table A: Determinants of National Death From Natural Disaster. Notes: Panel regression for 125 countries over 5- and 10-year intervals between 1980 and 2010 using time fixed effects. The dependent variable is the log of deaths per capita. Numbers in parentheses are standard errors based on the heteroskedasticity- and autocorrelation-resistant covariance matrix. Other independent variables not reported here are dummy variables for 17 world regions.
Significance codes: 0.01 = '***'; 0.05 = '**'; 0.1 = '*'.

	Model (4)		Model (5)		Model (6)	
	5-yr	10-yr	5-yr	10-yr	5-yr	10-yr
Log (Disasters/Pop in 1000)	0.707^{***}	0.715^{***}	0.702^{***}	0.686^{***}	0.698^{***}	0.681^{***}
	(0.076)	(0.115)	(0.076)	(0.116)	(0.075)	(0.114)
Log (Density)	0.124^{*}	0.162^{*}	0.180^{**}	0.221^{**}	0.141^{**}	0.157
	(0.067)	(0.096)	(0.071)	(0.102)	(0.069)	(0.098)
Polity Score	0.277^{**}	0.333	0.291^{**}	0.345^{*}	0.289^{**}	0.355^{*}
	(0.137)	(0.207)	(0.136)	(0.203)	(0.137)	(0.205)
Coastal Country	1.248^{***}	1.079^{***}	1.186^{***}	0.970^{***}	1.175^{***}	0.946^{***}
	(0.191)	(0.275)	(0.193)	(0.275)	(0.188)	(0.270)
HDI	-9.681^{***}	-11.780^{***}				
	(2.862)	(4.146)				
HDI^2	3.395	4.675				
	(2.492)	(3.629)				
LEX component of HDI			4.646	11.126^{*}	-2.822^{**}	-1.271
			(4.455)	(6.436)	(1.141)	(1.642)
GDP component of HDI			-2.274	-3.993	-0.531	-0.841
			(2.314)	(3.335)	(0.796)	(1.160)
EDU component of HDI			-6.789^{***}	-10.324^{***}	-3.623^{***}	-5.171^{***}
			(2.314)	(3.395)	(0.746)	(1.086)
LEX component of HDI^2			-6.319^{*}	-10.592^{**}		
			(3.622)	(5.264)		
GDP component of HDI^2			2.182	3.803		
			(2.346)	(3.396)		
EDU component of HDI^2			3.129	5.138		
			(2.173)	(3.198)		
Polity $Score^2$					0.011	-0.126
					(0.275)	(0.389)
F-Statistic	15.22	8.54	14.22	8.22	14.97	8.55
N	706	355	706	355	706	355

Table B: Regional Dummies Used in Table 1 and Table A.

	South America	Australia/New Zealand	Western Europe	South-Central Asia	Western Asia	Eastern Europe
1	Argentina	Australia	Austria	Bangladesh	Armenia	Bulgaria
2	Bolivia	New Zealand	Belgium	Sri Lanka	Cyprus	Czech Republic
3	Brazil		France	India	Jordan	Hungary
4	Chile		Germany	Iran (Islamic Republic of)	Saudi Arabia	Poland
5	Colombia		Netherlands	Kazakhstan	Syrian Arab Republic	Romania
6	Ecuador		Switzerland	Kyrgyzstan	Turkey	Russian Federation
7	Guyana			Nepal		Slovakia
8	Paraguay			Pakistan		Ukraine
9	Peru			Tajikistan		
10	Uruguay			Turkmenistan		
11				Uzbekistan		
	South-Eastern Asia	Middle Africa	Northern America	Eastern Asia	Eastern Africa	Central America
1	Cambodia	Cameroon	Canada	China	Comoros	Costa Rica
2	Indonesia	Central African Republic	United States of America	Japan	Ethiopia	El Salvador
3	Lao People's Democratic Republic	Chad		Republic of Korea	Eritrea	Guatemala
4	Malaysia	Gabon		Mongolia	Kenya	Honduras
5	Philippines				Madagascar	Mexico
6	Viet Nam				Malawi	Nicaragua
7	Thailand				Mauritius	Panama
8					Mozambique	
9					Rwanda	
10					Zimbabwe	
11					Uganda	
12					United Republic of Tanzania	
13					Zambia	
	Southern Europe	Caribbean	Western Africa	Northern Europe	Northern Africa	Southern Africa
1	Croatia	Cuba	Benin	Denmark	Morocco	Namibia
2	Greece	Dominican Republic	Ghana	Estonia	Egypt	South Africa
3	Italy	Haiti	Guinea	Finland		
4	Portugal		Côte d'Ivoire	Ireland		
5	Slovenia		Mali	Latvia		
6	Spain		Mauritania	Lithuania		
7	TFYR Macedonia		Niger	Norway		
8			Nigeria	Sweden		
9			Togo	United Kingdom		
10			Burkina Faso			

Table C: Regional aggregation of data used in Table 1 and Table A. The regional aggregate is the population-weighted mean of the individual countries' values. Population figures are in 1000s.

Region	Population	Density	Polity2	HDI	LEXhdi	GDPhdi	EDUhdi	EDU
Australia/New Zealand	16351	4	1.00	0.87	0.92	0.80	0.91	0.88
Caribbean	6651	196	0.77	0.68	0.78	0.56	0.71	0.65
Central America	72353	64	0.40	0.71	0.81	0.62	0.72	0.44
Eastern Africa	33916	76	-0.09	0.36	0.48	0.24	0.45	0.15
Eastern Asia	1093327	157	-0.51	0.61	0.80	0.43	0.68	0.61
Eastern Europe	85364	55	0.18	0.74	0.77	0.63	0.83	0.98
Melanesia	784	43	0.39	0.65	0.74	0.49	0.75	0.72
Middle Africa	36477	21	-0.23	0.34	0.46	0.22	0.45	0.20
Northern Africa	44165	45	-0.52	0.56	0.70	0.48	0.52	0.29
Northern America	257255	26	1.00	0.87	0.90	0.84	0.88	0.96
Northern Europe	38939	168	0.99	0.84	0.89	0.78	0.86	0.84
South-Central Asia	742085	330	0.59	0.48	0.64	0.36	0.49	0.25
South-Eastern Asia	133986	154	-0.08	0.59	0.72	0.42	0.70	0.42
South America	98505	22	0.65	0.71	0.78	0.60	0.77	0.49
Southern Africa	1576	39	0.12	0.53	0.55	0.46	0.61	0.38
Southern Europe	40248	133	0.95	0.83	0.91	0.76	0.82	0.79
Western Africa	76267	98	-0.02	0.39	0.46	0.33	0.43	0.19
Western Asia	39730	87	0.19	0.69	0.77	0.64	0.69	0.45
Western Europe	39421	167	0.93	0.86	0.91	0.80	0.86	0.85

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Education, Vulnerability, and Resilience after a Natural Disaster

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ABSTRACT. The extent to which education provides protection in the face of a large-scale natural disaster is investigated. Using longitudinal population-representative survey data collected in two provinces on the island of Sumatra, Indonesia, before and after the 2004 Indian Ocean tsunami, we examine changes in a broad array of indicators of well-being of adults. Focusing on adults who were living, before the tsunami, in areas that were subsequently severely damaged by the tsunami, better educated males were more likely to survive the tsunami, but education is not predictive of survival among females. Education is not associated with levels of post-traumatic stress among survivors 1 year after the tsunami, or with the likelihood of being displaced. Where education does appear to play a role is with respect to coping with the disaster over the longer term. The better educated were far less likely than others to live in a camp or other temporary housing, moving, instead, to private homes, staying with family or friends, or renting a new home. The better educated were more able to minimize dips in spending levels following the tsunami, relative to the cuts made by those with little education. Five years after the tsunami, the better educated were in better psycho-social health than those with less education. In sum, education is associated with higher levels of resilience over the longer term.

Key Words: *development; disaster; education; resilience; vulnerability*

INTRODUCTION

Disasters are threats to population well-being that derail socioeconomic progress, strain social safety nets, and require complex assistance and recovery interventions. Over the last decade alone, Indonesia, Sri Lanka, Pakistan, China, Haiti, and Japan have all experienced natural disasters with death tolls in the tens of thousands. The high mortality disasters in recent years, combined with predictions that these events will increase in frequency as a result of global warming and rising population densities in coastal areas, have increased interest in more fully understanding the factors that underlie trajectories of disaster recovery over the longer term.

Several challenges impede building this deeper understanding of disaster recovery from the existing research literature. These include the difficulty of studying events of catastrophic magnitude, the limited size and representativeness of the samples and follow-up periods of available data, and consequently the relative lack of empirical studies focusing on longer-term outcomes for large representative populations (National Research Council (NRC) 2006, Galea and Maxwell 2009, Sastry and Vanlandingham 2009). One emerging theoretical insight is the conceptualization of disaster impact and recovery in terms of vulnerability and resilience, with the attendant recognition that each is embedded in a context of social processes that may, themselves, contribute to pre-existing variation in inequality in multiple dimensions in a society (NRC 2006, Tierney 2007). This theoretical perspective complements needs on the empirical side to identify the population sub-groups who suffer the most devastating and longest-lasting impacts of disaster. These challenges are recognized as critical for both science and for policy (Linnerooth-Bayer et al. 2005, Telford and Cosgrave 2007, Buttenheim 2010, Horton 2011, Padgett and Warnecke 2011).

This study uses population-representative longitudinal survey data collected before and after the 2004 Indian Ocean tsunami to consider the specific question of whether education moderates the immediate and longer-term impacts of a catastrophic natural disaster. Addressing this question with data from a catastrophic disaster collected over a 5-year time frame speaks to the broader theoretical line of inquiry regarding the influence of socioeconomic status on "vulnerability" and longer-term "resilience" in the aftermath of a major disaster.

It is important to note that, in general, the better educated tend to earn more, have greater wealth, and live longer and healthier lives (Lutz and Samir 2011). They also tend to live in areas that are less prone to natural disasters and to be better protected against shocks either through some form of formal or informal insurance or through greater diversification of their livelihoods as well as their financial assets and social support (Strauss and Thomas 2008). As a result of these choices, it is difficult to disentangle whether the better educated are better able to recover over the longer term from a disaster that has equal immediate impacts regardless of education level, or whether the better educated suffer fewer immediate impacts at the outset because of prior investments in risk mitigation and insurance.

The Indian Ocean tsunami, in combination with the data we analyze, provides a window into this issue for several key reasons. First, it is reasonable to treat the tsunami as

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completely unanticipated, at least along the coast of the island of Sumatra. Second, in the communities that bore the most intense force of the waves, the tsunami had a devastating impact on livelihoods. Third, we draw on an unusual data set that provides information on multiple dimensions of impact and recovery for a population-representative sample first interviewed 10 months before the tsunami and then for 5 years after the event.

The destruction wreaked by the tsunami was massive and far reaching. Importantly for this research, we show that in severely damaged areas, the immediate impacts were broadly the same for people across the entire distribution of education. In contrast with many natural disasters, education conferred little protection from the tsunami's short-term effects. However, over the longer term, our analysis indicates that the better educated are substantially more resilient with respect to psychosocial health and economic status.

We conclude that the better educated are better placed to mitigate the deleterious consequences and to embrace new opportunities in the aftermath of even a major large-scale and unanticipated disaster. It is not possible to ascribe a causal interpretation to this evidence. Those who have invested more in education may be more entrepreneurial, nimble, and better equipped to take on new opportunities and challenges after a major disaster. The greater resilience of the better educated may also arise because of better access to financial resources or greater availability of social resources after the tsunami.

THE DISASTER

At 7:58 a.m. on 26 December 2004, an earthquake measuring an estimated 9.3 on the Richter scale occurred off the coast of Sumatra, Indonesia. Faulting from the earthquake lasted 8 minutes, temporarily disrupting the earth's rotation and generating a 1,200-km rupture along the floor of the Indian Ocean (Bunting et al. 2007). The vertical displacement from the quake was 5–15 m, which generated huge tsunami surges that ultimately reached the shores of all countries that rim the Indian Ocean (Kerr 2005, Lay et al. 2005, Marris 2005, Sinadinovski 2006).

The first of the waves slammed into the island of Sumatra within 15 minutes of the earthquake. In Aceh, the Indonesian province closest to the rupture, the tsunami engulfed communities along 800 km of coastline. Studies estimate that the tsunami killed 130,000 individuals, with another 30,000 classified as missing (Rofi et al. 2006, Doocy et al. 2007). Some 700,000 individuals were displaced, and damage to property and infrastructure was valued at 4.5 billion (The Consultative Group on Indonesia 2005).

In areas severely damaged by the tsunami, the water swept away everything in its path including roads, bridges, and buildings. At the beachfront in Banda Aceh, water depths were approximately 9 m and even further inland reached the height of two-storey buildings. Along parts of the west coast of Aceh, the water removed bark from trees as high as 13 m (Borrero 2005). Where rivers emptied into the ocean, the water moved inland as much as 6–9 km, flooding plains and arable land. In other areas, the water reached about 3–4 km inland (Kohl et al. 2005, Umitsu et al. 2007).

From the perspective of contrasting the impact of this catastrophic disaster on the better educated relative to those with less education, two important features of the Indian Ocean tsunami distinguish it from other natural and manmade disasters. First, the tsunami was completely unexpected. The last major tsunami on the coast of mainland Aceh took place over 600 years ago (Monecke et al. 2008). Waves reached some parts of coastal Aceh within minutes of the earthquake, and retreating water, a signature of an impending tsunami, was not interpreted as a sign of danger by the vast majority of the population. Only residents of Simeulue island, where a smaller tsunami occurred in 1907, systematically relocated to higher ground, and, correspondingly, the survival rate in Simeulue was very high (Gaillard et al.,2008). The unexpectedness of the tsunami contrasts sharply with disasters for which there is some advance warning, such as hurricanes, tornadoes, and floods. Warnings before Hurricane Katrina, for example, enabled people with more resources—which the better educated often have—to protect themselves and their livelihoods at least partially from the disaster.

The second important feature of the tsunami for this research is that the force with which the tsunami waves hit the shore varied locally as a function of geophysical factors. The height and inland reach of water from the tsunami were a complicated function of both the vertical displacement of the seafloor (which varied along the rupture) and features of coastal topography, such as the slope of the coastal zone, elevation of the beachfront, and the direction of the wave relative to the land (Ramakrishnan et al. 2005). Accordingly, a component of the intensity of the tsunami's impact is random and is unrelated to the education of those living in the area. It is, therefore, reasonable to treat the tsunami as a large and unanticipated natural disaster that is unlikely a priori to have spared the better educated.

DATA AND MEASUREMENT

Research on the impact of disasters has been limited by a dearth of population-representative data that follow samples of sufficient size before and after the disaster. Constructing population-representative samples after an event that displaces a large fraction of the population is extremely difficult, and few studies have access to information on populations before a major disaster strikes. The studies that do are rarely well positioned to locate and interview the individuals who move from place to place in the disaster's aftermath (Buttenheim 2010, Gray et al. 2011, Horton 2011).

Data

We draw on longitudinal data that we designed and collected as part of the Study of the Tsunami Aftermath and Recovery (STAR). The study covers individuals who were living in coastal areas of the Indonesian provinces of Aceh and North Sumatra before the tsunami. Building on the foundation provided by a pre-earthquake baseline survey that interviewed nearly 27,000 individuals, we conducted follow-up surveys annually for 5 years after the disaster.

The baseline survey participants were part of a socioeconomic survey, SUSENAS, conducted by Statistics Indonesia in February 2004, 10 months before the Sumatran-Andaman earthquake. Statistics Indonesia has conducted the SUSENAS annually throughout Indonesia since 1963. The survey, which is widely used in the international scientific and policy communities, is regarded as being of very high quality. It is designed to represent the population at the "kabupaten" (district) level. The baseline for STAR consists of households located in 13 districts along the coast of Aceh and North Sumatra when they were interviewed in the 2004 (pre-earthquake) wave of SUSENAS. We selected these 13 districts because they were geographically positioned so that their coastlines were at risk of inundation from the tsunami waves although not all parts of the coast were, in fact, inundated. This provides communities that were directly impacted by the tsunami and coastal communities that were not directly affected. Within these 13 districts, all SUSENAS enumeration areas were included in STAR, for a total of 410 enumeration areas (EAs) in 369 villages. Although all of the districts included in STAR had a potentially vulnerable coastline, the extent to which the tsunami inundated the 410 enumeration areas varied considerably as a function of position relative to the earthquake's epicenter, shape of the coastline, distance from the ocean, elevation of the land, and the presence of rivers or canals flowing into the ocean.

To characterize the tsunami's destructive effect on each enumeration area, we developed a classification method that combines information from remote-sensed satellite imagery, reports from community informants, and observations of survey team supervisors. We use several biophysical measures derived from satellite images, which were linked to the exact location of each EA using global positioning system (GPS) measurements made during the follow-up survey. We constructed one of these measures by comparing satellite imagery from the National Aeronautics and Space Administration's Moderate Resolution Imaging Spectroradiometer (MODIS) for 17 December 2004, a week before the tsunami, to imagery for 29 December 2004, 3 days after the tsunami. The proportion of land cover that the tsunami changed to bare earth (through scouring or sediment deposition) was manually assessed for a 0.6-km^2 area centered over each GPS point. These estimates of damage were cross-validated with estimates of damaged areas derived from remotely sensed imagery and prepared by the United States Geological Survey, the United States Agency for International Development, the Dartmouth Flood Observatory, and the German Aerospace Center (Gillespie et al. 2007). Additionally, in each community, we conducted interviews with local leaders, who provided their own assessments of the extent of destruction to the built and natural environment due to the tsunami and earthquake, and our survey supervisors completed a questionnaire that detailed damage due to the tsunami and earthquake based on their own direct observation.

We used these sources of information to construct a categorical indicator of damage to the enumeration area. This indicator is a strong and significant predictor of many tsunami-related outcomes derived from the household data including mortality, injuries, post-traumatic stress disorders, and extent of damage to houses and land (Frankenberg et al. 2008). By this indicator, 95 of the 410 STAR enumeration areas are classified as severely damaged. We conducted the analyses for this paper based on data from respondents who were living in the severely damaged areas at the time of the pre-earthquake baseline.

Before the earthquake, when interviewed as part of the 2004 baseline survey, one respondent in each household reported socioeconomic and demographic characteristics for themselves and all other household members. The first follow-up survey, STAR1, took place between May 2005 and July 2006, in collaboration with Statistics Indonesia and with the assistance of their field supervisors. In STAR1, we collected both individual and household-level data, drawing on and augmenting the baseline questionnaire. Every adult member of every household was eligible to be interviewed, and information about every child was collected from a parent or primary caretaker. Every member of the baseline household survey who survived the tsunami was eligible to be tracked and interviewed in their new location. In addition, village leaders and informants at local schools and health facilities provided information as part of a large community-level survey.

STAR1 was the first of five annual post-tsunami surveys. These data are combined with the subsequentr waves, STAR2—STAR5, the last of which took place between September 2009 and December 2010.

In this paper, we focus on 3,812 individuals who were between 20 and 59 years old at the time of the baseline survey and were living in the 95 enumeration areas classified as heavily damaged. We put enormous effort into identifying the baseline respondents who had died in the tsunami, which involved finding surviving members of baseline households, following up with neighbors and community leaders in the devastated areas, visiting camps and barracks, and consulting registers kept in each village of those who died or were missing (see Frankenberg et al. 2011 for more details). Of all the deaths

recorded in STAR and attributed to the tsunami, 92% occurred in the severely damaged enumeration areas on which we focus here.

High re-interview rates are critical to the success of longitudinal surveys. We developed and implemented extensive tracking protocols to find not only those who continued to live in their baseline locations but also those who moved. This is particularly important in the context of a disaster that causes massive disruption and displacement—as is the case with the tsunami.

Of the age-eligible respondents who were, at baseline, living in the severely damaged areas, 28% were dead as of the first follow-up survey. Of the remaining respondents, 87% were members of interviewed households in the first follow-up. Persistent attempts to track all survivors in subsequent waves paid off: over 95% have been interviewed at least once and 90% were assessed in the final interview.

Measures

In this section, we describe the measures that we use to indicate vulnerability to the immediate and shorter term impacts of the tsunami, as well measures that capture longer term outcomes and can be interpreted as indicators of resilience.

As the water came ashore, it swept up many people, killing some, exposing others to traumatic experiences, and damaging or destroying most of the homes in its path. Measures of these outcomes serve as indicators of the disaster's immediate impact. We begin by examining mortality. Among those who survived, we also analyze experiences during the tsunami, including hearing or seeing the water come ashore, being caught in the water or injured by it, seeing others struggling in the water, or having one's house damaged or destroyed as a result of the disaster.

In the months that followed the tsunami, residents of the communities that were heavily damaged struggled to cope with the magnitude of the event, and assistance began to arrive. To capture these dynamics, we focus on two dimensions: the built environment and psychosocial resources.

With respect to the built environment, damage to housing and infrastructure from the tsunami resulted in massive population displacement. We analyze whether respondents were displaced from their original residence and, if they were, whether they lived in temporary housing (defined as living in a camp or temporary settlement, a tent, or barracks) at some point during the 2 years after the tsunami. We also investigate whether they received assistance from the government or international agencies to build or repair housing.

With respect to psychosocial resources, we develop indicators of post-traumatic stress reactivity (PTSR) and receipt of mental health counseling. We believe it appropriate to focus on PTSR because it is one of the most common psychological sequelae of exposure to disasters and because higher levels of socioeconomic status, as measured by education and other indicators, have been shown to be protective in previous studies (Armenian et al. 2000; see also Norris et al. 2002 for a review). The stress measures are constructed from information on post-traumatic stress reactions, which were assessed using seven items from the 17-item Post-Traumatic Stress Disorder (PTSD) Checklist Civilian Version (PCL) (Weathers et al. 1993). The instrument has been validated among veterans, those exposed to disasters, violence, accidents, and sexual assault, and survivors of bone-marrow transplants and has been used in both advanced and developing countries (Blanchard et al. 1996, Smith et al. 1999). Adult respondents in the post-tsunami surveys were asked about specific symptom items that, in combination, covered three distinctive psychological domains of post-traumatic stress. These data were used to construct PTSR scales developed in Frankenberg et al. (2008), which range from 0 to 21. Higher values reflect higher PTSR, and thus poorer psychosocial health. Psychosocial counseling has been shown to mitigate the effects of disasters on psychosocial well-being, and efforts were made to strengthen mental health services in Aceh in the years following the disaster (Prasetiyawan et al. 2006). We assess who obtained counseling.

Our final set of indicators of well-being provides a summary of the economic status of each respondent and their families. Income is often used as a measure of economic well-being in socioeconomic studies, but it is complicated to interpret, particularly after the tsunami destroyed farmland and businesses, resulting in a substantial decline in employment and earnings. Moreover, a large fraction of the population—especially women—did not earn income before the tsunami.

For these reasons, we examine economic resources at the household rather than individual level. Because a large aid effort was mounted after the tsunami, it is important that the measure of economic well-being include assistance from the public sector as well as from friends and family. A measure that meets these criteria is household consumption, which includes the imputed value of goods produced at home and goods and services provided in kind, during the month before the survey. The value (market and imputed) of consumption is more likely to reflect economic well-being than income as it incorporates not only goods and services provided by family, friends, and the public sector but also consumption from drawing on savings or selling assets.

Another advantage of household consumption is that it is measured in every wave of the survey, including the baseline. Accordingly, we can trace the evolution of expenditure, and its relationship to education, before and after the tsunami. Generally, we expect households to attempt to mitigate the impact of a large negative shock on their well-being by keeping reductions in consumption to a minimum—that is, smoothing

consumption over time. If the better educated have more resources that they can call on—from savings, family members, or from other sources—then they are likely to reduce consumption less than those with fewer resources during times when resources are relatively scarce. We will provide direct evidence on this question.

In an effort to take into account variation in consumption with household composition, we adjust expenditure for the number of household members and examine household per capita expenditure (PCE). To evaluate the importance of this approximation, we explore changes in household composition. Per capita expenditure is specified in a logarithmic form because its distribution has a very long right tail, and it is well approximated by the log normal distribution.

We also examine the share of the budget allocated to food. Higher food shares have been interpreted as indicative of lower levels of well-being since at least Engel (1895), and the food share is the foundation of many measures of poverty used across the globe. Food shares provide an alternative indicator of economic well-being that complements the logarithm of PCE and, to some extent, takes into account changes in prices.

EMPIRICAL METHODS

The goal of this research is to provide new insights into the moderating effect of education in the face of a major shock to population health and well-being as a result of a large and unanticipated disaster. For each outcome, θ, described in the previous section, we examine its association with education, E, after adjusting for age, X, in a multivariate regression framework. We control for age because, in the study sample, levels of education are significantly higher among younger cohorts. In all analyses based on individual-level data, models are stratified by sex. All models also control location of residence at baseline in a flexible way.

The impacts of some disasters accrue disproportionately in communities whose locations on marginal land make them relatively vulnerable and whose residents tend to be poor and perhaps poorly educated. This was not generally the case with respect to the tsunami, which affected wealthy communities of business owners, and public servants located in cites along the coast as well as relatively poorer communities of fishermen and farmers, but left the more remote inland communities untouched. However, rather than rely on heterogeneity in education levels across communities that were all badly damaged, we draw contrasts among people who were living in the same community. Formally, all of the regression models include community (enumeration area) fixed effects, μ_c, which absorb the influence of all community-specific variation that does not change over time and affects the outcome, θ, in a linear and additive way. These fixed effects capture the extent of damage in the community because of the earthquake and tsunami, as well as prior levels of infrastructure and economic activity, and help ensure that individual-level measures of education are not simply proxying for community-level variations in resources before the disaster or degree of destruction during the disaster.

For each individual, i, at time t, the model

$$\theta_{it} = \alpha + \beta E_{it} + \gamma X_{it} + \mu_c + \varepsilon_{ict} \quad [1]$$

is estimated by ordinary least squares. Unobserved heterogeneity is captured by ε_{ict}. Estimates of variance–covariance matrices and all test statistics take into account clustering at the enumeration area level and are robust to arbitrary forms of heteroskedasticity (Huber 1981).

Education is measured by the highest grade attained. We interpret grade attained as a crude summary of the respondent's school-related level of human capital, but fully recognize that human capital is a far broader concept that reflects a wide array of skills, personality traits, health, and cognition. Because this research focuses on the relationship between education and each of the outcomes described above, we have carefully explored the shape of this relationship. Two model specifications are reported in the tables. The first model is linear in education and the second is piecewise linear with a knot at completion of grade 6. (Experiments with knots at other points and models that include indicator variables for education do not yield additional insights, and so we report these specifications.)

Table 1 reports the distribution of education of respondents in the baseline survey, conducted before the tsunami, and includes both those who survived the tsunami and those who did not. As shown in Table 1, among all respondents who were living, at baseline, in communities that were severely damaged by the tsunami (the study sample used in the regression analyses reported below), the average respondent completed 9.4 grades of school. This is equivalent to finishing junior secondary school. In contrast, the average respondent in the entire STAR sample of baseline respondents—which includes areas that were not severely damaged—has completed 8.3 grades of school. This difference underscores the fact that, unlike many natural disasters, education levels were on average higher in the areas that were more likely to be severely damaged by the tsunami.

The distribution of education of male and female adults who were living in severely damaged areas is displayed in panel B of Table 1. Very few adults in the sample had no schooling. Among the one-third who had some primary education, the vast majority completed primary school (six grades). About one in five attended junior high school (grades 7–9), about one-quarter attended senior high (grades 10–12), and slightly over one in six attended some college. Males are significantly better educated than females, with 49% of males in the sample attending senior high school or more, vs. only 42% of females.

Table 1. Distribution of age and education

	All sample	Females	Males
A. Highest completed grade			
1. All areas	8.3	8.0	8.7
	[0.03]	[0.05]	[0.05]
2. Severely damaged areas	9.4	9.2	9.7
	[0.07]	[0.10]	[0.09]
B. Grade completed (% sample)			
(among respondents in severely damaged areas)			
No school	1.8	2.6	1.0
Some primary school (Grade 1–5)	8.6	9.0	8.1
Completed primary school (Grade 6)	23.6	26.2	21.0
Junior secondary school (Grades 7–9)	20.5	19.9	21.1
Senior secondary school (Grades 10–12)	27.8	24.2	31.5
College (>Grade 12)	17.6	18.1	17.1
Age (% sample)			
20–29	35.9	38.0	33.7
30–39	30.2	29.4	31.1
40–49	20.8	20.4	21.3
50–59	13.0	12.1	13.9
Sample size	3415	1732	1683

Notes: [Standard errors].

The table also displays the age distribution of baseline respondents, with about one-third in their twenties, one-third in their thirties, and the rest in their forties and fifties.

RESULTS

This section presents results from estimating the regression model described above, which provides a summary of how educational attainment is related to outcomes that represent both vulnerability to the tsunami's immediate and short-term impacts and longer-term resilience in the disaster's aftermath. Attention is restricted to respondents who were, at the time of the pre-tsunami baseline survey, living in enumeration areas that were subsequently severely damaged by the tsunami. The samples include those who stayed in the areas and those who moved away so that they are representative of the population exposed to the full brunt of the tsunami.

Table 2 presents the results of estimating the model for our measures of the tsunami's immediate impact: mortality, exposure to traumatic experiences, and damage or destruction to housing. In the table (and in subsequent tables for other outcomes), panel A displays the average for the outcome. Mortality in the heavily damaged areas was extremely high: 30.2% of females and 19.1% of males died in the tsunami. Close to the coast, mortality was even higher. In communities within a kilometer of the shoreline, 54.5% of females and 33.3% of males died.

Panel B displays estimates of the shape of the relationship between education and each outcome, controlling age and EA fixed effects. Panel B1 reports estimates from a model that is linear in education. Panel B2 reports estimates from a spline function that allows the shape to be piece-wise linear in education with a knot at completed grade 6 (or completed primary school). Sample sizes are in panel C.

For females, education does not confer a survival advantage. Better-educated females are no more likely to survive the tsunami than females with little education (column 1). For males, some evidence suggests that education is protective, at least among those who advanced beyond primary school (column 2). Males who completed senior high school are about 6.5 percentage points more likely to survive the tsunami than those who left school after completing primary education. However, those who completed primary school are themselves about 8 percentage points more likely to die in the tsunami than those who never attended school.

One interpretation of these results is that, in part, the mortality differences by education of males reflect differences in height, strength, and possibly other dimensions of human capital. This interpretation is consistent with the evidence that mortality rates are higher among females than among males. As shown in Frankenberg et al. (2011), older males and females were also more likely to die in the tsunami relative to prime age males and females, respectively.

To explore the idea that education may be an important proxy for strength, we re-estimate the models for respondents who were living within 1 km of the coast, where mortality was

Table 2. Mortality and exposure at time of the tsunami

I. Mortality at time of tsunami				II. Exposure at time of tsunami						III. Damaged/ Destroyed Housing	
All respondents		≤1 km from coast		Females			Males			Females	Males
Females	Males	Females	Males	Injured or caught in the water	See others struggle	Hear or see the water	Injured or caught in the water	See others struggle	Hear or see the water		
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
A. Mean											
30.2	19.1	54.5	33.3	25.9	35.5	76.8	34.6	44.6	80.8	63.47	76.39
[3.62]	[2.41]	[8.33]	[7.15]	[2.75]	[3.30]	[3.52]	[2.77]	[3.03]	[3.03]	[3.87]	[4.00]
B. Education (highest grade)											
B.1 Linear											
-0.05	-0.59	-0.38	-1.58	-0.79	-0.71	-0.02	-0.10	-0.45	-0.24	0.02	-0.62
[0.17]	[0.22]	[0.44]	[0.63]	[0.39]	[0.45]	[0.32]	[0.44]	[0.44]	[0.31]	[0.28]	[0.37]
B.2 Spline (0–6)											
-0.42	1.16	-1.14	0.17	-0.23	-0.73	-0.22	0.95	-0.40	0.29	0.45	-1.04
[0.44]	[0.65]	[1.29]	[2.45]	[0.98]	[0.87]	[0.61]	[0.97]	[1.16]	[0.81]	[0.70]	[0.63]
Spline (≥7)											
0.09	-1.07	-0.09	-2.07	-0.96	-0.70	0.04	-0.35	-0.46	-0.37	-0.14	-0.46
[0.28]	[0.29]	[0.81]	[0.84]	[0.48]	[0.56]	[0.37]	[0.54]	[0.54]	[0.40]	[0.36]	[0.52]
C. Sample size											
1920	1889	314	318	1036	1036	1036	1166	1166	1166	1036	1166

Notes [Standard errors] take into account clustering at the enumeration area level and are robust to heteroskedasticity. Includes controls for respondent age and enumeration area fixed effects.

highest. Results are reported in columns 3 and 4. Close to the coast, education is unrelated to survival for females but is even more strongly predictive of survival among males, suggesting that strength is not the full explanation for the link between education and survival.

We cannot test directly whether education is a proxy for height and strength because neither height nor strength was measured at baseline and, therefore, is not known for those who died in the tsunami. However, using data from areas that were not damaged by the tsunami, where mortality is very low, we can estimate the association between height and education using data from the post-tsunami resurveys. On average, a male who completed senior high is 163 cm tall; a male who only completed primary school is 160 cm tall and a male who did not complete primary school is 142 cm tall. Controlling age, in a piece-wise linear specification, each year of education is associated with a 4.7 cm (standard error = 0.3 cm) increase in height until completing primary school and then an increase of 0.3 cm (standard error = 0.08 cm) for each additional grade thereafter. Because the association between education and mortality is positive for males up to completion of primary school and is then negative and significant only for males with more than primary schooling (whereas the association between education and height is positive throughout the education distribution), it seems unlikely that education serves only as a proxy for height and strength in these regression models. The education–height association is not strong enough nor the appropriate shape to fully explain the relationship between survival and education of males.

All subsequent regression analyses focus on those who survived the tsunami. Many of the survivors experienced harrowing events as the water came ashore. We next turn to the question of how education is related to these experiences, as reported by survivors who were living at baseline in areas that were subsequently severely damaged by the tsunami (these results are presented in columns 5 through 10 of Table 2). We begin with females. Overall, a quarter of women were caught up in the water or injured, just over one-third witnessed others struggling in the water, and about three-quarters heard or saw the water come ashore. Better-educated women were less likely to report being caught in the water, injured, or watching others struggle. For example, a female who completed senior high school is estimated to be between 4 and 5 percentage points less likely to have been caught up in or injured by the water relative to a female who completed primary school, and this difference is statistically significant. Education is unrelated to hearing or seeing the tsunami come ashore among females.

Among male survivors about one-third report being caught up in the water or injured, and nearly 45% saw others struggling in the water. These rates are higher than for females because females were less likely to have lived to report these experiences than were males. For males, conditional on surviving, exposure to the tsunami is unrelated to education.

The results presented thus far relate to the vulnerability of individuals along the health-related dimensions of mortality and exposure to traumatic experiences. The physical

Table 3. Displacement and receipt of housing assistance

	Females			Males		
	Displaced by tsunami [1]	Lived in temporary housing [2]	Received housing assistance [3]	Displaced by tsunami [4]	Lived in temporary housing [5]	Received housing assistance [6]
A. Mean	66.25	46.33	51.25	66.47	52.06	55.75
	[5.45]	[4.37]	[4.43]	[4.13]	[3.95]	[4.10]
B. Education (highest grade)						
B.1 Linear	0.17	-1.31	-0.78	-0.39	-1.39	-0.84
	[0.36]	[0.44]	[0.37]	[0.41]	[0.37]	[0.39]
B.2 Spline (0–6)	1.22	-1.64	-1.73	-0.73	-0.47	-0.57
	[0.92]	[0.86]	[1.03]	[0.73]	[0.88]	[0.83]
Spline (≥7)	-0.11	-1.21	-0.50	-0.30	-1.61	-0.90
	[0.42]	[0.46]	[0.48]	[0.52]	[0.41]	[0.49]
C. Sample size	1036	1036	1036	1166	1166	1166

Notes [Standard errors] take into account clustering at the enumeration area level and are robust to heteroskedasticity. Controls included for respondent age and enumeration area fixed effects..

vulnerability of respondents' homes is another dimension with strong implications for the well-being of survivors. The last two columns present results for experiencing damage or destruction to one's home. Overall, two-thirds of women and three-quarters of men report that their home was damaged or destroyed by the tsunami—again reflecting differential survival rates of men and women. But for neither men nor women are damage or destruction of housing related to level of education.

We turn next to outcomes that represent respondents' experiences as the aftermath of the disaster unfolded. We explore these along the dimensions discussed above: housing and psychosocial health. Table 3 focuses on housing in the disaster's aftermath. Whereas the models are reported separately for males and females, results do not differ by sex, and so we do not distinguish between males and females in the discussion.

We first consider displacement, which we define as moving within the first 4 months following the tsunami. About two-thirds of survivors were displaced by the tsunami, and being displaced is not associated with education.

About half the survivors who were living in areas that were severely damaged lived in temporary housing—typically a camp—at some point during the 2 years after the tsunami (columns 2 and 5). The rest of the displaced moved to private homes—either moving in with family or friends or renting a private home. The better educated, particularly those who completed more than primary school, were significantly less likely to move to temporary housing, but this is not because the better educated were less likely to be displaced. Displacement risks are not related to education. Rather, the education advantage with respect to avoiding temporary shelter likely reflects the greater availability of financial and/or social resources of those who are better educated.

A key dimension of the recovery and reconstruction effort was the provision of assistance with building or repairing houses that were damaged or destroyed by the tsunami. About half of the tsunami survivors received housing assistance from the government or a nongovernmental organization (NGO)—a fraction that is substantially less than the fraction whose houses were damaged. The better educated were just as likely to have their home damaged in the tsunami, but they were less likely to receive housing assistance. Although the decline in the probability of receiving aid as education increases is statistically significant, the rate of decline is small, and differences in the probability of receiving assistance for the best educated relative to those with little education are modest.

Another form of assistance, but one that relates to psychosocial dimensions of the disaster, is receipt of mental health counseling. As shown in the first two columns of Table 4, regardless of sex, around one in six survivors received some form of counseling after the tsunami. Although the relationship between education and receipt of counseling is positive, the association is only statistically significant for males who completed more than primary schooling.

Columns 3 through 6 of Table 4 report levels of PTSR. At the time of the first interview after the tsunami, levels of PTSR are higher among females (6.60 on a scale of 21) than among males (5.89). For neither sex are there differences across the education distribution. At the time of the most recent interview, approximately 5 years later, PTSR levels have declined substantially, although they remain higher for females relative to males (3.63 vs. 2.73 on the same 21-point scale). In addition, PTSR is significantly lower among the better educated, indicating that those with more education are more resilient in terms of psychosocial well-being. For example, the difference in PTSR of a male who completed senior high school relative to a male who did not attend school is about half the average level of PTSR for all males at the

Table 4. Mental health counseling and post-traumatic stress reactivity

	I. Received mental health counselling		II. Post-Traumatic Stress Reactivity			
	Females	Males	Females		Males	
	At any time during study period [1]	At any time during study period [2]	First interview afer tsunami [3]	Last interview [4]	First interview after tsunami [5]	Last interview [6]
A. Mean	14.58	13.38	6.60	3.63	5.89	2.73
	[1.63]	[1.42]	[0.16]	[0.21]	[0.17]	[0.16]
B. Education (highest grade)						
B.1 Linear	0.34	0.50	0.06	-0.08	-0.03	-0.11
	[0.30]	[0.30]	[0.05]	[0.03]	[0.04]	[0.03]
B.2 Spline (0–6)	0.73	-0.50	-0.02	0.05	0.02	-0.19
	[0.74]	[0.95]	[0.12]	[0.10]	[0.10]	[0.09]
Spline (≥7)	0.23	0.74	0.08	-0.11	-0.04	-0.09
	[0.38]	[0.33]	[0.06]	[0.04]	[0.05]	[0.04]
C. Sample size	1036	1166	860	860	829	829

Notes [Standard errors] take into account clustering at the enumeration area level and are robust to heteroskedasticity. Controls included for respondent age and enumeration area fixed effects.

final interview; for females, a comparable comparison accounts for about one-quarter of the average PTSR level.

In Table 5, we turn to indicators of the characteristics of households that respondents are in at each wave of the study. These characteristics include the logarithm of PCE, lnPCE, the share of spending that goes to food, household size, and the share of household members who are under 15. Because these indicators are measured at the household level, models are not estimated separately for males and females. The relationship between lnPCE and education of the respondent is estimated separately for every wave of the study, which provides evidence on evolution in the trajectory of lnPCE across the education distribution as time passes.

Panel 1A of the table reports the association between lnPCE and education for each wave. Specifying expenditure in logarithms means that the coefficient estimates can be interpreted as representing percentage changes. By estimating the models separately for each year after the tsunami, and by including enumeration area fixed effects, the models absorb the impact of changes in prices over time and at the local area level. This is important in the context of the tsunami—and most natural disasters—when supply chains are severely disrupted and shortages of food, housing, and transport are accompanied by high rates of price inflation that vary across time and space.

In the pre-tsunami wave, the better educated spend more: per capita expenditure is 2.16% higher for each year of completed education. This is a reflection of the fact that education and economic success are positively correlated. In the year after the tsunami, each year of education was associated with a 4.18% increase in PCE. The difference between the post- and pre-tsunami association, 2.02%, is displayed in panel 1B. That difference is statistically significant, indicating that the better educated were substantially better protected from the declines in PCE—and economic resource availability—that occurred in the aftermath of the tsunami. Thus, the better educated were better able to smooth consumption after this large shock, and inequality across the education distribution rose. As years since the tsunami passed, the gap in spending between the better and less educated remained larger than it was before the tsunami, but the difference is significant only during the first 2 years after the tsunami.

The piece-wise linear model, in panel 1C, establishes that consumption smoothing is more effective only among those who have completed primary education. In fact, for those who did not complete primary school, education and PCE are not related.

The interpretation of variation in the relationship between PCE and education is not entirely straightforward. First, immediately after the tsunami, prices rose substantially for many goods and, as a result, relative prices also changed. Changes in overall prices are captured by the intercept. The data to reliably compute such indices do not exist.

If prices of the consumption bundles consumed by the better educated rose more than those consumed by the less educated, then real resources of the better educated will be lower than those of the less educated, and this could explain the apparently greater consumption smoothing by the better educated. This is unlikely to be the case, as prices of food, housing, and transport rose the most, and these goods tend to account for a larger share of the budget of poorer households. Rather, our estimates of the differences in consumption smoothing are likely to be lower bounds because prices for the goods the least educated spend most of their money on are the prices that likely rose the most.

Table 5. Economic resources and household composition

Survey wave	Pre-tsunami	Post-tsunami survey wave (years after tsunami)				
		1	2	3	4	5
	[1]	[2]	[3]	[4]	[5]	[6]
1. lnPCE						
1A. Education	2.16	4.18	3.51	3.07	2.90	2.74
	[0.30]	[0.67]	[0.47]	[0.50]	[0.48]	[0.44]
1B. Difference (relative to pre-tsunami relationship)		2.02	1.34	0.91	0.73	0.57
		[0.73]	[0.55]	[0.58]	[0.56]	[0.53]
1C. Spline (0–6)	-0.01	1.10	0.44	1.44	0.47	1.46
	[0.66]	[1.59]	[1.54]	[1.01]	[0.95]	[1.06]
Spline (≥7)	2.74	4.96	4.30	3.50	3.52	3.07
	[0.34]	[0.87]	[0.54]	[0.64]	[0.57]	[0.56]
2. Food share						
Spline (0–6)	0.06	-0.13	-0.17	-0.38	-0.34	0.01
	[0.18]	[0.33]	[0.36]	[0.27]	[0.28]	[0.27]
Spline (≥7)	-0.45	-1.34	-1.03	-0.87	-0.77	-0.73
	[0.08]	[0.20]	[0.17]	[0.13]	[0.16]	[0.14]
3. Household size						
Spline (0–6)	0.07	0.09	0.05	0.06	0.03	0.05
	[0.04]	[0.04]	[0.04]	[0.03]	[0.03]	[0.04]
Spline (≥6)	0.010	-0.010	-0.020	-0.02	-0.03	-0.02
	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]
4. Share of HH members age <15						
Spline (0–6)	0.46	0.88	0.71	0.60	0.51	0.74
	[0.34]	[0.41]	[0.34]	[0.35]	[0.37]	[0.37]
Spline (≥6)	0.07	-0.01	-0.18	-0.16	0.06	0.05
	[0.16]	[0.17]	[0.16]	[0.17]	[0.16]	[0.17]
5. Sample size	3413	2692	2641	2627	2636	2732

Notes [Standard errors] take into account clustering at the enumeration area level and are robust to heteroskedasticity. All models include enumeration area fixed effects.

Additional evidence suggests this is the case. As shown in Panel 2 of Table 5, and paralleling results for lnPCE, food shares are unrelated to education for those with primary schooling or less and then decline with education for higher levels. The rate of decline is substantially and significantly greater in the year immediately after the tsunami, rising from 0.5% per grade of schooling before the tsunami to 1.3% after the tsunami. Food shares rose the most for the least educated, whereas the better educated were more able to protect their budget allocations to other goods. The estimated rate of decline of foods shares as education increases becomes less steep as time since the tsunami rises, but it remains significantly different from the pre-tsunami rate for 3 years after the tsunami —longer than is the case for lnPCE.

The second reason that interpretation of changes in PCE is complicated is that household size and composition may have changed over time. For the purposes of interpreting the evidence on the lnPCE-education profile, these changes need to differ across the distribution of education. A long literature focuses on the development of equivalence scales that seek to enable direct comparisons of well-being across different household structures. No consensus has been reached on a theoretically and empirically valid approach to this complex problem and so, *faute de mieux*, we have adjusted expenditure by household size. Rather than rely on some other ad hoc adjustment, we investigate whether there were changes in household size and composition following the tsunami that are systematically related to education.

Panel 3 of Table 5 reports results for household size and Panel 4 reports results for the share of household members who are age under 15. For both cases, there is evidence that household size and the share age under 15 rose with education immediately after the tsunami—but only among those who had no more than primary schooling—the group of people for whom lnPCE and food shares are not related to education. Among the better educated, there is no evidence that household size or the share age under 15 is related to education or that these associations changed over time. We conclude that variation in household size and composition is not likely to substantially contaminate our interpretation of changes in economic well-being based on variation in lnPCE and food shares. That evidence clearly indicates that, relative to those with little education, the better educated were more successful in smoothing consumption—or mitigating the deleterious impact of the tsunami on spending—immediately after the tsunami whereas those with less education took longer to adjust.

DISCUSSION

This research has traced out the tsunami's immediate impacts on health and well-being by comparing the markers before and after the tsunami for the same people. We have also traced out the evolution of the same markers during the 5 years after the tsunami. Throughout, we have given special prominence to variation in these trajectories across the distribution of education and, thereby, have provided new insights into the extent to which heterogeneity in resilience and recovery in the aftermath of a major disaster is related to education.

With respect to its immediate impact, we consider the tsunami as a threat to life and property. Education, particularly above the primary level, provides some protection against death for men, but not for women. Conditional on survival, education provides some protection from being caught in the water or injured for women, but not for men. If one assumes that those who perished in the tsunami were caught in the water, then rates of exposure to the tsunami's greatest threats to safety were similar for males and females, and decline with education for both. However, on the dimension of physical destruction of perhaps greatest salience to our respondents—the loss of a home—the better educated are no less likely to suffer than anyone else.

Thus, in terms of the tsunami's immediate impacts, the protective effect of education was limited. But does education distinguish decisions and outcomes in the aftermath of the tsunami?

The role of education varies by outcome. For those with more than a primary school education, increases in education were associated with a reduced likelihood of living in temporary housing in the form of camps, tents, or barracks. This is not because of greater access to housing assistance from official sources for the better educated. In fact, education is associated with a significant reduction in the likelihood of receiving such housing assistance, although the size of the effect is small.

Turning to psychosocial dimensions of well-being, in the period shortly after the tsunami, levels of PTSR did not differ across the education distribution. Over time, however, declines in PTSR proceed more rapidly for the better educated. As with housing, this does not reflect better access to mental health services among the better educated. Receipt of any counseling was rare.

Because data on levels and patterns of household spending are available before the tsunami, as well as annually for 5 years afterward, we investigate the evolution of spending before and after the tsunami, and how those trajectories differ by education level. In the year after the tsunami, absolute levels of spending decline for everyone, but the size of the decline shrinks as education rises. In other words, after the tsunami, the difference in spending levels by education increases, suggesting that the better educated were better able to protect spending after the disaster. But, over time, the difference by education level diminishes. A similar pattern is documented for the share of budget spent on food, an indicator used as a proxy for economic well-being.

Thus, although the tsunami took a huge immediate toll on individuals at all levels of education, the evidence suggests that the better educated were more effective at adjusting to the changed reality of their lives relative to those with less education. In part, this likely reflects the resources they had before the tsunami as well as their experiences in the months after the tsunami, when they were able to afford to move to private homes rather than live in camps. Moreover, although the destruction of livelihoods resulted in reductions in the economic resources of all households, the better educated were more able to mitigate declines in consumption levels relative to the cuts in spending made by those with less education. Finally, 5 years after the tsunami, the better educated were in better psychosocial health than those with less education, indicating a more rapid recovery.

The faster recovery of the better educated in the face of a major natural disaster does not appear to be because they thought an earthquake or tsunami was more likely than those with less education. In the baseline survey conducted before the tsunami, a randomly selected subsample of 15% of the respondents were asked whether they thought they were living in a location that was at high risk of a natural disaster. In all of Aceh and North Sumatra, 9% of the respondents answered this question in the affirmative, and 9% of those respondents said that the greatest risk was from an earthquake or tsunami. In the areas that were severely damaged by the tsunami, 12% of the respondents said they lived in a place that was at risk of a natural disaster, and 13% of them indicated the greatest risk was from an earthquake or tsunami. Importantly, for this research, responses to these questions are not associated with the education levels of the respondents.

Instead, the protective effects of education are likely a reflection of greater accumulated financial resources and possibly social resources available to the better educated in times of need. It is also possible that those who have invested more in education make better choices in times of adversity, are more entrepreneurial, and are more effective at taking on new challenges. Although the results presented here are important for the design of policies that seek to mitigate the impact of large-scale disasters, understanding the pathways through which the better educated were more able to weather the storm of the Indian Ocean tsunami remains an important and pressing question for scientific inquiry.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5377

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Education as a Determinant of Response to Cyclone Warnings: Evidence from Coastal Zones in India

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ABSTRACT. Education is often considered a means for enhancing adaptive capacity, based on the consideration that formal education is likely to improve the ability of individuals to evaluate risks and respond to warning information. We explore the relation between the level and nature of education and enhanced ability to respond to tropical cyclone risk. We make a distinction between formal school-based education and nonformal education in the form of traditional knowledge of environmental precursors and conditions that may be associated with tropical cyclone occurrence. We evaluate two possible routes through which education could lead to enhanced ability to respond to tropical cyclone risk; first, education, both formal and nonformal, may lead to a better ability to access, understand, and interpret warning information and hence lead to an appropriate response to the warning; and second, formal education may be associated with greater income levels and socioeconomic status and thus with greater resources for evacuating in response to cyclone warning. We find that the hypotheses regarding the link between formal education and adaptive capacity are actually not well supported by empirical data. On the other hand nonformal education in the form of traditional knowledge for predicting cyclones based on environmental precursors emerged as a significant determinant of the ability to understand and interpret warning information and provides a strong case for preserving and promoting a hazard-specific traditional knowledge base along with formal education.

Key Words: *cyclones; early warnings; education; traditional knowledge base; warning-response process*

INTRODUCTION

Scholars have identified targeted human and social development as an important approach to adaptation to climate change in the academic discourse (McGray et al. 2007). However, the link between human and social development and reduction in the vulnerability to climate risk is not as linear and simple as it may seem in the first instance. For example, consider the Millennium Development Goal of universal education; although the goal is commendable in itself, it may be too simplistic to assume that achievement of this goal would automatically lead to an enhancement of ability to respond to climate risk, i.e., adaptive capacity. It is important to investigate the hypothesized link between achievement of development goals and enhancement of adaptive capacity, not only from the point of view of scholarship, but also because it has practical implications for allocation of financial resources across the plethora of adaptation activities.

The question we ask is the following: Does the nature of education and the level of educational attainment lead to an improved ability to respond to current climate risks, such as tropical cyclone hazard? The extreme weather (tropical cyclone) context necessitates the use of available coping and adaptive capacity within the population at risk in which evacuation in response to early warning is one of the important options available for reducing risk of mortality. We identify two causal pathways to evaluate whether the level of educational attainment is a determinant of evacuation in response to cyclone early warning. First, for warnings to be useful, people need to correctly interpret and understand the information. We hypothesize that the level of educational attainment of the warning recipient ought to improve understanding and interpretation, and lead to more appropriate decisions with respect to evacuation. However, we make a distinction between different kinds of education based on the definition provided by La Belle (as cited in Mazza 2007:2) in which formal education is the "purposive and structural learning leading to recognized certificates and diplomas," which differs from nonformal education, i.e., "any educational activity taking place outside the formal system" and informal education, i.e., "the unplanned learning that goes on in daily life." This is because formal education is only one kind of education a person may receive, particularly in the context of rural communities in developing countries where the reach of formal education is not universal even today. Even in the areas where formal education has reached, the levels of formal education attainment and often the quality are not very high for a variety of reasons. Nonformal education, different from formal education and much more specific to the hazard itself, often results from experience and knowledge being passed down through generations. For example, some fishermen are able to anticipate the occurrence of cyclones based on environmental precursors they observe before the manifestation of the cyclone, like change in direction of winds, changes in animal and plant behavior, changes in the color of the sea, etc. We term this as the traditional knowledge base on predicting cyclones based on environmental precursors. We hypothesize that this traditional knowledge base for predicting

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cyclones is likely to influence response to cyclone risk and also interpretation and understanding of the cyclone warning messages sent by the meteorological department.

Second, correct interpretation and understanding of the warning message is only one aspect of responding to warning. For actual evacuations, resources are needed. We hypothesize that the level of formal education ought to improve income levels and access to resources for evacuation and thus to facilitate response in terms of evacuation. We examine the evidence that relevant literature provides with respect to our hypotheses about the effect of education on adaptive capacity or the ability to respond to risk.

BACKGROUND

Many studies provide evidence for a positive correlation between formal education and desirable life outcomes such as income (Angrist and Krueger 1991, Hanushek and Kimko 2000, Barro 2001, Barro and Lee 2001, Soto 2006, Cohen and Soto 2007, Jamison et al. 2007), life-expectancy and health (Caldwell 1979, Cochrane et al. 1980, Adams et al. 2003), well-being (Oreopoulos 2003, Oswald and Powdthavee 2007), civil and political participation (Verba et al. 1995, Nie et al. 1996), and of a negative correlation with many undesirable behaviors such as substance abuse (Baker et al. 2011) and criminal activities (Lochner 2004). The question of causality, however, remains unresolved. One hypothesis is that education builds human capital by creating both specific, job-related skills and a more generalized increase in cognitive capacities, causing increased income, health, and political participation, among many positive outcomes (Becker 1964, Lutz and KC 2011). A second hypothesis suggests that it is inherent abilities that lead to positive outcomes, and that education itself may do little to enhance those abilities; rather, it is those with the inherent abilities who want to and are able to complete formal education. In this way, Spence (1973) and Stiglitz (1975) suggested that formal education signals inherent abilities, to society in general and potential employers more specifically. Most likely both hypotheses hold, i.e., education has some independent effect on positive life outcomes, while also being affected by some other factors that also impact life outcomes.

Rather than examining the entire range of life outcomes with which education seems to be correlated, we focus on two strands of literature: first, the way formal education has been treated in the climate change adaptation and disaster management literature and more specifically in the warning-response literature; and second, the literature on traditional knowledge-based weather forecasting.

Formal education as a determinant of climate adaptive capacity

In recent years, the question of what constitutes adaptive capacity to climate change risk has brought to fore the role of education as an important factor in determining the coping or adaptive capacities of a population (e.g., UNDP 2004). Most studies (Adger et al. 2004, Toya and Skidmore 2007, Blankespoor et al. 2010, Patt et al. 2010) that have examined education as an indicator of adaptive capacity to current climate risk and climate change have used national level mortality (or other impacts) data on climate related disasters (mostly from the CRED International Disaster Database) as the dependent variable. Many of these studies show that formal education is negatively correlated with deaths or other forms of loss from disasters and the correlation seems to be particularly strong for developing countries. Many different indicators of formal education have been used in these studies such as literacy rates among different age groups (Adger et al. 2004); female to male literacy ratio (Adger et al. 2004); number of years of schooling (Toya and Skidmore 2007); and female educational enrollment rate (Blankespoor et al. 2010). At a finer scale, researchers have examined education as one of the factors leading to adoption of improved strategies for coping with climate impacts in the agriculture sector. A higher level of education appears to be associated with access to information on improved technologies and productivity consequences (Norris and Bati 1987). Evidence from various sources indicates that there is a positive relationship between the education level of the household head and the adoption of improved technologies (Igoden et al. 1988, Lin 1991) and adaptation to climate change (Maddison 2006). Therefore, farmers with higher levels of education are more likely to better adapt to climate change (Deressa et al. 2008). Other studies (e.g., Clay et al. 1998) provide contradictory evidence, suggesting that education does not correlate with reduced vulnerability and greater adaptation.

Moving from general disaster vulnerability as the dependent variable to the propensity to respond in particular ways to extreme event risk, researchers have looked at education as one of several determinants. There is a rich empirical literature base examining the effect of the warning message itself, the credibility of the warning, channels of warning, environmental cues (both social and physical), resources, cognitive factors, and physiological factors (see annotated bibliography by Mileti et al. 2006). The evidence regarding the particular effect of education on response to warning has been mixed. In general, most studies (Edwards 1993, Farley et al. 1993, Liu et al. 1996, Balluz et al. 2000) have found a positive correlation between education and evacuation (response to warning). Interestingly, Farley et al. (1993) find that the lower the education a person has, the more likely they are to 'believe' the warning, though in terms of responding to warning they find a positive correlation with education. Turner et al. (1979, 1981) find that the more education a person has, the more likely they are to understand a warning message; however, understanding may not necessarily lead to response because response would require resources, but it definitely facilitates

response, given the resources. However, a few studies find no relationship between education and a person's likelihood of responding to a warning message (Mileti et al. 1993, Miltei and DeRouen Darlington 1997, Bateman and Edwards 2002, Patt et al. 2005). In most warning-response studies education has only been used as a control variable in a regression equation and was of interest only indirectly, or as a means of simply indicating whether or not a respondent was educated or the level of a respondent's education, without much investigation into education as an explanatory factor. Consequently, research that examines variations in evacuation specifically in the context of varying levels of formal education seems to be scarce.

Nonformal education (traditional knowledge) in disaster management and climate change adaptation research

A number of studies have documented the use of traditional knowledge by farmers for understanding the weather and climate patterns to make decisions about cropping and irrigation. These document three broad kinds of indicators used by people to predict climate and weather-related parameters such as rainfall and extreme events. The first kind of indicators are the 'hydro-meteorological' indicators based on observations of certain weather-related parameters such as wind direction, temperature, rainfall, etc., by farmers and other people with nature-dependent livelihoods a few hours, days, or months in advance of the actual weather occurrence (for example, Kanani and Pastakia 1999, Singh and Dorjey 2004, Anandaraja et al. 2008, Irfanullah and Motaleb 2011, Pareek and Trivedi 2011, Sethi et al. 2011). The second category of indicators refers to a number of different 'bioindicators' based on phenology of certain local flora and behavior of certain local fauna before the actual occurrence of a weather event (for example, Samati and Begum 2006, Teron and Borthakur 2009, Acharya 2011, Chinlampianga 2011, Mao and Hynniewta 2011, Nedelcheva and Dogan 2011, Singh 2011). The third category of indicators is based on the traditional almanacs used in many places in India for making agricultural decisions (for example, Angchok and Dubey 2006, Sivaprakasam and Kanakasabai 2009, Vandeep et al. 2012). Although some studies have focused on a particular category of indicators, others have documented the use of two or more these categories (Kanani and Pastakia 1999, Anandaraja et al. 2008, Sethi et al. 2011, Pareek and Trivedi 2011).

Although most studies simply document the different kinds of traditional knowledge and practices used by various communities, tribes, and groups in the country, some studies even attempt to compare forecasts about weather and climate made by using these traditional knowledge-based indicators to actual weather events (Angchok and Dubey 2006, Sivaprakasam and Kanakasabai 2009, Vandeep et al. 2012). A few studies even compared the traditional knowledge-based forecast to the forecast of the meteorological department for the same period to see which forecast predicted the actual weather event more accurately (Rengalakshmi 2006).

Most studies on the use of traditional knowledge to predict weather and climate have been in the domain of agriculture and decisions related to cropping and irrigation. Except for the Westgate (1978) study, in which there is some documentation of the environmental precursors observed by certain island people in the Commonwealth of Bahamas to anticipate the occurrence of a hurricane, we did not find any other study that examines the use of traditional knowledge for decision making for evacuation in response to an extreme weather event like a tropical cyclone. There is some mention in the grey literature of tribal people in the Andaman and Nicobar islands being able to evacuate to safer places in time through the use of their traditional knowledge for predicting a disastrous event during the 2004 Indian Ocean Tsunami but we did not find any systematic treatment of this subject in scientific literature.

We did find one study (Rengalakshmi 2006) that examines the interaction of two knowledge systems, i.e., the scientific and the traditional, based on an experiment in a few villages in Tamil Nadu by MS Swaminathan Research Foundation. The study found that the scientific forecast and the traditional forecast both can be used by the farmers in a complementary manner; as in this case study, they tended to predict different meteorological aspects. For example, the scientific forecast predicted the probabilistic amount of rainfall during a period of time whereas the traditional forecast predicted the onset date of the rainfall. The experiment, which is still ongoing, provides the time and context for translating the forecast in the language and terminology understood by the farmers, but in rapid onset events like cyclones that might be difficult to achieve.

However, there appears to be no treatment in literature on whether the possession of traditional knowledge for forecasting weather and climate would have an effect on the interpretation, understanding of, and response to a modern scientific warning that is sent usually by the meteorological department. We attempt to elaborate on this issue.

In sum, there is a knowledge gap concerning the effects of education on the ability to respond to climate risk, i.e., adaptive capacity, but there is reason to hypothesize a causal relationship involving three different routes. First, formal education may lead to better understanding and interpretation of relevant risk information, e.g., cyclone warning messages. Second, hazard-specific nonformal education, i.e., traditional knowledge for predicting cyclones, may lead to better response to cyclone risk, i.e., through evacuation, and also a better understanding and interpretation of cyclone warning messages sent by the meteorology department. Third, a higher level of formal education is associated with a higher

socioeconomic status and more lifetime earnings (e.g., Cutter et al. 2003, Wisner et al. 2003), and education can thus be seen to reduce disaster risk through the link between income, socioeconomic status, livelihoods, and risk. Therefore, we test whether the abovementioned three linkages leads the better educated to respond more effectively to cyclone risk.

METHODOLOGY

The purpose of this research is to investigate the relationship between education and evacuation in a sample of coastal residents that encountered tropical cyclones 'Fanoos' and 'Ogni.' The household survey data used here were originally collected for the analysis of a range of factors that affect household-level evacuation pattern in response to cyclone warning (Sharma 2009). They were not collected specifically to examine the influence of education, formal or traditional, on evacuation decision. However, the data do allow us to examine a mix of respondent and warning system attributes and their relationship to whether education affected the respondents' decision to evacuate or not.

The cyclonic storm Fanoos crossed near Vedaranyam, in Nagapattinam district of Tamil Nadu at 1100 hours on 10 December 2005. The cyclonic storm Ogni made landfall near Bapatla in Guntur district of Andhra Pradesh at 1300 hours on 30 October 2006. For each of these events, the India Meteorological Department (IMD) prepared and issued early warnings to state and district authorities responsible for disaster management. An example of the actual warning for cyclone Ogni prepared by IMD and sent to the Cyclone Warning Centre (CWC) at the state level is given below:

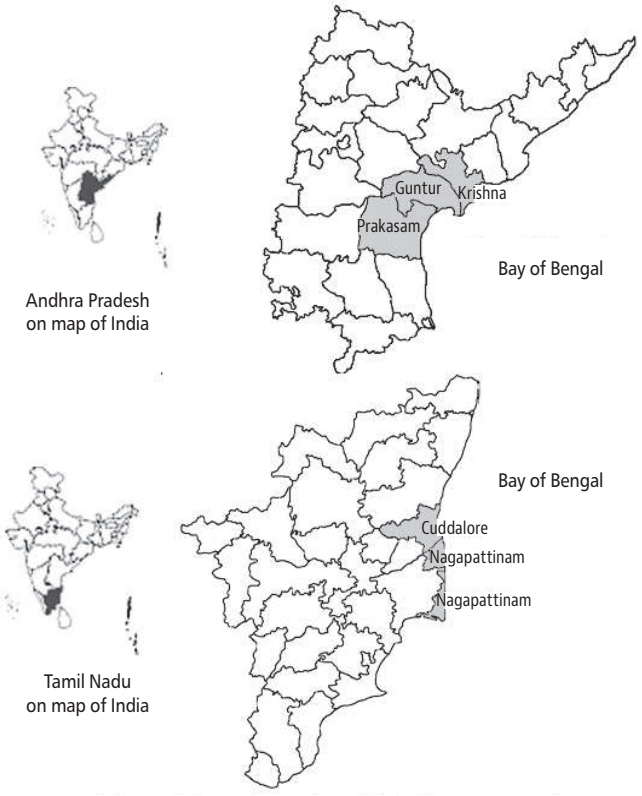
> *Two stage warning (.) Cyclone warning bulletin no. 3 issued by cwc vishakapatnam at 0400 hrs ist of 30-10-2006 (.) Cyclone warning for the districts of prakasam, guntur, krishna, east godavari & west godavari and vishakhapatnam distircts (.)*
>
> *The cyclonic storm Ogni over the westcentral Bay of Bengal moved northward and lay centred at 2330 hrs ist of y/day the 29th october 2006 near latitutde 15.5 degrees north and longitude 80.5 degrees east about 50 kms east of ongole (.) It is likley to move in a northernly direction and cross andhra coast between ongole and machilipatnam by morning of today the 30th (.)*
>
> *Under its influence rainfall at most places with heavy to very heavy falls likely at a few places and extreme heavy falls at one or two places likely over coastal ap during the next 24 hrs (.) Gale winds speed reaching 70 to 80 kmph likely along and off coastal areas of above districts, breaking off tree branches and causing some damages to kutcha houses (.)*
>
> *Tidal waves one to one decimal five mts above normal tide likely inundate coastal areas of above districts during the same period (.) State of sea will be high to very high (.) Fishermen advised not to venture into the sea (.) Danger signal no. 7 hoisted at vadarevu and nizampatnam ports (.) Danger signal no. 6 hoisted at machilipatnam and kakinada ports (.) Local cautionary signal no. 3 kept hoisted at krishnapatnam, vishakhapatnam, bheemunipatnam and kalingapatnam ports (.) The above warning is for prakasam, guntur, krishna, east godavari and west godavari and vishakhapatnam distircts (.) All cis only (.) Convey this message through v.h.f. sets to pass all the concerned p.s.s. (.)*

The warnings were disseminated through a complex set of communication channels, involving the media, public address systems, and face to face communication. The illustrative warning message given above was intended for the different authorities playing a role in warning dissemination and evacuation such as state and district disaster management authorities, fisheries department, etc. Often by the time a warning reached the last mile, i.e., the population at risk, it was modified in attempts by different authorities to simplify it for the layman or because certain media, e.g., public address systems, were conducive to simplified versions of the above message. Details on how the warning language got modified in the process of dissemination are described in Sharma (2009). Though both Fanoos and Ogni had weakened into a deep depression just before crossing land, it was confirmed from the relevant district collectors that evacuation orders had been given in many coastal villages and low-lying areas before landfall.

Study area and sampling

In case of Fanoos, Nagapattinam district and the adjoining Cuddalore district were affected. In the case of Ogni, Guntur and its adjoining districts, Krishna and Prakasam, were the affected districts. Within each of these districts, we chose those subdistrict units ('talukas' in Tamil Nadu, and 'mandals' in Andhra Pradesh) and villages within these talukas and mandals where evacuation orders had been given by local authorities. We identified these locations in consultation with the district administration. In all we selected a set of 34 villages to sample (Fig. 1) a number of variables being studied in the larger project (see Sharma 2009) of which our results here represent one part. Within each village, the strategy for selecting households was purposive convenience sampling, keeping in mind aspects such as gender, age, and minority groups in the village, so that the sample was as representative of the population as possible. Within the household, the respondent that was chosen was generally the head of the household or in absence of the head of the household, the person who would be the decision maker, which could be the wife, the mother, eldest son, or eldest daughter. Generally we collected four to eight responses per village.

Fig. 1. Location of the study area on the map of Andhra Pradesh and Tamil Nadu, India.



Survey instrument

The survey instrument (questionnaire) had originally been developed in English. This questionnaire was first translated into Tamil and Telugu, the local languages in Tamil Nadu and Andhra Pradesh, respectively, and then it was translated back into English to check for discrepancies in terms and meanings that were then corrected in the Tamil and Telugu versions of the questionnaire. The questionnaire was administered orally with the help of interpreters because a substantial proportion of the population in the coastal villages is illiterate. The interpreters were first sensitized to the objective of the survey and the items in the questionnaire were explained to them. This interaction with the interpreters also served as a pretesting of the questionnaire because a few questions were modified on the basis of the feedback given by the interpreters after a detailed discussion about how the meaning of a question may be interpreted when administered to the sample. Ethical procedures about informing respondents on consent and confidentiality were followed. This was especially important to avoid misunderstandings, because the language interpreters who accompanied were often, though not always, from the revenue services. If the purpose of the study, informed consent, and confidentiality issues were not properly and convincingly addressed in the beginning then the respondents may have been reluctant to talk freely. It took about 45 minutes to 1 hour to administer one questionnaire.

The questionnaire asked people whether they had evacuated in the most recent event, i.e., Fanoos or Ogni, and also covered several aspects of the hurricane event including questions on warning message content, clarity, timing, and frequency of warning, perceptions of people on physical and social environmental cues, their previous hurricane experience, their socioeconomic status, and demographic factors (Sharma 2009 has complete details of the study).

Relevant variables and their indicators

The relevant variables given the research question and hypothesis of this study were: appropriate response to warning; formal education; traditional knowledge for predicting cyclones based on environmental precursors; income and socioeconomic status; access to, understanding of, and interpretation of the cyclone warning message.

The appropriate response to the warning was deemed to be evacuation because the discussions with the district authorities (district collector and the revenue department) confirmed that the intensity of cyclones Ogni and Fanoos were considered severe enough that they had given evacuation orders in many coastal and other villages at risk, including the villages in our sample. Therefore, first, the respondent was asked a straight-forward question: "Did you evacuate your home/village to go to a safer place (for cyclone Fanoos/Ogni)?" The response was elicited as binary 'yes' or 'no.' This variable was termed as 'evacuation.'

For the respondents who evacuated, another question was asked: "Were you physically forced to evacuate or did you evacuate voluntarily?" with a binary response of 'yes' or 'no. ' In computing the total number of evacuees, we treated the people who were forced to evacuate as nonevacuees and hence term this variable as 'voluntary evacuation.' There were some respondents who reported that they did evacuate, but they did not evacuate to a cyclone shelter or a relief shelter; this may have been because they evacuated at the last moment and did not have time to reach a cyclone shelter or perhaps because they did not have the transportation to go to a shelter. In this case, these people took refuge in the concrete house of a neighbor or a concrete church or school building within the village. The above-mentioned two questions do not make a distinction between evacuation to a relief or cyclone shelter and simply evacuating to a neighborhood building, which may be more robust than the respondent's own house. If we make the definition of evacuation stricter and consider respondents who did not evacuate to a cyclone or relief shelter as nonevacuees, then we have another variable for evacuation. We simply combined voluntary evacuees (defined above) and

shelter evacuees and termed the variable as 'voluntary shelter evacuation.' Thus, people who were forced to evacuate and people who did not evacuate to a cyclone shelter or a government relief shelter were considered nonevacuees.

Level of formal education was elicited by asking the respondent what level of school and/or college they had attained. A traditional knowledge base for predicting cyclones based on environmental precursors was elicited by asking the respondent the following open-ended question: "What cues in the environment did you observe before the actual manifestation of the cyclone that indicated the occurrence, severity, or timing of the cyclone?" Based on people's responses, we converted this to a categorical variable indicating whether a respondent possessed traditional knowledge on predicting cyclones in at least some measure.

Information about income and socioeconomic status was elicited by simply asking about the total household income of the respondent. In this study, income was self-reported, therefore was likely underreported. Income and socioeconomic status were also captured through another indicator, i.e., housing quality. The respondent was asked in what kind of house he or she lived. Based on the material of house construction most respondents lived in one of three kinds of houses, mud brick house with thatched roofs, house with tiled roof with walls of varying kinds of materials, and house made of concrete material, also called "pucca" houses or buildings. The first kind was considered the poorest quality in terms of protection from a cyclonic storm and concrete houses were considered the best for protection against the storm.

The survey questionnaire elicited information on the 'channels' through which warning information was received by the respondents; the 'contents' of the warning message as recalled by the respondents; the 'clarity' of the message, i.e., how clearly the message was understood by the respondents; and respondents' estimate of the damage the cyclone might cause. The means by which a warning was delivered clearly had implications for access, e.g., a warning on television may have been heard by relatively fewer people than a warning on a public address system in the rural Indian context where the penetration of televisions was still low in the years 2005 and 2006. The question of 'content' of the warning message covers two aspects: (1) access, because better access would mean getting more and better quality information; and (2) understanding, because given the access conditions, a better recall of the warning information at the time of the survey would mean the message was better understood. The 'clarity' of the warning message also captures the understanding of the warning. A respondent's estimate of damage due to a cyclone of a particular severity reflects the interpretation of the warning message by the warning recipient and is often a factor in decisions about evacuation. Specific questions on access, understanding, and interpretation of warnings were as follows:

The following question was asked to elicit the contents of the warning message people received: "Did the warning message include:"

1. The severity of the cyclone in terms of wind speed and storm surge? (yes/no)
2. The likely location of landfall? (yes/no)
3. The likely time of landfall? (yes/no)
4. The order for evacuating your home? (yes/no)
5. Where and how to go when evacuating? (yes/no)

The following question was asked to elicit information on the clarity of the warning: "In your opinion how many words did you understand in the warning message?" (none/few/all)

For channels through which they received the warning communication, the following eleven options were provided in the questionnaire, from which the respondents could choose one or more:

1. Village secretary
2. A messenger from the revenue department
3. A messenger from fisheries department
4. Church father
5. NGO personnel
6. Heard from neighbors/family/friends/other community members
7. Public address system
8. Television
9. Radio
10. Newspaper
11. Any other (please mention)

Estimate of damage due to a cyclone of particular severity was captured through the following open-ended question with qualitative responses: "What impacts/damage do you think could occur due to the cyclone of severity ('x' km/hr wind speed and 'y' m storm surge) mentioned in the warning?" Actual numerical values of wind-speed and storm surge mentioned in the meteorological department warning were used in the questionnaire instead of 'x' and 'y.'

Sample characteristics

Of the 237 survey responses we obtained, 212 were sufficiently complete to include in our sample. This was large enough to allow us to test the statistical significance of relationships between education, evacuation, and the variables mentioned above. The sample consisted of 61% male

respondents and 39% female respondents. Fishermen accounted for 41% of respondents, 22% were agricultural laborers, 16% were agricultural landowners, and about 21% were engaged in other occupations such as weaving or trade. The age of the respondents ranged from 18 to 80 years, with the median age of 36 years.

Methods for data analysis

We tested for two effects: first, whether formal education and traditional knowledge were predictors of evacuation. To do this we regressed evacuation against formal education and against traditional knowledge separately. Because our dependent variable 'evacuation' was a binary categorical variable we used logistic regression for our analysis.

Second, we tested for interactive effects between education and other potential determinants of evacuation, i.e., we regressed evacuation against evacuation predictors (income and socioeconomic status, and access, understanding, and interpretation of warning information) for different levels of formal education, and for the presence and absence of nonformal education or traditional knowledge. Because the dependent variable 'evacuation' was a binary categorical variable, we used logistic regression.

Testing for interactive effects enables us to identify more complex relationships between education and evacuation. For example, a variable might have a positive effect on evacuation among the educated, but a negative one among the illiterate, or vice versa. These opposing effects would essentially cancel each other out, so that in the analysis of the full sample the variable would appear to have no effect on evacuation, or a variable might have a stronger effect on evacuation among the educated and a weaker or no effect among the illiterate, or vice versa. The differences in the strength/magnitude of the effects could mean that in the full sample analysis the variable may appear to have a weaker or no effect on evacuation. This kind of analysis would help in identifying differences in the way the income and social status predictors and information and warning message predictors matter across different categories of education

RESULTS

We present the results of data analysis, first with a summary of the frequencies of responses for variables used in the study (Table 1), and then with the logistic regression analyses conducted.

Education and evacuation

First, we regressed education on evacuation to test whether education had any explanatory power for appropriate response to warning. We used two variants of indicators for the variable 'formal education:' first, the number of years of formal education that a person had received. Number of years of education ranged from 0 years to 17 years with the median being 7 years of education. Second, we converted the number of years of education into a categorical variable with three categories: the first category was 'illiterate' and comprised 43 respondents who reported receiving 0 years of education; the second category comprised 127 respondents who reported receiving between 1 to 10 years of education; and the third category comprised 42 respondents who reported receiving 11 or more years of education. The hazard specific nonformal education or traditional knowledge base for predicting cyclones was converted from an open ended question into a binary categorical variable with two categories being, 'people who possessed no traditional knowledge to predict cyclones' and 'people who possessed some measure of traditional knowledge for predicting cyclones'. Table 2 presents the results of regressing evacuation against each of the three indicators mentioned above.

Table 2 shows that as the definition of evacuation was made stricter, i.e., people who were forced to evacuate and people who did not evacuate outside the village were counted as nonevacuees, the effect of formal education on evacuation first diminishes and then becomes completely insignificant. This implies that among the people who were forced to evacuate there were a relatively large number of formally educated people. Also people who did not evacuate outside the village but took shelter in a "pucca" building within the village also consisted of a relatively larger number of educated people. This was probably because the more educated people had higher incomes and therefore better quality housing, or better access to quality housing; the significant and positive association between formal education and income and formal education and housing quality in Sharma (2009) supports this. Table 2 shows that the odds of evacuation for people who possessed even some measure of traditional knowledge for predicting the occurrence of cyclones were much higher than the odds of evacuating for people without any traditional knowledge base.

Interactive effects

We tested the strength and direction of evacuation predictors across different categories of formal education. For this we first examined the effect of predictor variables, i.e., income and socioeconomic status, and access, understanding, and interpretation of the warning message on evacuation among the full sample, and then separately for respondents with different levels of formal education (Table 3).

Income did not have a significant influence on evacuation, neither for the whole sample nor for different levels of education. Housing quality did not seem to significantly influence evacuation when considering the complete sample of respondents. However, it had a significant and negative influence on evacuation among the higher educated respondents, i.e., better housing quality meant less evacuation. The kind of effect housing quality had on illiterate and educated respondents was notably different: housing quality

Table 1. Summary of variables used in the analysis

Indicators of interest	Categories of response		Distribution of responses
Response to warning			
Evacuation	Not evacuated		75 (35.4%)
	Evacuated		137 (64.6%)
Voluntary evacuation	Not evacuated		89 (42%)
	Evacuated		123 (58%)
Voluntary Shelter evacuation	Not evacuated		118 (55.7%)
	Evacuated		94 (44.3%)
Education			
Formal education	Range: 0 to 17 years; Median: 7 years		
Hazard specific traditional knowledge base	Couldn't tell anything		111
	Reported observing cues and could provide some or more detail on the cues		101
Income and socioeconomic status			
Income	Range: INR 3000 p.a. to INR 60,000 p.a. Median: INR 12,000 p.a.		
Housing Quality	Thatched huts		113
	Tiled roof house		20
	Concrete roof house		79
Indicators related to access, understanding, and interpretation of warning information			
Whether the following were included in the warning message:			
Severity of cyclone	No		61
	Yes		151
Landfall Location of cyclone	No		66
	Yes		146
Landfall time of cyclone	No		74
	Yes		138
Evacuation order in the warning	No		36
	Yes		176
Protective guidance in the warning	No		81
	Yes		131
Clarity of the warning message (Whether all or few words understood?)	A few		82
	All		130
Type of channel through which warning was received	Face to face channels	Village Secretary	104
		Revenue dept. official	44
		Fisheries dept. official	27
		Church person	10
		NGO personnel	18
		Community members	42
	Media Channels	Public address system	48
		Television	99
		Radio	71
		Newspaper	37
		Others	21
Estimate of damage due to cyclone given a particular severity	Either some vague estimate of damage or could not estimate damage		88
	Some concrete estimate of damage		124

had a negative effect on evacuation in case of the educated, whereas in the case of the illiterate, housing quality had a positive though insignificant effect on evacuation, i.e., even with better housing quality there were greater odds of evacuation among the illiterates.

Warning message contents mattered. Four of five indicators, i.e., cyclone severity, landfall location, landfall time, information on where and how to evacuate (protective guidance) were significant predictors of evacuation; among the whole sample of respondents, those who reported having received information on severity of the cyclone, landfall time, landfall location, and protective guidance had greater odds of evacuating than those who did not report receiving information on cyclone attributes. However, message content (severity of cyclone, landfall location, landfall time, protective guidance) had significant effect on evacuation for the respondents who

Table 2. Bivariate logistic regression of formal education and traditional knowledge base on evacuation.

Education (formal and nonformal)	Evacuation	Voluntary evacuation	Voluntary shelter evacuation
Number of years of education	1.055*	1.051*	0.998
Education (categorical): with 0 years of education as reference			
Education between 1 to 10 years	1.006	0.804	0.619
Education between 11 to 17 years	2.779**	2.304*	1.05
Education (categorical): with 1 to 10 years of education as reference			
Zero years of education	0.993	1.243	1.61
Education between 11 to 17 years	2.76**	2.866**	1.7
Traditional knowledge base on predicting cyclones based on environmental precursors	1.914**	2.384***	1.743**

The number in the cells are exponentiated betas or odds ratios. An odds ratio of 1 (or not significantly different from 1) indicates no effect. An odds ratio larger (or smaller) than 1 indicates factor by which odds of evacuation are increased (or decreased) by one unit change in independent variable. *, **, *** represent the level of significance (alpha)
*** implies alpha ≤ 0.01
** implies alpha ≤ 0.05
* implies alpha ≤ 0.10

had an education of between 1 and 10 years. The message content had no effect on evacuation for the illiterates or for the higher educated (11 years and above) respondents. This seems strange and counterintuitive. Simply receiving an evacuation order did not seem to influence evacuation either for whole sample or for different levels of education.

Clarity of warning also significantly and positively influenced evacuation for the sample as a whole. However, when considering the influence of this factor by level of education, it had a notably stronger and a significantly positive effect on evacuation among the illiterates and higher educated respondents, but did not significantly influence evacuation in case of respondents who received an education of between 1 and 10 years. This also seems strange and counterintuitive.

Type of channel had a significant influence on evacuation for the sample as a whole. However, it had a significantly strong effect on evacuation for the illiterate category of respondents. For the illiterate category, respondents who receiving a warning face to face were 3.89 times more likely to evacuate than the respondents who received a warning from media channels.

Estimate of damage of the cyclone had a significant influence on the sample as a whole. However, it had a significantly strong effect on evacuation for the illiterate category of respondents, but did not seem to significantly influence evacuation in the case of educated respondents.

We also tested for interactive effects for having a traditional knowledge base as we did for formal education, i.e., we first examined the effect of predictor variables on evacuation among the full sample (N = 212) and then separately for respondents with and without traditional knowledge for predicting cyclones based on environmental precursors (Table 4). We did this analysis only for variables related to the warning message and interpretation of warning and not for income and housing quality because we do not expect possession of traditional knowledge for predicting cyclones to have an effect on income and housing quality in general.

With the exception of protective guidance, the warning message characteristics and the ability to estimate damage significantly and positively influenced evacuation among the respondents who possessed traditional knowledge and did not affect evacuation for the respondents who did not possess traditional knowledge (Table 4). Among the respondents without a traditional knowledge base, what mattered most were the instructions on where and how to evacuate.

A cross-tabulation (Table 5) of education and possession of some traditional knowledge for predicting cyclones based on environmental precursors showed that a greater proportion of both the illiterate and higher educated (11 or more years of education) people did not possess the traditional knowledge to predict cyclone occurrence based on environmental precursors compared to the medium educated people (1 to 10 years of education). In case of higher educated people, it is understandable that traditional knowledge may not get passed on to them as they pursue higher education instead of their traditional vocations. In the case of illiterates, the reason a smaller proportion of people possessed traditional knowledge might be because most of them did not possess assets such as boats or land and were often laborers on the farms or in the fishing trade. Traditionally they did not really need this knowledge base. Qualitative interviews had revealed that people who possessed traditional knowledge tended to be fishing boat owners and agricultural landholders, i.e., people who possessed livelihood assets that could be at stake during a cyclone. Most of these people had the means to receive some

Table 3. Bivariate logistic regression of evacuation predictors on evacuation among all respondents and separately by level of education.

Independent variables	Voluntary shelter evacuation			
	All respondents (N = 212)	Illiterate (N = 43)	Educated 1 to 10 (N = 127)	Educated 11 to 17 (N = 42)
Income and socioeconomic status				
Income	1	1	1	1
Housing Quality	0.66	2.67	0.59	0.222***
Indicators related to access, understanding, and interpretation of warning information				
Severity of cyclone	2.42***	2.43	3.13**	1.83
Landfall location of cyclone	2.61***	2.55	2.91**	2.27
Landfall time of cyclone	2.35***	2.55	2.66**	1.75
Evacuation order in the warning	1.51	1.41	1.83	1.5
Protective guidance in the warning	2.28***	2.36	2.64**	1.75
Clarity of the warning message	2.36***	3.74**	1.51	6.67**
Type of channel	2.036**	3.89*	1.74	1.93
Estimate of damage due to cyclone given a particular severity	1.73**	2.89*	1.58	1.25

The number in the cells are exponentiated betas or odds ratios. An odds ratio of 1 (or not significantly different from 1) indicates no effect. An odds ratio larger (or smaller) than 1 indicates factor by which odds of evacuation are increased (or decreased) by one unit change in independent variable. *, **, *** represent the level of significance (alpha)
*** implies alpha ≤ 0.01
** implies alpha ≤ 0.05
* implies alpha ≤ 0.10

education (between 1 to 10 years), though often they tended to continue in their vocations instead of pursuing higher education. Hence, traditional knowledge got passed from one generation to another in many cases, though in general there has been a decline in the prevalence and use of traditional knowledge.

DISCUSSION

Our results provide evidence for the relationship between education and the ability to respond to climate risk. We consider both formal school education and nonformal education, i.e., hazard specific traditional knowledge to predict the hazard (cyclones). Adaptive capacity is represented by the ability to respond appropriately to tropical cyclone risk, i.e., to evacuate in response to the cyclone early warning message.

We expected formal school education to lead to improved response because: (1) we expected formal school education to lead to a better ability to access, understand, and interpret cyclone early warning messages, and (2) we expected formal school education to lead to greater income, which in turn would mean a greater access to resources for evacuation, e.g., vehicles for transportation, and hence a better response to the warning. The results show that the relationship between formal education and evacuation is not as strong as expected and in fact disappears completely as definition of appropriate response (evacuation) is made stricter.

Let us first consider income and socioeconomic status. The positive and significant correlation in our study between education and income is in conformance with literature on education and its effect on positive life outcomes; Sharma (2009) showed a positive and significant correlation between education and income even though the magnitude of correlation was not very high. However, the question of direction of causality, i.e., whether greater education causes greater income or having a greater income provides an opportunity for more number of years in school, remains unresolved. The original study (Sharma 2009) on which this paper draws, was not designed to resolve this question. However, given the positive correlation between education and income, it seems surprising and perhaps counterintuitive that for evacuation decisions, income does not seem to matter either for all respondents or across different categories of education. However, we need to acknowledge that the ability to respond better because of the 'income effect' could not be explored adequately in this paper because there was not enough variance in the incomes of the sample of respondents. For example, if one considers the income distribution across the sample, which is representative of the affected coastal population, then one can see that the income levels are not very high in general. In fact qualitative data revealed that people often depend on transportation provided by the government to evacuate out of the village. The village-wise data collected on average assets in the village also revealed that the resources for evacuation such as transportation are on

Table 4. Bivariate logistic regression of evacuation predictors on evacuation among all respondents and separately by presence or absence of traditional knowledge base.

Independent variables	Voluntary shelter evacuation		
	All respondents (N = 212)	Respondents without traditional knowledge base (N = 111)	Respondents with traditional knowledge base (N = 101)
Indicators related to access, understanding, and interpretation of warning information			
Severity of cyclone	2.42***	1.289	5.82***
Landfall location of cyclone	2.61***	1.71	4.07***
Landfall time of cyclone	2.35***	1.43	4.07***
Evacuation order in the warning	1.51	1.28	1.57
Protective guidance in the warning	2.28***	3.07***	1.56
Clarity of the warning message	2.36***	1.96*	2.57**
Type of channel	2.03**	1.5	2.77*
Estimate of damage due to cyclone given a particular severity	1.73**	1.012	3.73***

The number in the cells are exponentiated betas or odds ratios. An odds ratio of 1 (or not significantly different from 1) indicates no effect. An odds ratio larger (or smaller) than 1 indicates factor by which odds of evacuation are increased (or decreased) by one unit change in independent variable. *, **, *** represent the level of significance (alpha)

*** implies alpha ≤ 0.01

** implies alpha ≤ 0.05

* implies alpha ≤ 0.10

the whole quite scarce in these villages. Unless the cyclone shelter is in walking distance, the means of transportation for evacuating are rather limited. This aspect could perhaps be explored in future studies.

However, one needs to be cautious about assertions that better socioeconomic status can lead to a better capacity to respond to risk. This positive relationship may not always be true as the results with respect to housing quality reveal in this paper. Better housing quality had actually led to reduced response to warning among the higher educated respondents. Better housing quality probably made these respondents feel safe in their homes. This may have been a fatal decision on the part of the respondents if Ogni and Fanoos had continued to be severe cyclones, instead of lowering in intensity before crossing land. Sometimes a better socioeconomic status may give a false sense of protection against the risk.

Table 5. Cross-tabulation of respondents by level of education and possession of traditional knowledge for predicting cyclones.

Years of education	Without traditional knowledge	With traditional knowledge
0	27	16
1 to 10	58	69
11 or more	26	16

To explain the unexpected positive effect of housing quality on evacuation in the case of illiterate respondents, we dug deeper into the data and found that a greater proportion of illiterates who had good quality housing also had access to a cyclone shelter nearby, whereas the greater proportion of people who had poor quality housing also tended not to have a cyclone shelter nearby. This brings to fore the importance of appropriate infrastructure and its effect on response to risk, particularly in the case of populations with lower levels of socioeconomic means, as is the case in our study.

With respect to access, understanding, and interpretation of the warning, the results are also unexpected and counterintuitive. Based on literature in the area of adaptation to climate change (i.e., Norris and Bati 1987, Igoden et al. 1988, Lin 1991, Maddison 2006, Deressa et al. 2008) and literature on warning response (e.g., Edwards 1993, Farley et al. 1993, Liu et al. 1996, Balluz et al. 2000) we expected that the respondents with more formal education would be able to better access, understand, and interpret warning messages. The results revealed that education did seem to make a difference in this regard when compared to noneducated respondents. However, the results were counterintuitive because the effects were not observed consistently in cases of different categories of educated people. For example, we considered reporting of warning message content, i.e., cyclone severity, landfall location, landfall time, evacuation order, and protective guidance, by respondents as an indicator of understanding because recall of the message content reflects at least some understanding. Those respondents who recalled receiving information on cyclone severity, landfall location, and landfall time in the warning message had a greater chance of heeding the warning and evacuating for the whole sample, but across different categories of education, only for the category with 1 to 10 years of education and not for the illiterates and 11 or more years of education categories. This seems counterintuitive because one would expect the more educated (11 or more years) to have understood the message even better and hence to have evacuated.

By contrast, nonformal forms of education, i.e., a traditional knowledge base for predicting cyclones based on environmental precursors, was much more relevant in terms of understanding and interpreting warning information. For example, in the context of the point made in the above paragraph, when we considered the nonformal education we found that message content, with the exception of protective guidance, significantly and positively influenced evacuation among the respondents who possessed traditional knowledge and did not affect evacuation for those who did not possess traditional knowledge. This probably happened because their own understanding of the occurrence of the cyclone that they gleaned from the environmental precursors helped them trust, understand, and interpret the warning information better. This finding in addition with the fact that there was a greater prevalence of traditional knowledge among respondents with 1 to 10 years of education seem to explain the counterintuitive result that cyclone severity, landfall location, and landfall time are significant predictors of evacuation among respondents with education between 1 and 10 years and not for people with higher levels (11 or more years) of education.

However, an observation of the study is that formal education correlated to deterioration in traditional knowledge for predicting cyclone occurrence based on environmental precursors. Qualitative data revealed that there has been deterioration in the traditional knowledge base as more and more people go into the formal higher education system. With formal education not playing a strong role in the correct interpretation of warning messages because it is usually not hazard specific, combined with the deterioration in the traditional knowledge base, the warning recipients tend to follow a wait and see approach and the decision to evacuate is often made when it is too late to evacuate.

Our study makes a contribution to the literature on adaptation to climate change, disaster risk reduction, and warning-response and evacuation literature in a two different ways: first, it suggests that whether formal education is a determinant of adaptive capacity is not a straightforward question. Although formal education may provide greater access to income earning opportunities and may enhance welfare in general, it is the hazard-specific knowledge and understanding gained from nonformal sources that tends to play a greater role in responding appropriately to hazard risk. Hence, there is value in preserving and promoting the traditional knowledge base along with greater enrolment in the formal education system.

Second, it makes a contribution to warning-response literature because it seems to be the first study that attempts to study the role of traditional knowledge in evacuation decisions. The only study that addressed the issue of traditional knowledge in evacuation decisions is Westgate (1978) but even this study only documents some of the environmental precursors people reported observing before a cyclone and does not attempt to examine whether these had any effect on evacuation decision or not. Similarly, as discussed earlier, the literature so far has mostly documented different indicators used by people for their decision making without actually examining whether use of such traditional knowledge indicators actually led to better decisions or not. In this study we attempt to address this issue and found that possession of traditional knowledge could lead to better decision making and outcomes with respect to adaptive behavior, i.e., evacuation. Also it seemed to complement the warning message based on the modern scientific expert knowledge system (meteorology). However, whether traditional knowledge systems and modern scientific knowledge systems as reflected in the forecasts of the meteorology department would always complement each other or may at times even contradict each is an empirical question which needs further investigation and research.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5439

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Differential Vulnerability to Hurricanes in Cuba, Haiti, and the Dominican Republic: The Contribution of Education

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ABSTRACT. The possible impacts of the level of formal education on different aspects of disaster management, prevention, alarm, emergency, or postdisaster activities, were studied in a comparative perspective for three countries with a comparable exposure to hurricane hazards but different capacities for preventing harm. The study focused on the role of formal education in reducing vulnerability operating through a long-term learning process and put particular emphasis on the education of women. The comparative statistical analysis of the three countries was complemented through qualitative studies in Cuba and the Dominican Republic collected in 2010-2011. We also analyzed to what degree targeted efforts to reduce vulnerability were interconnected with other policy domains, including education and science, health, national defense, regional development, and cultural factors. We found that better education in the population had clear short-term effects on reducing vulnerability through awareness about crucial information, faster and more efficient responses to alerts, and better postdisaster recuperation. However, there were also important longer term effects of educational efforts to reduce social vulnerability through the empowerment of women, its effect on the quality of institutions and social networks for mutual assistance creating a general culture of safety and preparedness. Not surprisingly, on all three accounts Cuba clearly did the best; whereas Haiti was worst, and the Dominican Republic took an intermediate position.

Key Words: *adaptive capacities; Caribbean; education; vulnerability*

INTRODUCTION

Owing to their geographic location, Cuba, the Dominican Republic, and Haiti are all equally exposed to the threat of extreme natural events associated with the sea. The numerous hurricanes and floods that have struck these Caribbean islands throughout their history demonstrate the particular vulnerability of small island development states to climate change. According to United Nations Environment Programme (UNEP) Regional, none of the Caribbean islands is ranked as resilient as measured by the Environmental Vulnerability Index, and all of them are highly vulnerable to natural catastrophes (UNEP 2007: Chapter 7). Sea-level rise and the increasing frequency and severity of extreme events threaten livelihoods and limit adaptation options.

However, populations in these countries are not affected in the same way. The desperate situation of the Dominican Republic and Haiti, where repeated hurricanes and related floods have caused, over the years, a steadily high number of casualties, stands in stark contrast to the apparent sustainability success story of Cuba. Although damage to property, industry, agriculture, and infrastructure tends to be large in Cuba as well, lives are seldom lost, and, even in comparison to most other Latin American countries, Cuba stands out with its remarkably robustness to extreme natural events.

Unlike predominant strategies for dealing with disaster risk that focus on emergency response and reconstruction, we looked at the impact of education and preparedness and found that reducing the occurrence and impact of disasters requires not only investment in response and reconstruction efforts but also changes in the paths of development.

When looking at the deeper reasons for differential disaster vulnerability in the Caribbean, several factors were shown to be at work in Cuba to make it a relative success story. Education and training-enhancing social networks of support and reciprocity were one way of improving local resilience. Cuban policy managed to establish legal frameworks for disaster management from the very beginning of the Socialist Revolution in 1959. However, the real turning point in creating Cuba's "culture of safety" was Hurricane Flora in 1963. The tragedy of 1157 fatalities was taken seriously and was used to invoke the right of communities to protection and access to resources both during and in the wake of disasters. Since that time, the country has been able to protect its populace from catastrophes of a similar magnitude (Ramos Guadalupe 2009:126).

This has been possible because of a clear commitment of the Cuban government to undertake disaster mitigation measures. Challenges to building local resilience remain in contemporary Cuba, especially since it entered its "Special Period" when it could no longer count on help from the Soviet Union. Household economies are weak, and resources for the pursuit of livelihoods after disasters are limited. Nevertheless, the strategies developed by Cubans to cope with environmental stresses stand in complete contrast to the powerlessness of the population in the Dominican Republic,

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as reflected in the respective significant idioms used to describe the prevention cultures in both countries, in Cuba, *sembrando el futuro*, or "sowing the future," an allusion to the agrarian reform that was the first magnum opus of the Revolution; in the Dominican Republic, *la mala unión*, literally a "poor consolidation," such as a fracture badly reset or wires badly soldered, an expression of hope in Cuba and an expression of disjuncture, mistrust, and despair in the Dominican Republic (Whiteford and Manderson 2000).

These differentiated ways of defining a relationship between a responsible government and its population are a qualitative expression of human vulnerability in the Dominican Republic and Haiti. Even small hazards can turn into large social disasters where high vulnerability means that many people are at risk because state institutions and cooperation communities are insufficiently prepared, emergency response is inadequate, and the critical infrastructure is fragile. In countries like the Dominican Republic or Haiti, the collapse of civil order resulting from natural catastrophes is a particular threat to girls and women who are exposed to multiple forms of violence in a space of lawlessness (Duramy 2011).

Compared to their Caribbean neighbors, Cubans are far better prepared for emergencies. Not only do they benefit from better infrastructure and housing, as well as a highly effective risk-communication system, but more importantly, Cuba is populated by the most educated population in the developing world that is trained for dealing with catastrophes. According to the 2005 *World Disasters Report*, education predisposes popular understanding and action, making it a "vital link" in the early warning chain that makes the difference between life and death in the face of some of the planet's most ferocious storms (CRED and IFRC 2005).

The aim of this comparative study was to focus on adaptive capacities to climate change by shedding some light on the factors influencing adaptive human behavior, particularly formal education, institutional resources, community involvement, and well-implemented health services accessible to the population.

METHODOLOGY

Our study built upon work by (Striessnig et al. 2013) who studied the link between education and disaster vulnerability across a range of 125 countries. In a first stage, therefore, we used macrodata to sketch the quantitative evidence on the number of casualties from climate-related extreme natural events by plotting the data against the educational attainment levels of the three island states of interest. This comparison of the available empirical data highlighted the profound impact of education on differential social vulnerability, gender equality, and sustainability.

To support those macrolevel findings with microlevel evidence, in a second step, we attempted to evaluate the impact of formal education on adaptive capacities within specific social contexts. For this, extensive fieldwork was conducted both within Cuba and the Dominican Republic (Pichler 2011). Because we did not conduct similar field work in Haiti, in our qualitative analysis we did not judge Haiti based on the same evidence as Cuba and the Dominican Republic but relied more strongly on secondary sources. Our qualitative analysis of a total of 51 interviews, 32 in Cuba and 19 in the Dominican Republic, was based on a questionnaire centered on formal education. The preliminary study was conducted in December 2010 and January 2011 in Cuba and was subsequently extended to the Dominican Republic in March 2011. Feedback from both Cuban and Dominican interview partners informed the structure of the survey. Local experts reviewed the modified survey and approved its research design.

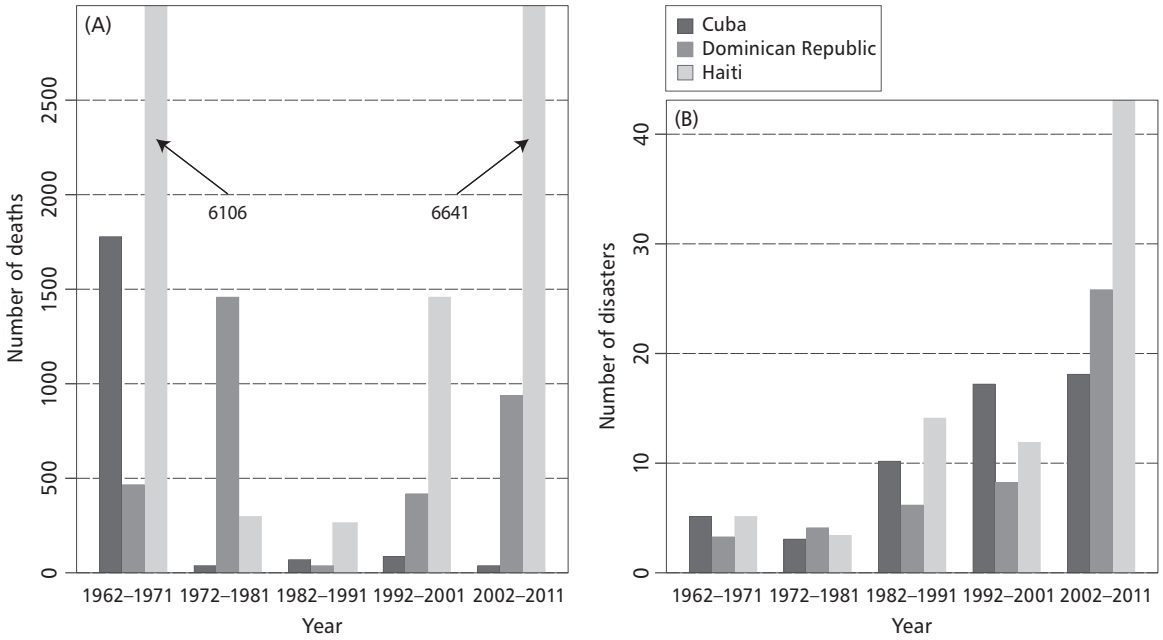
In the Dominican Republic, the research was conducted in two widely separated regions, the towns of Miches and Barahona, both located in geographically vulnerable zones, near the coastline and at the mouths of rivers, both rated as high-risk localities in the national vulnerability maps. Parts of both Barahona and Miches have been hit by hurricanes in recent years and, in the case of Barahona, by flooding. Some of the interviews took place in settlements that had been rebuilt only 2 years earlier.

In Cuba, the research was conducted in greater Havana and Pinar del Río, which had been affected by Hurricanes Gustav and Ida in 2008. Interviews were held at the interviewees' houses. Especially in the Dominican Republic, it was impossible to conduct a public interview without a group forming and everyone expressing common views about their increased vulnerability following the flooding of the village. The people interviewed invariably confirmed that they were in the habit of talking about these events, a constant subject of conversation among themselves. Further interviews were carried out with several experts within Cuban and Dominican civil defense organizations.

The questionnaire was grouped according to what are commonly defined as the four different stages of response to disaster: (1) the initial emergency; (2) the alert, 72 hours before the event; (3) the alarm, 48 hours before the event; and (4) the recovery phase (Thompson 2007, IFRC 2010*b*, Puig González et al. 2010). In addition to that, based on the primary research question, concerning the quality of formal education as a tacit aspect of the social and human capital employed in coping strategies, the questionnaire was divided into questions on (1) institutional resources, (2) information, (3) community involvement, and (4) knowledge. For a more detailed description, refer to the Appendix.

A main goal of these detailed interviews was to look deeper into what drives the behavioral patterns of people who have experienced recent hurricanes and floods. The questionnaire

Fig. 1. Total number of deaths from climatic natural disaster (A) and the number of natural disasters (B) for Cuba, the Dominican Republic, and Haiti between 1962 and 2011, from CRED (2004).



asked about the resources that those affected have at their disposal, their behavior in emergency situations, and their strategies to overcome the difficulties these occasioned and to reorganize their lives during and after such events. The central objective in the development of this questionnaire was to arrive at a methodology to conceptualize the impact of education on the process of disaster adaptation.

Although the small sample size of only 51 interviews does not provide a sufficiently comprehensive empirical basis to trace how education impacts disaster preparedness and mitigation and to define the full role of education in the improvement of adaptive capacities with regard to climate change, it nevertheless suffices to further stress the need for expanded studies of the important role of education as a key indicator for adaptive capacity building and disaster management (Striessnig et al. 2013).

DIFFERENTIAL SOCIAL VULNERABILITY IN THE CARIBBEAN

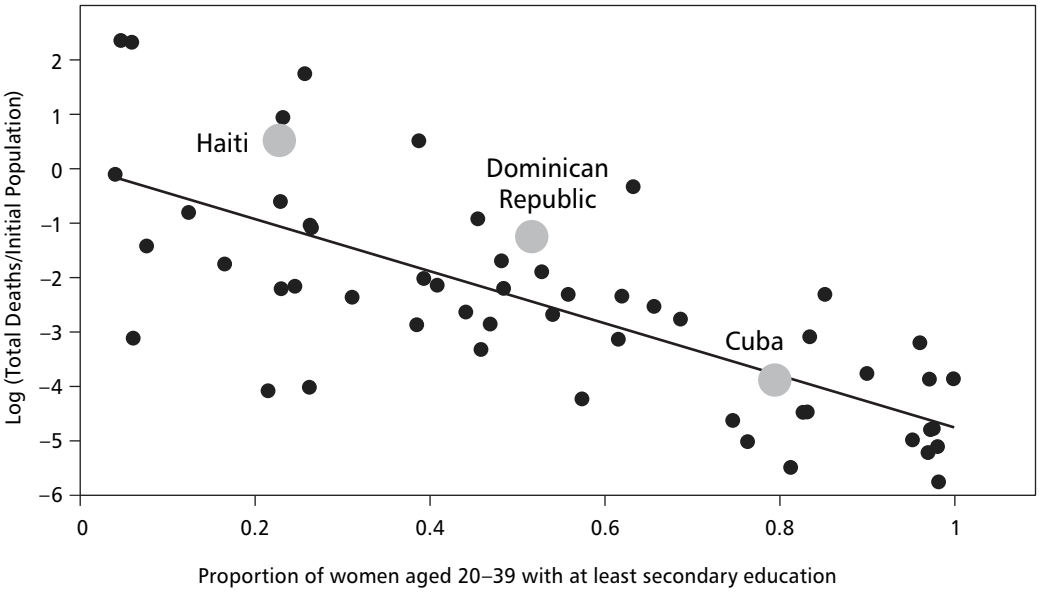
The dissolution of the Council for Mutual Economic Assistance, which ended the Soviet Union's economic support to Cuba, marked the beginning of Cuba's "Special Period," or *período especial*, bringing chronic poverty and economic hardship (Coyula and Hamberg 2003, Espina Prieto 2008). However, despite the pervasive limitations imposed by the economic crisis, the disaster prevention system, first implemented half a century ago by the civil defense, continues to function as successfully as it ever did.

As shown in Figure 1, the continuing vulnerability of the island, its infrastructure and production facilities, is undeniable. Recently, Hurricanes Gustav and Ike, for example, which struck the Pinar del Río area on 28 August and 1 September 2008, caused substantial damage to the built environment, electrical and communications systems, and important export crops such as sugar and citrus. However, compared to its Latin American neighbors, Cuba has shown itself to be remarkably robust in response to hurricanes, and its coping strategies are incomparably more effective than those of any of its Caribbean neighbors.

In 2001, in total, nearly 6 million people were affected by natural disasters in the Caribbean. Hurricane Michelle, which hit the Cuban Matanzas area on 4 November 2001, caused tremendous material damage (Ritter 2002) but cost only 5 lives, 4 of which were lost in a building collapse. The same can be said about the consequences of Hurricane Jeanne, which in 2004 claimed more than 2700 victims in Haiti; whereas in the Dominican Republic fewer than 20 persons lost their lives, and there were no deaths in Cuba (Cuba Hurricanes, http://www.cubahurricanes.org).

Even though Cuba suffers from a similar, and sometimes even larger, number of hurricanes than other states in the region, and damage to property, industry, agriculture, and infrastructure tends to be great, hurricanes do not claim many lives in Cuba. This has not always been the case. As Figure 1 also shows, Cuba was anything but well prepared in 1963 for

Fig. 2. Relationship between the log of deaths from climatic natural disasters including floods, droughts, and storms per 1000 of the 1980 population (CRED 2004) and female education, proportional to secondary and higher education among women aged 20-39 (Lutz et al. 2007), for 56 countries with one or more disasters on average per year.



Hurricane Flora, which killed 1157 people on that island alone. In those days, the educational system still suffered from a colonial heritage characterized by entirely class-based access to education. Higher education was reserved for the offspring of high-earning parents, a privileged minority. In 1953, only 56% of Cuba's children completed grade school, and 28% completed high school (from ninth grade up); roughly 23% of the overall population was completely illiterate, and among the rural population the percentage reached 41.7%, both groups including significantly more women than men (Hickling-Hudson et al. 2006).

Compared with today, those figures are dramatic, as are those of Cuba's Caribbean neighbors. What has happened in the meantime? First and foremost, Cuba underwent an unprecedented country-wide educational campaign with full community participation even in the remotest areas of the country. Within a very short period of time, the country was able to advance its status from "basic literacy" to "postliteracy" to "literacy equivalent to primary and secondary schooling" (Carnoy and Samoff 1990:176-178). Up through the 1980s, the Cuban education system, together with its health system, was celebrated both at home and abroad. In total, literacy rates increased from 76% to 96% (UNESCO 2005). Today, literacy among 15- to 24-year-olds in Cuba is 100%, and Cuba is one of only a few Latin American countries expected to fulfill the Millennium Development Goals with regard to education by 2015. Evaluations of Cuba's educational system differ, depending on ideological approaches, but none of its critics would deny its intrinsic quality or its impact on Cuban society as a whole.

Figure 2 indicates the education revolution that has set Cuba apart from its Caribbean neighbors in developmental terms and puts it into the context of reduced disaster vulnerability. As can be seen in this cross-country comparison, for the 1970-2011 period there is a high correlation between the educational attainment levels of women and the death count from natural disasters. Compared internationally, Haiti and the Dominican Republic suffer from an even higher number of casualties than could be expected at their respective levels of educational attainment.

The role of girls and women in building resilience and reducing disaster vulnerability is apparent and has recently been accredited by the International Federation of Red Cross and Red Crescent Societies (IFRC 2010*a*), as well as in the theme of the 2012 International Day for Disaster Reduction: "Women and Girls – the [in]Visibile Force of Resilience." Nevertheless, women also belong to the most vulnerable groups in disaster situations, particularly so in countries where the lack of female education leads to lower social status and their disempowerment. Neumayer and Plümper (2007) found that

the higher women's status, the smaller is the differential negative effect of natural disasters on female relative to male life expectancy. Where men and women do have equal access to education and women participate fully in the various groups and organizations that respond to catastrophes, their death rates do not differ significantly.

A CONSOLIDATION OF QUALITATIVE INTERVIEWS AND FINDINGS FROM THE QUESTIONNAIRE

Education as key for prevention: preparedness

Measured by the approach established in disaster studies to categorize and understand the various stages of intervention, including preparedness, response, reconstruction, recovery, and mitigation (Tierney et al. 2001), the Cuban state has a relatively good record when it comes to preparedness and response, but a very poor one when it comes to reconstruction and recovery. In Cuba, the subject of response to natural disasters has clearly been assimilated by the entire population, including schoolchildren, as was confirmed from several informal interactions and encounters on the street. Children, or cleaning personnel in Cuban hotels, will readily converse about any of this. In a conversation in Santa Rosa, located to the east of Havana, a 12-year-old boy (Carlito) recalled Hurricane Wilma in 2005 as follows:

> *Carlito: I hope that I never have to go through anything like it again. But now I feel prepared, and if it happens again, I'll know exactly what to do. Hopefully not, but nature is nature. I lost many things, I don't want to talk about that. My Atari, and really a lot.*
>
> *Interviewer: What do you have to do when a hurricane strikes?*
>
> *Carlito: As soon as the first information appears on the news, we discuss what has to be done. Who should go to live in whose house? Which things are really necessary to pack together? Then we seal the doors and windows with tape. That's the first thing to do.*
>
> *Carlito: I know in advance in which house my grandmother will be relocated, and in which one I myself will go.* (Interview, 28 December 2011)

This boy, just like all of his Cuban peers who were interviewed, was very well informed and clearly knew what to do in case of an emergency.

All Cuban children when asked whether these topics were taught at school replied with a clear "yes." A 45-year-old female teacher from Havana explained that children were provided with detailed information on the subject at school: "They create groups of child 'guards' of the fifth grade (9 years old) to impart instruction along with adults. In the training of 'guards' by the CDRs [Committees for the Defense of the Revolution, or *Comités para la Defensa de la Revolución*], which is realized in every neighborhood so children can learn what they are doing, monthly 'interest circles' are organized." At school, children also get information leaflets that provide them with information relevant to emergencies.

The same level of preparedness was not observed in the Dominican Republic, where in general the level of information on any related topic and especially on disaster response seemed to be poor. The interviews strongly confirmed earlier findings from the *World Disasters Report* (CRED and IFRC 2005) that throughout the rest of the Caribbean, lack of education and literacy prevents people from even understanding warnings. In a conversation with children on the streets of Barahona, they sometimes even had difficulty understanding the interviewer's questions. Asked about when one learns how to behave when a cyclone hits, more than half reported that they were not being taught anything like this at school. It is much more customary, they said, that family members teach children what protective measures to take. Eric, a 42-year-old teacher in Miches confirmed: "Up to now this subject has not been integrated into school curricula. We are lacking both informational material and personnel trained to communicate knowledge on the subject. It's high time for the government to take the problem seriously."

Institutional resources and community involvement

Although formal education in Cuba lays the foundation and the school system provides basic knowledge about what to do before, during, and in response to disaster situations, "preparedness" is also a medium-term planning activity that involves developing and testing disaster management plans, implementing early warning systems, coordinating agencies, and ensuring that evacuation plans work. In doing so, state and nongovernmental institutions have to pay particular attention to groups especially at risk, such as women, pregnant women, or the elderly.

Cuba has an effective risk-management and risk-communication system, with neighborhood-based organizations capable of developing preparedness, mobilizing labor, and guaranteeing cooperation, both among citizens and between the population and the authorities. Chapter 2 of the *World Disasters Report* (CRED and IFRC 2005), which covers hurricane warning systems in the Caribbean, comes to the conclusion that local organization and awareness working from "below" are just as important as timely, accurate hi-tech warnings from "above." In accordance with these findings, the capacities of the Cuban system include self-help and social protection at the neighborhood level, as well as the training of neighborhood activists ("below"), as much as scientific capabilities, such as Havana's Weather Institute and public health services ("above"). In addition to that, Cuban public

media provide an institutionalized historical memory of past disasters (Wisner 2001, Thompson and Gaviria 2004, Thompson 2007).

The CDRs are one of the two major national "mass organizations" with a community presence and responsibility for vulnerability mapping in the neighborhoods. They work together with the Federation of Cuban Women, or *Federación de Mujeres Cubanas*. The CDRs are all-purpose block associations that maintain block watches, run blood drives, and engage in cleanup, infrastructure, and neighborhood embellishment activities, when resources are available.

> *The most important thing is the mutual help among those who live in the neighborhood. The primary goal is to save human lives, only then they take measures to protect material [belongings]. They are setting up a system of vigilantes, a social control in the quarter, they are the CDRistas.* (Conversation with Ariel, Matanzas, Varadero, 12 November 2010)

Because mass evacuation is Cuba's first line of defense, in the event of an emergency all available means of transport are mobilized by the local Civil Defense as needed and placed at the disposition of the evacuation. Cooperation is obligatory. The abandoned houses are sealed tight, and material possessions are transported to a safe place, where they remain under lock and key. The military patrols the flooded zones, and there have been no known incidents of looting. Cuban community shelters are set up in schools or community buildings at the beginning of the alarm stage. They receive stocks of water, medicines, and supplies and are generally reported by affected victims to be "safe places."

In the Dominican Republic, the results of the study indicate a complete lack of such institutionalized long-term prevention plans and both ignorance and indifference at the state level. The data gathered from informants confirmed an inadequate administrative and legislative framework for risk management and response to disasters, i.e., no regulations concerning overflowing rivers. Although 25 out of the 32 people interviewed in Cuba confirmed that they were willing to cooperate with state organizations in an evacuation procedure, the majority of Dominicans when asked stated that they would refuse collaboration with the authorities if evacuation was ordered and be exposed to even greater risk.

As a result of the absence of institutionally provided safety procedures, the major lesson learned from earlier flooding for Dominicans is to not leave their homes because organized gangs will loot them. A woman who, in the most recent flood, entrenched herself in the roof truss of her house described the situation as follows: "I always stay there. It doesn't matter how high the water rises. Anyone has to stand watch, otherwise everything will be gone. Gangs will arrive, and take from wherever they can."

The collapse of civil order is a particular threat for the safety and health of women. Daria, a woman interviewed in the Dominican Republic, said that she does not allow herself to be evacuated because she would not feel safe in shelters used for the evacuation, where dormitories and toilet facilities are not separated by gender. The reports from Haiti on sexual violence and rape following the earthquake of 2010 are dramatic (Duramy 2011, Kang 2011), and more specifically, the number of rapes in shelters under exclusively Haitian authority was significantly higher than in those run by international nongovernmental organizations (NGOs). Amnesty International and other NGOs reported that many women were forced to exchange sex for water, food, and safety, i.e. they had to prostitute themselves in order to survive (Amnesty International 2011).

In addition to that, women suffer from the deteriorated sanitary conditions. The World Health Organization (WHO 2002) names many factors that disproportionately affect women when catastrophes strike. Oversalty and polluted water has a particularly negative effect on female hygiene and puts pregnant women at risk. Although all women interviewed in the Dominican Republic said that after floods they suffered from diarrhea, fever, and other diseases caused by lack of hygiene and that some children became ill with dengue and cholera, such diseases are either exceedingly rare or simply do not exist in Cuba. Preventive medicine, including obligatory fumigation in every household, and vaccination campaigns control or eliminate them on a permanent basis (Thompson 2007).

Although efforts to respond to disasters also take place in the Dominican Republic, this does not happen as a centralized effort by government authorities, but instead in individual regions. In large part, international NGOs take the lead in designing, disseminating, and directing programs for disaster mitigation. Respondents claimed that the central government had little to offer for the survivors of catastrophes and that, in many cases, the first response mobilization was led by locally built civil society groups supported by NGOs. One of the groups was organized by Augusto, the head of the civil defense in Barahona, whom we interviewed.

Some interviewees stated that over the past 10 years, state-provided measures had improved; however, in many cases, they still do not address the risk itself or the underlying processes that generate it. Some university sectors are now beginning to factor risk considerations into their curricula. However, there remains a lack of social perspective in risk management that explicitly focuses on the links between gender, poverty, and vulnerability and the risks faced by highly vulnerable social groups.

The local civil defense groups, which consist entirely of volunteers, have too few means placed at their disposal by the authorities, who, in general, assume little responsibility for the

dramatic shortfalls during disaster relief operations. The first active efforts toward the formation of regional groups for protection from catastrophes were taken only in 2002. On both national and regional levels, the agenda for handling emergencies and disasters "are still in a preparatory stage, and the authorities are not attending in any thorough or precise way to these functions" (interview with Augusto Moreta Peña, director of the civil defense group in Barahona, 26 March 2011).

The important cultural factor of trust: education, training, and past successes guarantee preparation, participation, and cooperation

As a consequence, the important factor of trust, which is crucial in providing effective help during disaster situations (Whiteford and Manderson 2000), is very weak in the Dominican Republic, and so is the willingness of people to cooperate with aid institutions. Trust influences the adoption (or failure) of educative prevention programs on the community level (Ostrom 1990) and is mainly a consequence of past positive learning experiences with these institutions during episodes of environmental stress. Answers to the questionnaire revealed that these institutions were generally valued for enabling coordinated behavior and what individuals viewed as effective practice based on a transparent repository of knowledge. Education comes into play as relationships of trust are established in long-term learning settings, in schools, training camps, and neighborhood participation over generations.

The Cuban disaster policy took highly visible and transparent measures at all stages of its intervention, beginning with prevention (the warnings of its Weather Institute), and the advance preparation of care in the public health sector. The government that marshals whatever material and discursive power it has at its disposal is rewarded with even higher levels of popular response to emergencies and postdisaster legitimacy. Therefore, the social constructions of trust between government and local communities, established over long periods of experience in both countries and repeatedly evaluated in terms of human behavior and decision making, vary widely.

Asked about whether they believe that state agencies were adequately prepared for natural catastrophes, 75% of the people interviewed in the Dominican Republic replied in the negative. An equally high proportion asserted that they did not believe that the state lived up to its responsibilities. In Cuba, the picture was inverted: 27 out of 32 informants stated that the government was well prepared for natural catastrophes. Asked about trust in actions taken by the civil defense, in Cuba 30 of 32 informants replied positively, whereas in the Dominican Republic all 19 persons asked asserted that neither preventive measures nor the early warning system functioned.

Although Cubans described themselves as individually well prepared and believed that their government was too, Dominicans considered themselves completely unprepared (14 out of 19), and only 5 believed that the government was prepared. This high correlation between answers to the two questions led to the hypothesis that individually perceived safety is closely linked to perceived government preparedness. If the government is not prepared, neither is the individual. If government responsibility fails, or simply is not present, then there is no trust in one's own competence either, with corresponding apathy, ignorance, and a sense of impotence on the part of individuals in the face of their plight.

In Cuba, where the government assumes responsibility for prevention programs that have proved to be effective, citizens have the corresponding confidence that they too will act in a secure and competent way as participants. If, however, educational campaigns and information programs fail to reach the persons in need, citizens do not have the capability to confront the stresses of extreme weather events.

DISCUSSION AND CONCLUDING REMARKS

Disasters serve as a lens for revealing failings in underlying development processes. Clearly, the two case studies presented very different and contrasting contexts within which hazards are managed. However, there are shared lessons from both studies that offer insights on the role of formal education for adaptive capacity building and disaster risk reduction.

In the Dominican case study, we found only weak state-supported measures. Civil defense activities were carried out by local groups of volunteers, which remained for the most part dependent on international NGOs and other private funds, while the state seemed in denial.

Cuba, on the other hand, has made significant efforts to improve its educational system, producing a high number of qualified teachers and professionals and building schools and universities, resulting in nearly universal literacy. At the same time, the health sector was expanded, and public health professionals recognized that changing health outcomes from "very bad" to "better" could be accomplished through the provision of potable water, sanitation, access to basic medical care, and effective immunization campaigns.

All of these efforts to strengthen the human resource base have also impacted the population's capacity to cope with natural disasters. Both disaster mortality and morbidity have been significantly reduced in Cuba compared to its Caribbean neighbors. The case study showed that radical and significant changes in health and education outcomes are important preventative measures that can have major impacts on the extent to which natural disasters affect human populations.

Thus, we can conclude that the political and social reform processes started in Cuba in the 1960s can be identified with

effective civil defense measures up to the present day. These include popular mobilization and information campaigns legitimized by discursive/ideological, organizational/social capital, and material/financial support. The Cuban experience demonstrates that risk management systems should give maximal support to training and education programs that create a relationship of trust between the state and its citizens. Sufficient governance for risk reduction begins with political will and results in a bottom-up "culture of responsibility," empowering even its most vulnerable social groups to cope with natural disasters.

Without being a prosperous country, Cuba has found purposeful interventions to cope with natural disasters. Looking into the future, its society seems astoundingly resilient with respect to the expected climate change and should be considered a blueprint for the entire region.

Responses to this article can be read online at: http://www.ecologyandsociety.org/issues/responses.php/5774

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Appendix 1.

Categories chosen for the questionnaire:

Based on the primary research question, concerning the quality of formal education as a tacit aspect of the social and human capital employed in coping strategies, the following categories were chosen for the questionnaire to highlight the impact of education on the process of response (emergency, alert, alarm, and recovery):

- Information on the aid systems available in the neighborhood, whether originating outside, or in self-help, or in the help of neighbors
- Trust in official aid systems (i.e., trust between the authorities and the population)
- Preparation, and the timely distribution of provisions and reserves
- Training, on a neighborhood basis
- The transparency with which aid groups close to the Government work and act
- The advancement and conveyance of scientific knowledge on the subject (i.e. mapping of geographic vulnerability or the research of the meteorological institute)
- The possibilities for prediction and warning
- Public health services

Accordingly, the questionnaire was divided into the following types of questions:

1 Questions on INFORMATION: including advance information, early warning- systems, mass media, communications systems, etc.

2 Questions on INSTITUTIONAL RESOURCES and support to cope with disaster situations, including lifeline structures, evacuation, shelters

3 Questions on COMMUNITY INVOLVEMENT on the neighborhood level: cooperation with aid systems, with neighbors, with families

4 Questions on KNOWLEDGE: this category is divided into

4.1 questions of personal preparedness, personal participation in aid systems

4.2 questions on implicit or tacit resources, cognitive social capital such as trust, responsibility, and solidarity on individual and collective levels

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Vulnerability and the Role of Education in Environmentally Induced Migration in Mali and Senegal

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ABSTRACT. In the West African Sahel, the majority of the population depends on subsistence farming and livestock breeding and is thus particularly vulnerable to climatic changes. One possible response to natural hazards is migration. Recent research suggests that environmentally induced mobility is closely linked to the social vulnerability and adaptive capacity of individuals and groups. However, only little attention has been paid thus far to the role of formal education in this context. Our objective was to fill this gap by examining the role of formal education in environmentally induced migration as one characteristic of social vulnerability to environmental change. Our analysis focuses on two regions in the West African Sahel, Bandiagara in Mali and Linguère in Senegal, that are presumed to be particularly affected by climate change and environmental degradation. Our results reveal that formal education plays an important role in reducing vulnerability to environmental stress because people with a higher level of education are usually less dependent on environmentally sensitive economic activities such as farming. Moreover, an agricultural economic activity can be an obstacle to a high level of formal education. We found no significant effect of people's education on the migration experience as such. However, motives for migration differ considerably depending on the amount of education received, suggesting that migration constitutes a livelihood strategy, particularly for the lower educated.

Key Words: *adaptive capacity; education; environmentally induced migration; livelihood strategies; Sahel; social vulnerability*

INTRODUCTION

The impact of climate change and climate variability on human populations in the West African Sahel is a major global concern. Today, most people living in that region still depend on subsistence and small-scale farming or livestock breeding and are thus highly vulnerable to climatic and environmental changes. An extremely variable rate of rainfall plus land degradation caused by climatic changes and human activities make it particularly pressing for people to adopt adequate adaptation strategies (Cline 2007, Mertz et al. 2010, Samimi and Brandt 2012). Given these social-ecological conditions, migration constitutes a possible response and has been widely reported for regions in the West African Sahel (Findley 1994, Doevenspeck 2011, Scheffran et al. 2012). However, there is an increasing consensus within academic debate that environmentally induced migration is a multi-causal phenomenon. The decision to migrate is usually influenced not only by environmental drivers but also by cultural, economic, political, and social conditions. In each specific context, these interactions can increase or decrease migration (Black et al. 2011, Piguet et al. 2011, Renaud et al. 2011).

The concept of social vulnerability and the sustainable livelihoods approach (SLA; Chambers and Conway 1992, Carney 1998) represent useful analytical tools in analyzing the role of formal education in environmentally induced migration (McLeman and Smit 2006, McLeman and Hunter 2010, Tacoli 2011*a*). According to these concepts, social factors constitute a mediating function in the relation between environmental factors and migration. People have access to different assets such as natural resources, education, and skills, or to networks of social support. These assets can be translated into different livelihood strategies and they determine the capacity or incapacity of individuals and groups to subsist under conditions of stress. Social vulnerability thus refers to "the ability or inability of individuals and social groupings to respond to, in the sense of cope with, recover from or adapt to, any external stress placed on their livelihoods and well-being" (Kelly and Adger 2000:328). Migration then, both domestic and international, can be regarded either as a failure to adapt to environmental changes or as a strategy on the part of individuals and households to reduce their vulnerability to environmental and nonenvironmental stresses, or as a key component of livelihoods (Tacoli 2011*b,* Rademacher-Schulz and Mahama 2012, Scheffran et al. 2012).

Education is considered one of several indicators (e.g., socioeconomic status, sex/gender, ethnicity, age, occupation, family structure) that affect people's social vulnerability (Cutter et al. 2003). Yet there is little scientific knowledge so far about the role of education when it comes to people's vulnerability to environmental hazards and environmentally induced migration. Recent studies illustrate that people's education level may enhance their ability to cope with environmental disasters and stress (Wamsler et al. 2012, K.C. 2013), and Lutz and K.C. (2011) note that educational attainment is associated with different migration patterns. According to Adger et al. (2004:75), "education is strongly related to poverty and livelihoods; populations with overall low levels of education are likely to depend on climate-

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sensitive economic activities such as agriculture." Striessnig et al. (2013:5) revealed that education "is the single most important social and economic factor associated with a reduction in vulnerability to natural disasters." One of several reasons listed by the authors for reduced vulnerability to climate-change-related risks is that formal education results in higher income at the individual and household level. Furthermore, K.C. (2013:8) found that educated individuals in a household are likely to be involved in nontraditional occupations; this helps to diversify the household's income and makes the household better equipped to cope in times of disaster. A high standard of education for individuals, both men and women, is assumed not only to present greater opportunities for employment in the formal sector, but also to enhance their (autonomous) mobility, locally and internationally, so that they exhibit a higher propensity for migration (Adepoju 1995*a,* 2002, de Haas 2008).

Against such a backdrop, we aim to analyze the role of formal education in the context of social vulnerability in fragile environments, with a focus on migration. Our analysis is based on empirical research into the social-ecological conditions of population movements in two selected regions in the Sahelian countries Mali and Senegal (Hummel et al. 2012). The analysis starts from the premise that education is one characteristic of social vulnerability to environmental changes. We assume that people with a low level of education are more dependent on climate-sensitive economic activities such as agriculture and are thus generally more vulnerable to any type of hazard. This leads to our hypotheses that: (1) people with a high formal education are less vulnerable to environmental changes, and (2) a high level of education increases the propensity for (and hence probability of) migration for both men and women.

Drawing on the quantitative and qualitative data from the empirical study, we analyze the role of formal education in vulnerability to environmental stress in the light of other attributes such as gender, age, and ethnicity, and examine migration motives, coping strategies, and the environment sensitivity of people's economic activities.

STUDY AREAS AND METHODS

Our analysis is based on research conducted within the interdisciplinary research project "micle: migration, climate change, and environment" (http://www.micle-project.net). The micle project examines the interdependencies between climate and environmental change, with a focus on land degradation and migration in two study areas in the West African Sahel.

The West African Sahel experienced a substantial decrease in rainfall from the 1950s until at least the late 1980s, with severe droughts in the 1970s and 1980s. In addition, the Sahel has been identified as one of the regions that are particularly vulnerable to future climate change, with a major impact on human livelihoods (IPCC 2007).

The empirical research was carried out at two spatial levels: with villagers in two rural study areas in the West African Sahel, Bandiagara in Mali and Linguère in Senegal (Fig. 1); and with migrants originating from these two study areas but now living in the national capitals, Bamako and Dakar (chosen as examples for destinations of migration). The rural study areas were selected for several reasons. First, they suffer from highly variable precipitation and changes in vegetation and are considered likely to be affected by future droughts and land degradation. Second, subsistence and small-scale farming/livestock breeding are the main sources of income in both areas, which means that people are considered extremely vulnerable to environmental changes. Finally, both areas are characterized by high population dynamics with a negative net migration rate, meaning that more people are leaving than are entering the areas (Bocquier and Diarra 1999, ANSD 2006, Mbow et al. 2008).

Fig. 1. Location of the study areas in Linguère, Senegal, and in Bandiagara, Mali.

The empirical data collection was divided into two phases combining different qualitative and quantitative methods: an explorative phase from February to April 2011 and a main field phase from January to April 2012. The explorative phase included qualitative interviews and participant observation as applied methods in the two study regions and was designed to prepare for the main field work in 2012. During the main field work, a survey with 905 people was conducted with villagers in both rural study areas (661 questionnaires) and with migrants in the capitals (244 questionnaires). In addition, 60 qualitative interviews and eight group interviews, as well as participant observation, were conducted over several months in the two study areas and in the capitals. Interviews were conducted in French if possible, but more often in local languages with the assistance of translators.

Interviewees and survey participants in the villages were selected randomly; they differed in terms of age, education, ethnicity, gender, and migration experience. The survey was confined to people aged ≥18 yr, whereas the interviews were also conducted with younger people. The composition of

ethnicities depended on the location of the rural study areas: in Senegal the survey and the interviews included the Wolof (traditionally farmers) and the sedentary Fulani or Peulh (traditionally nomadic livestock breeders); in Mali it was mainly the Dogon (traditional farmers) who participated in the study. In the two capitals, people from the rural study areas were identified by a mixed method of migrant tracking and snowball sampling (Urry 1999, Diekmann 2005).

In the standardized analysis, cross-tabulations were applied to identify relationships between different attributes/variables and to test our assumptions and hypotheses as described above. Statistical significance was tested by applying chi-square (χ^2) tests, with the significance level set at $P \leq 0.05$. For analyzing the role of formal education, three categories of education were used: "no formal education", which includes people classed as illiterate or as having a basic knowledge of reading and writing without any school attendance; "primary education"; and "high level of education", which includes secondary and university education. These three categories were the result of combining the two lowest and two highest of the original five categories for statistical purposes because very few people saw themselves in the categories "basic knowledge of reading and writing", either in a local or official language, and "university level". We combined "basic knowledge" with illiteracy into a "no formal education" category, rather than including it with "primary education", for several reasons: (1) the aim of the study was to analyze the impact of formal education, (2) tests showed that responses of this group were often more akin to the illiteracy group than the primary education group, and (3) this was a necessary step to control the social desirability that might have a distortive effect on the "basic knowledge" group (Roth and Heidenreich 1995). The social vulnerability of interviewees to environmental stress has been operationalized by the main economic activities of the survey participants and their families (and the environmental sensitivity of these activities) as well as by people's strategies for coping with bad harvests and bad conditions for pasture and by their migration motives. The survey participants were asked for the motives behind their initial and last migration.

The qualitative interviews were analyzed by applying a content analysis with different categories (Mayring 2007). The citations from the interviews in this study were translated from French into English by the authors. Here, the qualitative research aimed at gaining deeper understanding of the living conditions and customs in the villages, of people's motives for migration, and of the prevailing trends and attitudes toward schooling and migration. In addition, they completed the results of the quantitative analysis, either to support the survey results or to supplement them with any contrary or new aspects mentioned; they also helped us to cross-check information from other sources.

RESULTS

Differences in education level based on age, gender, ethnicity, and study area

The level of education is very low among the survey participants: the rate of illiteracy is very high (69%), and only 24% have obtained formal education. The level of schooling held by the survey participants differs significantly between the two study areas, with a higher level of education held by the Senegalese respondents. The differences in formal education are particularly high among the youngest participants (aged 18 to 30). In this age group, 52% of the Senegalese survey participants have no formal education, compared to 70% in Mali. Although most of the youngest participants still have no kind of formal schooling, our results show a general trend toward education. Regarding gender, the level of education is significantly lower among women than men in both countries. In the Senegalese study area, we also noticed a significant difference between the two main ethnicities, the Fulani and the Wolof, with a higher level of education found among the Wolof respondents. The survey participants in the Malian study belonged mainly to one ethnicity, the Dogon (Table 1).

The link between people's economic activities and level of education

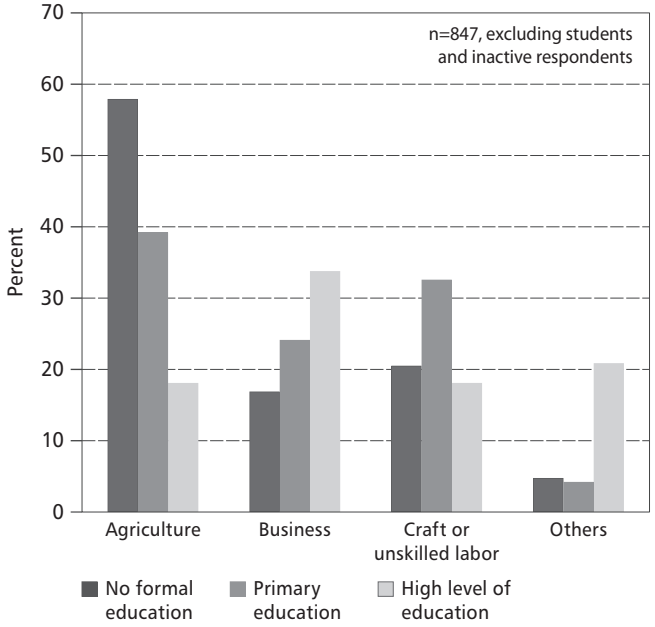
Agriculture is the main economic activity of the study participants' families (89%) and for half of the survey participants themselves. Arable farming makes up the largest proportion of survey participants' activities, with a higher percentage in Mali than in Senegal (52% vs. 30%), where livestock breeding constitutes another important source of income (16%). Among the Senegalese survey participants, trading in commodities such as car tires or agricultural products is another important source of income (27%), whereas the Malian respondents are more likely to work as craftsmen or unskilled laborers (28%) such as watchmen or housemaids. Nonagricultural activities are more often named by participants surveyed in the capitals.

With regard to education, the analysis shows a significant relationship between the survey participants' level of formal education and their main economic activity ($\chi^2 = 95.19$, $P < 0.001$). The lower their level of education, the more likely respondents are to rely on agriculture as their main source of income (Fig. 2). Agriculture is an economic activity for 58% of survey participants with no formal education, but only for 18% of participants with a high level of education. On the contrary, participants with a high level of formal schooling are more likely than those with no formal education to be involved in business or in other sectors such as administration, health, or teaching, which are not directly dependent on climatic or environmental factors.

Table 1. Respondents' level of formal education by country, age, gender, and ethnicity.

Characteristic	Number of cases	Level of education			χ^2	*P*
		No formal	Primary	High level		
Country:					9.358	0.009
Mali	445	80%	12%	7%		
Senegal	460	73%	14%	13%		
Age:					77.86	< 0.001
18 to 30 yr	301	61%	19%	21%		
31 to 50 yr	362	79%	14%	7%		
51 yr and older	242	91%	6%	3%		
Gender:					12.02	0.002
Male	532	73%	14%	13%		
Female	373	81%	13%	6%		
Ethnicity (Senegal only):					27.32	< 0.001
Fulani	102	93%	5%	2%		
Wolof	354	67%	17%	16%		

Fig. 2. Main economic activities according to the education level of respondents.



However, not only does the level of education influence the economic activity of the survey participants, but the economic activity of the family also influences the level of education and economic activity of the respondents. The results indicate that survey participants from a family that is involved in agriculture as its main economic activity are far more likely to be involved in an environment-sensitive activity (58% vs. 9%) and less likely to have a formal education than those whose families do not depend on agriculture (22% vs. 33%).

The majority of the active survey participants (76%) have more than one source of income: respondents mostly combine arable farming with livestock breeding, small-scale business, or gardening. However, with an increasing level of education and a nonagricultural activity, respondents are more likely to engage in a sole economic activity.

The qualitative interviews support these survey results. Interviewees indicate that children were and still are expected to assist their families in agricultural and domestic work (girls only) instead of attending classes, as shown by the following statement by Aliou, a 34-yr-old man from the Senegalese study area: "It's because of farming that we couldn't go to school. We learned the Koran instead of going to a school because our parents said that their children are destined for farming."

However, the interviews, in line with the survey results, show a trend toward a lower involvement of young people in agricultural activities, which might be linked to an increasing school attendance. The main reasons given for this apart from a higher education are that farming is hard physical work and that the yield of farming has become much lower and more uncertain than it used to be. Young people thus prefer to migrate to the cities to become involved in business and other income-generating activities. People with a high level of education are often attracted by the cities due to better job opportunities. This is illustrated by another statement from Aliou: "Young people who really want to make something of their future have to leave the village to do something other than farming because farming no longer allows you to live well."

Migration and education

Migration is very common in both study areas: 87% of the survey participants have personal migration experience, with only small differences between men and women (91% vs.

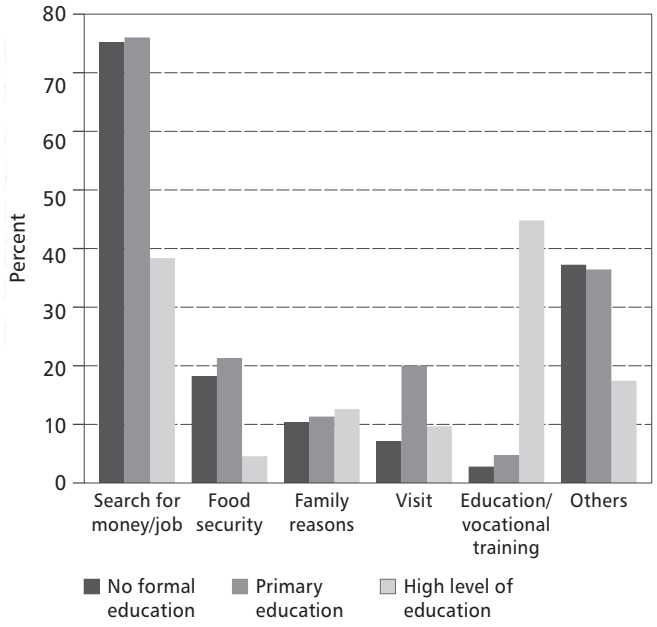
81%). We found no significant relationship between the level of formal education and migration experience. However, the results illustrate that educational attainment influences migration motives. Different levels of education are most significant in connection with the two migration motives "search for money/job opportunities" (initial migration $\chi^2 = 70.40$, $P < 0.001$; last migration $\chi^2 = 35.44$, $P < 0.001$) and "education/vocational training" (initial migration $\chi^2 = 180.31$, $P < 0.001$; last migration $\chi^2 = 132.11$, $P < 0.001$) for the survey participant's initial and last migration. Whereas 61% of survey participants with a high level of education indicate "education and/or vocational training" as one of their main objectives for initial migration, this applies only to 9% of participants with no formal education or a primary education. Most respondents with no formal education or only primary education (each 64%) give "search for money/job opportunities" as one of their main objectives for initial migration, whereas the more highly educated express far less agreement with this motive (17%). This is hardly surprising because scholars, particularly for secondary education, often have to move to bigger villages or cities to attend classes.

More surprising is that the differences between the migration motives and the level of education also apply for people's last migration (Fig. 3). Whereas 45% of survey participants with a high level of education state "education and/or vocational training" as one of their main objectives for initial migration, it plays only a minor role for those with no formal education or a primary education. The "search for money and job opportunities" is an important motive for the last migration of survey participants, but it plays a bigger role for participants with no formal education or a primary education.

With regard to gender, hardly any women confirm education or vocational training as a motive for initial migration compared to men (5% vs. 19%). Women's main motives for their first migration is, as for men, the "search for money/job opportunities" (45% vs. 67%). However, they also mention other motives that are hardly mentioned by men: "family reasons" (36% vs. 5%) and visits (19% vs. 7%). A similar relationship regarding the motives of men and women applies also for people's last migration. With respect to its role in their migration, men state education more often than do women as one main motive for their first (19% vs. 5%) and last migration (10% vs. 3%).

Our findings reveal that migration can be one of several coping strategies to compensate for climate variability and environmental changes. The survey results illustrate that with an increasing level of education, people more often confirm that their families compensate for a bad harvest or bad conditions for livestock breeding by increasing money transfers from migrant family members (high education: 70% vs. 47% for participants with no formal education; $\chi^2 = 17.04$, $P < 0.001$). Another strategy is to increase the number of migrants in the family; this is reported slightly more frequently by participants with primary-level education or no formal education than by the better educated (29% and 36% vs. 19%; $\chi^2 = 6.52$, $P < 0.05$). We found no significant relationship between the level of education and other coping strategies such as borrowing money from someone or taking out a bank loan, selling livestock, or engaging in small-scale business.

Fig. 3. Main motives behind people's last migration, depending on their education level.



The qualitative interviews illustrate that, particularly in the past but also today, young people refuse to go to school, or leave school earlier to migrate in search of a job to support their families by sending money, food, or other goods. The following statement by Abdou, a 60-yr-old man from Senegal, confirms migration as a common strategy to compensate for bad harvests: "Every family is divided in two groups: one group stays in the village for farming (...) and one group migrates to the cities to work and support the family. If the yields are not good, those in the cities are obliged to support the family by sending money to the village."

However, the qualitative analysis indicates that migration patterns among the young people change with improved opportunities for schooling: in some villages today, fewer young people are leaving in search of job opportunities than in the past because they attend school more often and for a longer period instead. This is confirmed by a quote from Binta, a 22-yr-old woman in Mali: "If you have no education, if you do not go to school and you do nothing, you have to leave to search for money, like I did."

Interviewees and survey participants assess migration in a positive light, not least because it is an important means of supporting their family's livelihood: 86% of survey participants would recommend migration to other family members, although 27% would qualify this in terms of destination. We found no significant relationship between the level of education and attitudes toward migration. However, some interviewees consider migration itself as "a school of life," which is confirmed by the statement by Oumu, a 22-yr-old woman in Mali: "When I left the village, I got to know many people, I learned how to live, that's to say I gathered a lot of experience and was able to derive personal benefit from it. I also learned a language, Bambara."

DISCUSSION

The results indicate a general trend toward formal education in both study areas, which can be confirmed by current literature on schooling enrolment (UNESCO 2012). However, the level of education is still low, with 61% of the youngest participants (aged 18 to 30 yr) receiving no formal schooling. Female participants generally tend to be educated to a lower level than men. With regard to ethnicities in the Senegalese study area, our results reveal that formal education among the Fulani interviewees is less common than among the Wolof. This can be explained by the traditionally nomadic culture of the Fulani, which makes it difficult to enrol their children in schools.

Most families in our study regions depend on agricultural activities as their main source of income and are thus presumed to be vulnerable to environmental change and high climate variability. This affects not only education but also the decision to migrate.

Formal education reduces vulnerability to environmental changes

The results illustrate that the probability of young people not being involved in agriculture as their main economic activity rises with their level of education. Thus, the hypothesis that people with a high level of formal education are less vulnerable to environmental changes is confirmed because people with a formal education, and particularly the better educated, are less dependent on climate-sensitive economic activities. But in turn, the economic activity of the family also influences the level of formal education held by survey participants.

Quantitative and qualitative results show that many youths do not seem to see their future in agriculture, which is highly dependent on unpredictable, highly variable, or scarce rainfall and decreasing soil fertility. Although 89% of the survey participants' families in both study areas rely heavily on agricultural activity, the percentage is much lower for the participants themselves. According to the interviews, this is due to a better schooling infrastructure and also to decreasing yields. Instead, they aspire to alternative job opportunities in the cities and to a life that seems more likely to be better with a (better) education.

Moreover, our results show that people from families that do not obtain their livelihood from agricultural activity are more likely to exhibit a high level of education and do not depend on agriculture themselves. Families relying on agriculture as a main source of income often prefer their children to support them in farming or in domestic work, instead of attending classes. This is also supported by Hadley (2012), who illustrated that in sub-Saharan Africa, access to education is also subject to seasonal dimensions: In Senegal, for example, seasonal absenteeism from school is common during planting and harvesting seasons, when children are required to care for livestock and mind younger siblings to allow adults to undertake income-generating activities. In addition, our interviews indicate that young boys and girls from such families often leave school early to migrate in search of money and job opportunities to support the family in the village. Agriculture as a main economic activity of the family thus may reduce the likelihood of achieving a higher education level. However, whether or not children go to school, and for how long, depends also on many other aspects such as the distance or transport to school, the financial situation of their parents, and their parents' attitudes toward education (Fentiman et al. 1999, Hadley 2012).

Although some studies oppose the link between formal education and people's economic activity (Ndiaye 1998, Weyer 2011), our results reveal that the higher the level of education, the less dependent survey participants are on an environment-sensitive economic activity. Respondents with no formal education or a primary education depend more often on agricultural activities and are thus more vulnerable to natural hazards. They are mainly engaged in several economic activities, often related to migration, to spread the families' risk related to environmental stress. Several studies emphasize that in the Sahel, women make up 50–80% of the agricultural labor force. They rely on land, soil conditions, and regular rainfall for agriculture, which makes them particularly vulnerable to environmental changes (Denton 2002, UNEP 2011). In this context, more detailed empirical research is required to examine whether and how women are more vulnerable due to their lower education attainment.

Migration motives differ with level of education

Current debates on environmentally induced migration argue in favor of a context-specific analysis of the determining factors of migration that takes account of social, cultural, economic, and political aspects that interact with environmental factors (Black 2001, Castles 2002, Piguet et al. 2011). Our results show no significant relationship between people's migration experience or propensity for migration and their level of education, for men and for women. Therefore, our hypothesis that a higher level of education increases the

propensity for migration and hence its probability for both men and women has to be rejected. This result contradicts the statement in the literature that educational attainment enhances the mobility of women (Adepoju 1995*b,* 2002, de Haas 2008).

However, our results do illustrate that education is one of several important social aspects influencing a migration decision in fragile environments. In the West African Sahel, circular migration is an important livelihood strategy to diversify income and to reduce the household's vulnerability to environmental stress through remittances (Adepoju 1995*b,* Black 2001), which is confirmed by the qualitative interviews. However, this seems to apply only to people with no formal education or with primary education, who give the search for job or money-earning opportunities as the main objective of their first and last migration. On the contrary, the better educated survey participants (at least to secondary level) mainly migrate in pursuit of education or vocational training. Female survey participants barely mention education as a motive for their migration, which might be explained by their lower education level.

The qualitative interviews illustrate that respondents have to leave school early to migrate: females primarily to earn their dowry or to assist relatives, and males in search of a job to support their family. This is particularly the case for the first born, who has a cultural obligation to support the parents. Migration is specifically reported in the literature as a constraint for education in the case of low-skilled migration (de Haas 2008) and for girls (Fentiman et al. 1999). However, the survey results illustrate that the well-educated respondents tend to be in a better position to increase the money transfers from migration to their families than are people with no formal education or primary education. Remittances from family members in migration are often invested in the education of other family members and can thus turn education into a strategy to improve the lives of the family members (Adepoju 1995*b*). Moreover, many migrants consider migration itself as an education that opens up possibilities of discovering and learning new things. Overall, these different findings are very much in keeping with the basic assumptions of the sustainable livelihoods approach and the social vulnerability concept described above, which emphasize the role of education as an important asset when it comes to improving the quality of life and adaptive capacity.

CONCLUSION

We examined the role of formal education in environmentally induced migration using the example of two Sahelian regions in Mali and Senegal. These regions are presumed to be affected negatively by climate change and by environmental changes such as land degradation, which place pressure on the majority of inhabitants, who mainly have a low level of education and rely heavily on agriculture to sustain their livelihoods.

In summary, the results confirm that people with a high formal education are less vulnerable to environmental stress because they are less dependent on environment-sensitive economic activities. Interestingly, the education level has no significant effect on the migration experience as such. However, motives for migration differ clearly depending on people's level of education. This suggests that labor migration appears to be a strategy to reduce vulnerability to environmental changes mainly for people with no formal education or with primary education, whereas the better educated primarily migrate for education or vocational training.

Based on our empirical findings, people's capacity to adapt to natural hazards is clearly influenced by their educational status: education increases their options so that they are no longer entirely at the mercy of a fragile environment. We conclude that policies designed to promote and facilitate formal education, particularly for those dependent on agriculture to sustain their livelihoods, first and foremost reduce the vulnerability of the population in Sahelian regions and other areas negatively affected by climate and environmental changes. Once they have migrated, the better educated people do not usually return to their rural places of origin. For those who want to leave and aspire to a better life in a nonagricultural activity, a formal education is a critical requisite. For those who want to stay, it is essential to create perspectives by embedding policies for the enhancement of formal education in comprehensive strategies for sustainable regional development.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5830

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Impacts of the 2010 Droughts and Floods on Community Welfare in Rural Thailand: Differential Effects of Village Educational Attainment

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ABSTRACT. Climatic events can have disastrous consequences on rural livelihoods, which rely mainly on agriculture and natural resources. The way households and communities respond to climatic shocks depends on their available resources. We formulated that education is a human capital asset that can increase coping abilities in difficult times because education improves access to both social and economic resources. Based on the Thai government surveys of the living conditions and life quality of 68,343 rural villages for the years 2009 and 2011, we investigated the impacts of floods and droughts in 2010 on community welfare, i.e., consumption and income in 2011 at the village level. Using difference-in-difference methods, we analyzed how differential demographic composition and education could reduce or increase economic vulnerability to natural disasters. We found that floods and droughts do not produce a negative effect either on food and nonfood consumption, investment in agriculture and education, or on income. However, this applies mainly to communities with higher educational attainment partly because these communities can better secure government financial aid for flood and drought affected areas. Education thus may have an important role in reducing economic vulnerability.

Key Words: *consumption and income smoothing; drought; economic vulnerability; education; flood; Thailand; welfare*

INTRODUCTION

The frequency and severity of extreme weather events and natural disasters has increased in the past decades worldwide (Diffenbaugh et al. 2005, Solomon et al. 2007). Although some anticipated impacts of climate change are positive in certain areas, developing countries are most likely to suffer from its negative impacts (IPCC 2001). The climate change models in Southeast Asia projected that the region would experience prominent increases in the intensity and/or frequency of extreme events such as tropical cyclones, droughts, floods, as well as a rising sea level (ADB 2009). Apart from fatalities and casualties, these extreme climate events disrupt livelihoods and income generating economic activities. With crops and livestock being destroyed, incomes and consumption decline and savings deplete. This can have long-term implications for well-being, future human capital accumulation, and economic development.

The impacts of natural disasters, both in terms of human and financial losses, are distributed disproportionately across social groups as are coping abilities. Social factors, such as race and ethnicity, health, education, infrastructure, and poverty are crucial determinants of vulnerability (Fothergill et al. 1999, Adger et al. 2004, Vincent 2004, Brooks et al. 2005) because they are related to resource distribution (Blaikie et al. 1994). Social differentiation, in the availability of and access to resources, makes certain groups more exposed to risk and less capable of adapting (Adger et al. 2004, Smit and Wandel 2006).

Consequently, households and communities respond to multiple stressors, including climate stress, depending on available resources. For instance, although households above the poverty line respond to disaster shocks through consumption smoothing, e.g., sell assets, poorer households are more likely to smooth their assets, e.g., decrease consumption, a strategy that can result in human capital depletion (Hoddinott 2006). Coping strategies also vary considerably with household socio-demographic characteristics. Whereas households with female heads, for example, experience consumption reduction because of idiosyncratic income shocks (Kim and Prskawetz 2010), households with higher education have lower vulnerability to income shocks (Skoufias 2007, Silbert 2011). Human assets, such as education and skills, can thus be an important element in promoting adaptive capacity.

The plausible, positive effect of education on risk reduction is noteworthy and can have important policy implications. Education is a human capital asset that can increase adaptive capacity, i.e., "the preconditions necessary to enable adaptation, including social and physical elements, and the ability to mobilize these elements" (Nelson et al. 2007:397). Education is one important way individuals acquired knowledge, skills, and competences that could directly or indirectly influence coping capacities in times of crisis. More educated individuals may have improved access to information and a better ability to interpret and evaluate that information (Patrick and Kehrberg 1973, Jerit et al. 2006), including climate risks and self-protection. Education endows individuals with real skills that are useful for work and for life, such as decision making abilities (Pudasaini 1983) and problem solving skills that can be useful in hard times.

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Likewise, education also indirectly affects adaptive capacity through income. The relationships between education and labor market outcomes, such as earnings and employment, are well established (Oreopoulos 2006, Riddell and Song 2011). Education provides individuals with greater access to full-time, high status, and well-paid work. The improved economic conditions can reduce vulnerability to climate change through enhancing livelihood options and access to external support. Thus, education can provide individuals with additional resources, i.e., skills, information, and relevant knowledge, which may compensate for the assets lost and damages caused by climatic shocks.

We assessed the impacts of natural disasters on community welfare and investigated the role of education as a buffer to livelihood and climate shocks, using Thailand as a case study. Given Thailand's strong reliance on agriculture and natural resources, and its annual experience of natural disasters, particularly floods, droughts, and tropical storms, we analyzed, ex-post, economic vulnerability to climate events, i.e., droughts and floods in 2010 using village-level survey data from Thailand. We hypothesized that although external climate stresses exacerbate economic vulnerability, the areas with an educated population would experience less economic impacts. Education is a human capital, which is fundamental to development, and unlike physical capital, it is transferable and remunerable in different locations. Thus, when experiencing external stresses, areas with high human capital might be able to adapt and recover faster to a new situation.

Most extant studies on climatic stresses and vulnerability rely on household surveys, which generally comprise a sample of households in a selected area or country. Although such data are useful in understanding individual or household-level vulnerability, they might not be nationally representative. As well, longitudinal data are required in this type of analysis, which aims to examine the change in welfare after experiencing extreme weather events. Because individual-level panel data are not widely available in developing countries, exploiting the government survey of all villages located in rural areas in Thailand in the years before and after the disasters hit allowed us to observe how floods and droughts affected community welfare all over the country. In addition, whereas the studies focusing on the impacts of natural disasters in African and Latin American countries are relatively abundant, there is relatively little evidence for countries in Southeast Asia, despite the increasing multiple climate threats in the region. We thus further provide new empirical evidence for Thailand.

SOME BACKGROUND INFORMATION ON THAILAND

Located in the center of the Southeast Asian peninsula, Thailand covers an area of 513,115 km² and comprises 76 provinces. The country has 65.5 million inhabitants, the majority (56%) living in nonmunicipal, i.e., rural, areas (NSO 2010). Based on economic, social, and ecological characteristics, Thailand is usually classified into four geographical regions: central, including Bangkok Metropolitan Region, north, northeast, and south. The central plain is a wide, flat, fertile land, covered predominantly by the Chao Phraya River valley, which runs into the Gulf of Thailand. This is the most populous and productive region, often referred to as the Rice Bowl of Asia. The northern part is mainly mountainous and was traditionally covered by dense forest. The northeast comprises the semiarid Khorat Plateau, a few low hills, and shallow lakes. Its poor soil and long, dry season make the region the least agriculturally productive and the poorest in the country. The south is a narrow peninsula joining the landmass with the Malay Peninsula. It has the highest rainfall in the country.

Thailand's economic activities rely heavily on land and water resources, which are vital to both the development of agriculture and nonagriculture sectors. Apart from the problem of land quality deterioration and problematic soils, many areas have been classified as drought- or flood-prone areas. Highly intensive land use, rainfall fluctuations, and physical characteristics in different regions partly contribute to these climate risks (ONREP 2011). The increasing demand for water because of population growth and economic development overstretches the water supply. The increasing frequency and severity of droughts and floods further amplify the water resource tensions.

Although floods are common during the monsoon season, and droughts are common in the summer, climate variability in the past decade has resulted in fluctuating rainfall, which increases the risk of severe droughts and floods. In 2005 and 2008, over 11 million people were affected by water shortages, which largely damaged the rural agricultural region. Meanwhile, in 1994-1995, in 2010, and recently in 2011, an intense rainfall resulted in the worst floods in half a century. The 2011 flood affected 13.6 million people, 65 provinces, and over 20,000 km² of farmland. The estimated economic damages and losses equaled US$45.7 billion (World Bank 2011). The impacts of these natural disasters pose significant risks and burden the development and environment of the country and can seriously harm the local economy.

Likewise, many parts of Thailand are under threat from climate change. Observational records and climate projections predicted that rainfall would increase by about 10-20% across all regions of Thailand in the next 50 years. Mean annual temperatures across the country are predicted to increase with the longer summer, as are more days with temperatures of higher than 33ºC (Chinvanno et al. 2009). Changes in rainfall patterns and the frequency and intensity of rainfall will result in a higher frequency of severe floods and droughts. This can cause substantial damage, not only to property and human life,

but also to the ecosystem, agriculture, and other economic activities, such as food processing and tourism industries that rely heavily on agriculture and natural resources.

The 2010 droughts and floods

The year 2010 provided evidence of increasing extreme weather events in Thailand. In 2010, Thailand experienced the worst droughts and the second worst floods in the past two decades. Because the tropical rainy season ended earlier than usual in November 2009, together with global warming and the El Niño phenomenon, Thailand experienced unusually hot weather and a lack of rainfall at the beginning of 2010. As the country entered the hot season in March, experts had issued national drought warnings, and these droughts stretched until almost the end of August. The Disaster Prevention and Mitigation Department declared 64 provinces to be disaster areas because of severe water shortages. The drought had an adverse impact on more than 4 million people, mainly through damaged agricultural production. The drought damaged 2746 km² of farmland with the estimated loss of 1.5 billion baht (US$46 million; Rerngnirunsathit 2012). Later in the year, Thailand experienced a series of flash floods and seven incidents of flooding. From 15 July to 30 December 2010, all regions in Thailand were hit by floods caused by the La Niña phenomenon, which brought about higher than average rainfall and a longer period of precipitation. The southern part was further hit by a tropical depression, which brought about heavy rainfall and flash floods lasting from 1 November 2010 to 25 February 2011. A combination of inadequate drainage and a well above average rainfall intensity left the country totally unprepared for the disaster. The death toll from the floods stands at 266 people with 1665 people injured. In total, 74 provinces were affected by the floods, 17,455 km² of farmland was damaged with the total estimated loss of 16 billion baht (US$536.6 million; Rerngnirunsathit 2012). A long, severe drought prolonged beyond the first half of the year, followed by destructive floods later in the year, made 2010 a unique year to study the impacts of climate variability.

DATA

Data from different sources were used to analyze the impacts of natural disasters on village welfare. Information on demographic and socioeconomic characteristics at the village level was obtained from two data sources: Basic Minimum Need Survey (BMN) and the National Rural Development Committee Survey (NRD 2C). The Community Development Department (CDD), Ministry of Interior, administered both surveys, which covered all villages located in rural areas in 76 provinces in Thailand. Rural areas are defined as the areas outside the municipality, which is a local administration unit with greater than 5000 citizens. The surveys covered approximately 70,000 villages, accounting for about half of the Thai population.

The BMN is an annual survey of every household in villages and communities all over Thailand. The survey objective is to improve household members' quality of life by enabling local people and communities to meet their own basic, minimum needs in five categories: health, dwelling, education, economy, and values. The head or members of a household are interviewed face-to-face by interviewers selected from members of their village using a structured questionnaire. The information on expenditures and income is adjusted for the number of people in the household. The data are then processed and aggregated at the village level.

The NRD 2C is a biannual survey of living conditions in a village, which focuses on six themes: infrastructure, employment/agricultural productivity and income, health and sanitation, knowledge and education, community strength, and natural resources and environment. The structured questionnaire is filled out by members of the village committee, the village head, and local government officials. The latter provide information acquired through their work, e.g., education of people in the village, death registration, number of disabled people, and village health statistics, including the number of individuals who suffered from various communicable and noncommunicable diseases, such as hepatitis B, tuberculosis, diabetes, and cancer.

The two surveys provide extensive information on demographic, physical, economic, and social conditions covering every village in the country. Because the BMN and the NRD 2C are collected annually and biannually, this allowed us to construct a panel data and assess economic vulnerability after the natural disaster events, controlling for village characteristics in the year before the disasters occurred. Note that the data cover only rural areas, thus the results might not be generalizable to urban areas because the nature of livelihoods differs in the two locations.

The analysis sample was for the years 2009 and 2011 comprising 68,343 villages. We excluded 2486 observations in which socioeconomic information was not available for both years. We matched this sample with district-level disaster data, i.e., the floods and droughts reports for the year 2010, provided by the Department of Disaster Prevention and Mitigation, Ministry of Interior. The floods and droughts reports contain information on the population, the number of households and villages affected by flood/drought, estimated economic loss, and the amount of public aid.

METHODS

The analysis is an ex-post assessment of the extent to which climate shocks cause economic vulnerability to welfare loss at the village level. Although some areas are flood and drought prone, such large-scale disasters, like the ones that occurred in the year 2010, were not anticipated. Thus, the 2010 floods and droughts can be considered to be climatic shocks to

community welfare. We defined vulnerability as a function of shocks, susceptibility and resilience, and namely the interplay between the realization of stochastic events, i.e., shocks, and individual, household, community, and country's ability to anticipate and respond to such events. A community is considered vulnerable to floods and droughts if the risk will result in a loss of well-being or welfare with which the individual or household in a community is unable to cope (Heltberg and Bonch-Osmolovskiy 2011).

Community welfare is measured by income and consumption, which are common, direct, and observable measures of welfare level after experiencing external climatic shocks (Skoufias and Vinha 2013). Both droughts and floods can damage crop production via a decrease in cultivated area and crop yield, which leads to income loss. In addition, floods can destroy households, assets, and infrastructure, which can inhibit income-generating activities. If households cannot perfectly smooth consumption, i.e., maintain the same level of consumption when income is affected by transitory shocks, they then have to finance a fraction of their current consumption and investment based on the income they have.

Reducing expenditures on food and nonfood consumption is one way to deal with a reduction in household income. Households may also change investment priorities because of limited economic resources. For example, to supplement their income, households may send their children to work instead of school, thus reducing the investment in human capital (Jacoby and Skoufias 1997). On the other hand, upon seeing that natural disasters can reduce the expected return to physical capital, rational individuals may shift their investment toward human capital (Skidmore and Toya 2002). Because there is evidence that households adjust their consumption in response to an adverse shock differentially, e.g., reducing nonfood consumption but smoothing food consumption (Skoufias et al. 2011), it is important to analyze the impacts of catastrophic climate shocks on the different dimensions of welfare. We used five variables as indicators of welfare, namely, food expenditure, nonfood expenditure, productive expenditure on agriculture, expenditure on education, and income.

We used a difference-in-difference approach with continuous treatment to assess the effects of floods and droughts on community welfare following a commonly used equation to estimate the degree of consumption smoothing (Townsend 1994, 1995). The intensity of the treatment variable is Sc_j, that is, exposure to floods or droughts in the year 2010.

The model estimating community welfare can be defined as:

$$\Delta \ln w_i = \gamma Sc_j + \partial E_{i2009} + \beta S_{i2009} + \Delta\sigma Z_i + \Delta\delta X_i + \Delta\varepsilon_a \quad (1)$$

where $\ln w_i$ is first difference in the logarithm of expenditures on food, nonfood, agriculture and education, and income of village *i* between the years 2009 and 2011;

Sc_j is a vector of stochastic measures of floods and droughts in district *j* in 2010;

E_{i2009} is a vector of education composition in village *i* in 2009, i.e., proportion of people with elementary and lower secondary education; proportion of people with at least upper secondary education; proportion of people with other education. People with no education are excluded from the model;

S_{i2009} represents a series of demographic and socioeconomic characteristics of village *i* in 2009, i.e., income; proportion of people aged 0-14; proportion of people aged 60+; proportion of female-headed households; proportion of households engaging in agriculture; proportion of households with insufficient access to water; and proportion of households without access to electricity;

Z_i is first difference of a vector of population dynamics of village *i* between years 2009 and 2011, i.e., proportion of disabled people; proportion of sick people; and proportion of deaths. The term Z_i captures the change in the burden of morbidity and mortality, which can be considered as another shock to rural livelihoods and can possibly be related to floods and droughts;

X_i is first difference of a vector of self-reported environmental and economic constraints in land use for agriculture of village *i* between years 2009 and 2011, i.e., poor soil quality; labor shortage; crops plantation not breaking even with investments; lack of knowledge to grow other crops; shortage of water; and inundations; and

$\Delta\varepsilon_a$ is a time-varying idiosyncratic error term.

Note that S_{i2009} and E_{i2009} are measured in 2009 because we want to control for initial conditions. Essentially, we aimed to explore how these characteristics, in the initial year before the floods and droughts hit, contribute to community welfare in 2011. On the other hand, X_i and Z_i are measured as the difference between the years 2009 and 2011 because we wanted to capture the changes in environmental and economic constraints in land use, as well as mortality and morbidity after the experience of floods and droughts. The Stata software version 11.0 was used for the analyses.

Measurement of floods and droughts

The exposure to floods and droughts were measured at the district level. Although the village might not have been hit directly by floods/droughts, there could have been indirect effects that were common to all villages within a district, such as food shortages, rising food prices, and ruptures in infrastructure or transportation. Using the number of villages affected by floods and droughts in the district, the scale of floods/droughts was divided into five levels:

- No villages were hit by floods/droughts;

- 1 - 24% of villages in the district were hit by floods/ droughts;
- 25 - 49% of villages in the district were hit by floods/ droughts;
- 50 - 74% of villages in the district were hit by floods/ droughts;
- 75 - 100% of villages in the district were hit by floods/ droughts.

Summary statistics

Table 1 presents summary statistics of the dependent and independent variables in 2009 and 2011 including the distribution of villages affected by floods and droughts in 2010. Overall, we observed an increase in income and all types of expenditures except for nonfood expenditure in 2011. As for demographic and socioeconomic characteristics of the villages, the mean proportion of people aged 0-14 declined from 19.5% in 2009 to 18.3 % in 2011, whereas the mean proportion of people aged 60 years and over increased from 12.9% to 14.1% in 2011. The proportion of sick people, deaths, people with disabilities, and female-headed households did not substantially change between the two years. The proportion of households engaging in agriculture declined in 2011 as did the proportion of households with inadequate access to water. On average, there was a decline in 2011 of people who mentioned poor soil quality, crop yields not breaking even with investment, and a lack of knowledge of other potential crops as the serious problems inhibiting the full use of land.

The distribution of the proportion of villages affected by floods and droughts in a district is also displayed in Table 1. Both droughts and floods were widespread in rural Thailand in 2010. More than half of the villages were located in the district in which droughts and floods affected all villages. Only 6.3% and 19.5% of villages were located in the district in which flood and droughts, respectively, hit none of the villages. The variation in flood and drought exposure could have different effects on village-level welfare.

In Table 2, we present the distribution of the proportion of individuals with upper secondary education and higher by region and by the level of exposure to floods and droughts. We divided the distribution of the proportion of village members with upper secondary education and higher into a quartile. For the whole country, the average proportion of individuals with upper secondary education and higher is 6.6% in the first quartile compared with 27.8% in the fourth quartile. On average, the north and northeast have the lowest proportion of highly educated individuals. We also verified whether there was an association between education and living in flood and drought prone areas. Table 2 shows that in 2009, the distribution of people with upper secondary education and higher was virtually the same across all levels of flood exposure. In the case of drought exposure, the areas in which 75-100% of the villages were affected by drought had a slightly lower proportion of highly educated individuals. This distribution however, did not change in 2011, apart from the fact that the proportion of highly educated individuals became larger over time. Thus, there is no clear evidence that highly educated individuals moved out of drought affected areas after being affected by the 2010 droughts.

EMPIRICAL RESULTS

Welfare effects of droughts and floods

We matched the flood and drought data with the village-level survey data and ran a series of difference-in-difference OLS regressions to assess the short-term impacts of flood and drought exposures on welfare expenditures and income, as well as to explore the determinants of such economic vulnerability. The regression results of the estimates of expenditures on food, nonfood, agricultural inputs, education, and income are illustrated in Table 3. Because the outcome variables ($\ln w_i$) are on the log-scale, one unit change in a dependent variable x corresponds to $100*\beta 1x$ percent change in $\ln w_i$.

Socio-demographic characteristics associated with the village's income were as predicted. The higher the village income in 2009, the greater was the increase of its income in 2011. Also, the higher the proportion of children aged 0-14 years in 2009, the lower was the increase in village income, whereas the opposite was true for the proportion of female-headed households. The economic shock, because of an increase in the number of deaths and the proportion of disabled people, had a negative impact on income increase. As for the impacts of droughts and floods, incomes rose as the scale of floods increased and decreased as the scale of drought got larger. Education was strongly and positively associated with income. A 1% increase in the proportion of villagers with at least an upper secondary education resulted in a 19% increase in income.

The coefficient estimates for exposure to floods and droughts showed that the average village consumption per month was protected against any negative income shocks from floods and droughts. There was no evidence that expenditures on food and nonfood declined when the villages were exposed to greater droughts and floods. To the contrary, there was a significant positive impact of floods and droughts in all types of expenditures, except for nonfood expenditures. However, when a community was severely affected by both floods and droughts, as shown in the parameter "flood index x drought index" in Table 3, their expenditures of all types declined.

In terms of physical capital and human capital investments, communities did not cut their expenditures either on

Table 1. Summary statistics of dependent and independent variables for the years 2009 and 2011 (N = 68,343).

	2009		2011		
	Mean	Sd	Mean	Sd	Δ Mean
Dependent variables					
Food expenditure	364,591	8777841	409,214	8623081	44,623
Non-food expenditure	1,114,472	22000000	1,103,187	14900000	-11,285
Agriculture input expenditure	93,981	4099454	114,927	4624393	20,946
Education expenditure	93,252	3076278	95,732	3283681	2479
Income	1,715,840	2457227	1,963,383	2370921	247,543
Independent variables					
Proportion with no education (omitted in regression estimates)	0.126	0.093	0.119	0.092	0.008
Proportion with elementary & lower secondary	0.635	0.137	0.638	0.638	0.003
Proportion with upper secondary & higher	0.159	0.090	0.175	0.094	0.015
Proportion with other education	0.079	0.148	0.068	0.122	-0.011
Proportion of female headed household	0.064	0.216	0.062	0.166	-0.002
Proportion aged 0-14 years	0.195	0.055	0.183	0.055	-0.011
Proportion aged 60 years and over	0.129	0.048	0.141	0.052	0.012
Proportion with disability	0.013	0.059	0.015	0.043	0.002
Proportion of sick people	0.051	0.313	0.052	0.257	0.002
Proportion of deaths	0.002	0.024	0.002	0.016	0.000
Proportion of households in agriculture	0.733	1.806	0.715	1.488	-0.019
Proportion of households with insufficient water	0.079	0.326	0.059	0.347	-0.020
Proportion of households with no electricity	0.010	0.065	0.008	0.063	-0.002
Problem with poor soil	0.278	0.448	0.262	0.440	-0.016
Problem with labor shortage	0.140	0.346	0.140	0.347	0.001
Problem with crop planted	0.356	0.479	0.328	0.469	-0.028
Problem with lack of knowledge	0.240	0.427	0.224	0.417	-0.016
Problem with water shortage	0.405	0.491	0.400	0.490	-0.005
Problem with inundation	0.149	0.360	0.148	0.360	0.000
Distribution of villages by level of flood and drought exposure in a district		Proportion	N		
Not affected by floods in 2010		0.06	4298		
1-24% of villages in the district hit by floods in 2010		0.15	9995		
25-49% of villages in the district hit by floods in 2010		0.15	10,096		
50-74% of villages in the district hit by floods in 2010		0.12	8178		
75-100% of villages in the district hit by floods in 2010		0.52	35,776		
Not affected by droughts in 2010		0.20	13,352		
1-24% of villages in the district hit by droughts in 2010		0.06	4049		
25-49% of villages in the district hit by droughts in 2010		0.09	6135		
50-74% of villages in the district hit by droughts in 2010		0.15	10,377		
75-100% of villages in the district hit by droughts in 2010		0.50	34,430		

agriculture or education. Agricultural expenditures include costs of production, such as seed/animal breeding costs, chemical cost, e.g., fertilizers, and other costs, e.g., machinery and petrol. When faced with environmental constraints related to land use, such as water shortages or planted crops not breaking even with investments, expenditures on agriculture increased. Similarly, agriculture spending also increased for villages located in districts with greater exposure to floods and droughts. A 1% increase in the severity of floods and droughts exposure was associated with 0.07% and 0.19% increases in expenditures on agriculture, respectively.

Likewise, spending on education also increased with the level of exposure to floods and droughts. In particular, education expenditure increased the higher the average level of education in the villages. This pattern also holds for other types of expenditures, except for expenditure on agricultural inputs in which communities with higher education spend less. Similarly, the communities with higher income in 2009 have more expenditures of all types.

Differences in welfare effects by community educational attainment

To explore whether there is any heterogeneity across the impacts of natural disasters on consumption and income by level of education, we split our sample into two groups following a median distribution of the proportion of people with upper secondary education and higher. The first group was made up of villages with lower education (N = 34, 172) and the second group of villages with higher education (N = 34, 171). The average proportion of people with at least upper secondary education for the former was 9% compared to 22%

Table 2. Mean proportion of village members with upper secondary education and higher by region and level of exposure to floods and droughts.

Mean proportion upper secondary & higher by region and education quartile †	1st quartile	2nd quartile	3rd quartile	4th quartile	Total
Whole country					
Mean	0.07	0.12	0.17	0.28	0.16
N	17,087	17,085	17,086	17,085	68,343
Central					
Mean	0.06	0.12	0.17	0.29	0.19
N	2246	2969	3839	5596	14,650
North					
Mean	0.06	0.12	0.17	0.27	0.15
N	4251	3834	3703	3328	15,116
Northeast					
Mean	0.07	0.12	0.17	0.27	0.14
N	9759	9001	7049	4515	30,324
South					
Mean	0.06	0.12	0.18	0.27	0.20
N	831	1281	2495	3646	8253

Mean proportion upper secondary & higher by year and disasters	2009		2011	
	Floods	Droughts	Floods	Droughts
Not affected by the disaster	0.16	0.18	0.17	0.20
1-24% of villages in the district hit by the disaster	0.16	0.18	0.18	0.20
25-49% of villages in the district hit by the disaster	0.16	0.17	0.18	0.19
50-74% of villages in the district hit by the disaster	0.16	0.17	0.18	0.18
75-100% of villages in the district hit by the disaster	0.16	0.14	0.17	0.16

† Education quartile is created by splitting up the proportion of village members with at least secondary education into four groups. The first quartile consists the cluster of villages with the lowest proportion while the fourth quartile consists the cluster of villages with the highest proportion of members with at least secondary education.

for the latter. The effects of floods and droughts on community welfare given the different distribution of people with at least upper secondary education across villages are shown in Table 4 (full results are shown in Appendix 1).

When splitting our sample into two groups, i.e., low and high education, the impacts of droughts on consumption did not vary considerably between the two groups. Expenditures of all types increased the greater the exposure to drought, and this applied to both villages in the low and high education groups. The impact of flood exposure on spending, however, varied with types of expenditures and village-level education. Particularly for educational expenditure, villages in the high education group were far more likely to increase the level of spending on education even with flood exposure. With respect to income, educational variation in income changed after climatic shocks. Although villages in the high education group managed to smooth their income given exposure to floods and droughts, those in the low education group experienced significant income reduction after drought exposure.

In addition, the main effects of the proportion of people with at least secondary education differed between villages in low and high education groups. For villages in the low education group, an increase in the proportion of those with at least secondary education resulted in a large, significant increase in expenditures of all types. This was not necessarily the case for villages in the high education group. This finding suggests that there is a ceiling effect such that the increase in the proportion of people with at least secondary education in the high education group does not make as much difference in the increase in expenditures compared with the low education group.

Government aid and income smoothing

Given that the 2010 floods caused much greater economic loss and infrastructure damage than the droughts, one would expect to observe an income reduction for villages with greater flood exposure. However, our empirical results show that income actually increased for the villages with more severe flood exposure. Because the Thai government allocated a budget of approximately US$550 million to help flood victims, together with US$13 million for drought-affected households, this financial support might explain why we observed an increase in income. In Table 5, we included the amount of government

Table 3. Difference-in-difference estimates of community welfare (standard errors in parentheses): all in sample.

	Food expenditure	Nonfood expenditure	Agriculture input expenditure	Education expenditure	Income
Socioeconomic characteristics in 2009					
Income	0.957***	0.915***	0.919***	0.991***	0.857***
	(0.044)	(0.039)	(0.060)	(0.048)	(0.005)
Proportion with elementary & lower secondary	2.976***	3.373***	6.225***	5.044***	0.062+
	(0.351)	(0.317)	(0.483)	(0.386)	(0.037)
Proportion with upper secondary & higher	2.014***	3.264***	-9.533***	4.856***	0.191***
	(0.475)	(0.429)	(0.655)	(0.523)	(0.050)
Proportion with other education	-0.297	0.552+	-1.810***	1.007**	0.112***
	(0.322)	(0.291)	(0.443)	(0.355)	(0.034)
Proportion of female headed household	0.444**	0.386**	0.184	0.377*	0.109***
	(0.144)	(0.130)	(0.198)	(0.159)	(0.015)
Proportion aged 0-14 years	6.693***	4.636***	10.255***	9.893***	-0.350***
	(0.633)	(0.571)	(0.872)	(0.698)	(0.067)
Proportion aged 60 years and over	4.146***	2.295***	10.810***	4.655***	-0.115+
	(0.639)	(0.577)	(0.881)	(0.704)	(0.067)
Proportion of households in agriculture	0.052**	0.019	0.112***	-0.001	0.004+
	(0.018)	(0.016)	(0.024)	(0.019)	(0.002)
Proportion of households with insufficient water	-0.140+	-0.051	0.220+	-0.012	0.011
	(0.085)	(0.077)	(0.117)	(0.094)	(0.009)
Proportion of households with no electricity	0.170	0.273	-0.331	-0.377	0.026
	(0.419)	(0.379)	(0.578)	(0.462)	(0.044)
Δ (Difference between 2009 and 2011)					
Proportion with disability	-0.894+	-0.329	-1.287+	-0.830	-0.408***
	(0.542)	(0.489)	(0.746)	(0.597)	(0.057)
Proportion of sick people	0.133	0.040	-0.018	-0.124	0.013
	(0.094)	(0.085)	(0.130)	(0.104)	(0.010)
Proportion of deaths	0.561	0.455	0.801	1.781	-0.356**
	(1.288)	(1.163)	(1.775)	(1.420)	(0.136)
Problem with poor soil	0.043	0.012	0.098	0.019	-0.001
	(0.051)	(0.046)	(0.070)	(0.056)	(0.005)
Problem with labor shortage	0.032	0.036	-0.054	0.009	-0.002
	(0.061)	(0.055)	(0.084)	(0.067)	(0.006)
Problem with crop planted	0.083	0.080+	0.263***	0.082	0.002
	(0.052)	(0.047)	(0.071)	(0.057)	(0.005)
Problem with lack of knowledge	-0.010	-0.073	-0.045	0.022	-0.004
	(0.055)	(0.050)	(0.076)	(0.061)	(0.006)
Problem with water shortage	0.129**	0.142***	0.294***	0.193***	0.003
	(0.045)	(0.041)	(0.062)	(0.050)	(0.005)
Problem with inundation	-0.055	-0.019	0.082	-0.048	-0.006
	(0.057)	(0.051)	(0.078)	(0.063)	(0.006)
Experience of floods and droughts in 2010					
Log flood index	0.021**	0.006	0.067***	0.021*	0.002*
	(0.008)	(0.007)	(0.011)	(0.008)	(0.001)
Log drought index	0.061***	0.050***	0.192***	0.083***	-0.001**
	(0.005)	(0.004)	(0.006)	(0.005)	(0.0005)
Flood index x drought index	-0.008***	-0.007***	-0.015***	-0.008***	-0.0001
	(0.001)	(0.001)	(0.002)	(0.001)	(0.0001)
Constant	-17.505***	-16.796***	-18.448***	-20.461***	-12.125***
	(0.712)	(0.643)	(0.981)	(0.785)	(0.075)
Observations	68,338	68,330	68,322	68,338	68,340
R-squared	0.02	0.02	0.05	0.02	0.37

*** p < 0.001, ** p < 0.01, * p < 0.05, + p < 0.1

monetary assistance for floods and droughts in the affected districts for the estimation of village monthly income. Note that the sample size, i.e., number of villages, gets smaller because of unavailable information on government aid for many flood and drought affected districts.

Table 4. Difference-in-difference estimates of community welfare (standard errors in parentheses)[†]: splitting sample into low and high education groups[‡].

	Food expenditure	Nonfood expenditure	Agriculture input expenditure	Education expenditure	Income
Low education group					
Socioeconomic characteristics in 2009					
Proportion with elementary & lower secondary	2.847***	3.313***	5.338***	5.013***	0.074+
	(0.416)	(0.376)	(0.561)	(0.464)	(0.045)
Proportion with upper secondary & higher	8.061***	7.362***	6.405***	15.306***	0.328*
	(1.251)	(1.131)	(1.686)	(1.394)	(0.134)
Proportion with other education	0.097	0.808*	-0.838+	1.893***	0.125**
	(0.374)	(0.339)	(0.505)	(0.417)	(0.040)
Experience of floods and droughts in 2010					
Log flood index	0.021*	0.002	0.049***	0.011	0.002+
	(0.010)	(0.009)	(0.014)	(0.011)	(0.001)
Log drought index	0.030***	0.024***	0.132***	0.048***	-0.002*
	(0.007)	(0.006)	(0.010)	(0.008)	(0.001)
Flood index x drought index	-0.011***	-0.008***	-0.011***	-0.012***	0.0001
	(0.002)	(0.002)	(0.003)	(0.002)	(0.0002)
Constant	-16.331***	-15.237***	-19.973***	-19.328***	-11.689***
	(0.996)	(0.901)	(1.342)	(1.110)	(0.107)
Observations	34,169	34,165	34,158	34,169	34,170
R-squared	0.02	0.02	0.03	0.02	0.32
High education group					
Socioeconomic characteristics in 2009					
Proportion with elementary & lower secondary	2.102**	2.576***	5.591***	3.069***	0.023
	(0.666)	(0.601)	(0.934)	(0.726)	(0.069)
Proportion with upper secondary & higher	-0.383	1.470*	-14.645***	0.376	0.234**
	(0.824)	(0.744)	(1.156)	(0.898)	(0.086)
Experience of floods and droughts in 2010					
Log flood index	0.021+	0.008	0.074***	0.031*	0.001
	(0.012)	(0.011)	(0.016)	(0.013)	(0.001)
Log drought index	0.085***	0.071***	0.232***	0.109***	-0.001
	(0.006)	(0.006)	(0.009)	(0.007)	(0.001)
Flood index x drought index	-0.005**	-0.006***	-0.017***	-0.005**	-0.0002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.0002)
Constant	-17.243***	-17.041***	-15.303***	-18.767***	-12.469***
	(1.089)	(0.982)	(1.527)	(1.187)	(0.113)
Observations	34,169	34,165	34,164	34,169	34,170
R-squared	0.02	0.02	0.06	0.02	0.40

*** p < 0.001, ** p < 0.01, * p < 0.05, + p < 0.1

[†]The full estimation results are presented in Appendix 1.

[‡] The villages are split into two educational groups following a median distribution of the proportion of people with at least upper secondary education. The average proportion of people with at least upper secondary education for the low education group is 9% and 22% for the high education group.

In the first model (Table 5), we did not control for village income in 2009. Exposure to floods no longer had a significant effect on income in the main model when we controlled for government financial assistance for the flood and drought affected districts. In fact, village-level income increased by 0.02% for each 1% increase in financial aid from the government for flood affected areas. Exposure to drought still had a negative effect on income, and government financial aid helped smooth income only slightly with an income increase of 0.002% for each 1% increase in government aid for drought affected areas. However, when controlling for initial income in 2009 in Model 2 (Table 5), the positive association between government financial assistance for flood-affected areas and income increase disappeared. This is because village income in 2009 was likely to be correlated with financial aid received because of floods.

When splitting the sample of villages into low and high education groups in Models 2.1 and 2.2 (Table 5), respectively, villages in the high education group experienced an extra increase in income when the financial assistance for droughts was greater.

Table 5. Difference-in-difference estimates of income (standard errors in parentheses): effects of government financial assistance.

	Model 1: All in sample	Model 2: All in sample	Model 2.1: Low education	Model 2.2: High education
Socioeconomic characteristics in 2009				
Income	-	0.834***	0.806***	0.859***
		(0.009)	(0.013)	(0.013)
Proportion with elementary & lower secondary	0.264**	-0.015	0.020	-0.105
	(0.101)	(0.084)	(0.105)	(0.144)
Proportion with upper secondary & higher	1.238***	0.085	0.195	0.045
	(0.126)	(0.106)	(0.248)	(0.180)
Proportion with other education	0.486***	0.081	0.080	0.247+
	(0.087)	(0.073)	(0.089)	(0.138)
Proportion of female headed household	-0.031	0.200***	0.034	0.238***
	(0.040)	(0.034)	(0.071)	(0.038)
Proportion aged 0-14 years	-0.593***	-0.342**	-0.408*	-0.280
	(0.154)	(0.129)	(0.162)	(0.217)
Proportion aged 60 years and over	-0.766***	0.052	0.204	-0.053
	(0.143)	(0.120)	(0.168)	(0.173)
Proportion of households in agriculture	-0.074***	0.006	-0.021	0.017*
	(0.008)	(0.007)	(0.014)	(0.008)
Proportion of households with insufficient water	-0.099***	-0.036*	-0.012	-0.057*
	(0.021)	(0.017)	(0.025)	(0.024)
Proportion of households with no electricity	-0.156	0.041	0.067	-0.020
	(0.120)	(0.101)	(0.127)	(0.164)
Δ (Difference between 2009 and 2011)				
Proportion with disability	-1.793***	-0.704***	-0.636**	-0.710***
	(0.178)	(0.149)	(0.219)	(0.209)
Proportion of sick people	0.069*	0.030	0.046	0.006
	(0.031)	(0.026)	(0.034)	(0.039)
Proportion of deaths	-1.753**	-0.164	-0.617	0.192
	(0.534)	(0.446)	(0.836)	(0.537)
Problem with poor soil	-0.009	0.012	0.002	0.025+
	(0.011)	(0.009)	(0.013)	(0.014)
Problem with labor shortage	-0.012	-0.008	-0.000	-0.020
	(0.014)	(0.011)	(0.015)	(0.017)
Problem with crop planted	0.017	0.015	0.019	0.012
	(0.012)	(0.010)	(0.013)	(0.014)
Problem with lack of knowledge	-0.016	-0.007	-0.014	0.001
	(0.012)	(0.010)	(0.014)	(0.015)
Problem with water shortage	-0.012	-0.002	0.006	-0.010
	(0.010)	(0.008)	(0.011)	(0.013)
Problem with inundation	0.000	-0.011	-0.023	0.003
	(0.012)	(0.010)	(0.014)	(0.015)
Experience of floods and droughts in 2010				
Log flood index	0.020	0.026+	0.022	0.033
	(0.016)	(0.014)	(0.018)	(0.021)
Log drought index	-0.019***	-0.005	-0.004	-0.005
	(0.004)	(0.003)	(0.004)	(0.004)
Log financial aid for flood	0.019***	0.001	0.002	-0.0005
	(0.004)	(0.003)	(0.005)	(0.005)
Log financial aid for drought	0.002**	0.002**	0.001	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)
Flood index x drought index	0.004	0.0003	0.0003	0.0003
	(0.003)	(0.002)	(0.003)	(0.003)
Constant	-0.450***	-11.813***	-11.444***	-12.118***
	(0.123)	(0.159)	(0.215)	(0.242)
Observations	20,192	20,192	11,103	9089
R-squared	0.04	0.33	0.30	0.37

*** p < 0.001, ** p < 0.01, * p < 0.05, + p < 0.1

DISCUSSION

The results from the main model, i.e., total sample, shows the positive impact of floods and droughts on consumption as measured by food and nonfood expenditures. This might appear counterintuitive but it is in line with other literature, which reports that weather shocks have a positive impact on household consumption (Dercon and Krishnan 2000, Irac and Minoiu 2007, Davies 2010). This suggests that communities are able to keep their consumption from deteriorating, as found in previous studies in developing countries, i.e., household consumption is smoothed notwithstanding the occurrence of economic shocks (Townsend 1994, Chetty and Looney 2006, Irac and Minoiu 2007).

In terms of investment in agriculture and human capital, agricultural spending also increased for villages located in districts with greater exposure to floods and droughts. Communities do not shy away from investment in agricultural production because of expected lower returns to investment or high risks involved. Similar to a previous study on the effects of natural disasters on educational investment in Indonesia (Kim and Prskawetz 2010), spending on education increased with the scale of floods and droughts. Thai rural communities continued to invest both in income-generating activities, i.e., agriculture, as well as human capital, i.e., education, after experiencing climate shocks.

Although communities managed to protect their consumption when affected by flood or drought, when both events occurred together their expenditures were significantly reduced. This is likely because two disaster events in the same year were quite rare. Although the communities were able to cope with the expected seasonal floods or droughts, the shock of a severe drought followed by a flood later in the year did disrupt lives and livelihoods considerably. Thus, the increase in intensity and frequency of climate shocks may pose negative consequences on community welfare, especially when the events are not anticipated.

In addition, flood and drought do not always have the same impact on community welfare. Although income significantly increases with exposure to flood; the opposite is true for exposure to drought. This is probably because of the difference in intensity and duration of the two shocks (McCann et al. 2011). Drought is a slow-onset type of disaster, whereas flood is rapid onset. Because droughts typically unfold on a timescale of months to years, can have a strong impact on agriculture, and affect prices for agricultural commodities, the deleterious impacts of droughts can be long lasting. However, floods are likely to be more localized and rather short-lived. Thus, communities may be able to compensate for flood damage more quickly than those of droughts.

With respect to welfare differentials by level of education, increased average level of education in a village was associated with higher food and nonfood consumption, expenditure on education, and income. The positive effect of education on consumption was also reported in studies investigating consumption smoothing at the household level. Studies in rural Malawi and in Indonesia reported higher per capita consumption among households with heads who had higher education levels (Davies 2010, Skoufias et al. 2011). Education is positively associated with recovery after natural disasters. A study on household-level recovery after floods in Pakistan reported the positive effect of the education of household heads on the overall recovery (Kurosaki et al. 2012). This suggests that higher education may offer a wider portfolio of coping strategies, such as borrowing, receiving help from formal and informal safety networks, or generating alternative income sources.

The protective effect of education can be seen not only in terms of consumption smoothing, but also in terms of avoiding inefficient coping mechanisms, such as the reduction of investment in education. In general, the expenditure on education increases the greater the exposure to droughts for both villages with low and high education. However, for the groups of villages with higher education, spending on education is even greater among communities with more exposure to floods. Highly educated communities might have considered the lower return to physical capital because of frequent weather shocks and decided to shift their investment toward human capital instead (Skidmore and Toya 2002).

Villages with high education benefitted from government financial aid for drought more than villages in the low education group. It is possible that higher education facilitates access to external resources as recorded in a study in Bangladesh, which demonstrated that education was positively associated with access to support from government and nongovernment sources (Paul 1998). Although government aid does explain the increase in income after natural disasters, the benefit seems to be concentrated among the communities with higher educational attainment.

CONCLUSION

We investigated how Thailand's worst droughts and second worst floods in two decades affected community welfare. Our results suggest that rural communities are able to smooth consumption in such a way that droughts and floods do not produce a negative effect on food and nonfood expenditures. Rather than cutting down their investment in physical and human capital to smooth consumption on necessary items such as food, spending on agriculture and education increased with flood and drought exposure.

There was some variation in consumption smoothing across communities with differing educational levels. In particular, communities with high education were able to increase education expenditure following the experience of flood or drought, whereas communities with low education increased their spending on education only marginally after drought.

Also, there was no evidence of income reduction because of flood or drought exposure in the highly educated communities partly because these communities were more able to benefit from government financial assistance.

These findings shed light on the presence of positive externalities of education. In normal times, education enhances skills and knowledge, which in turn can increase earning capacity. Education could also reduce vulnerability to climatic shocks by enabling individuals, households, and communities to overcome hardships after natural disasters because education is a transferable asset. In addition, that government financial assistance plays a key role in reducing climate-induced income shock is relevant for targeting flood and drought relief and transfers.

Responses to this article can be read online at: http://www.ecologyandsociety.org/issues/responses.php/5871

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Appendix 1

Table A1.1. Difference-in-difference estimates of community welfare (standard errors in parentheses): low education group

	Food expenditure	Non-food expenditure	Agriculture input expenditure	Education expenditure	Income
Socio-economic characteristics in 2009					
Income	0.854***	0.792***	0.979***	0.859***	0.825***
	(0.064)	(0.058)	(0.087)	(0.072)	(0.007)
Proportion with elementary & lower secondary	2.847***	3.313***	5.338***	5.013***	0.074+
	(0.416)	(0.376)	(0.561)	(0.464)	(0.045)
Proportion with upper secondary & higher	8.061***	7.362***	6.405***	15.306***	0.328*
	(1.251)	(1.131)	(1.686)	(1.394)	(0.134)
Proportion with other education	0.097	0.808*	-0.838+	1.893***	0.125**
	(0.374)	(0.339)	(0.505)	(0.417)	(0.040)
Proportion of female headed household	0.002	0.128	-0.874*	0.509+	0.092***
	(0.259)	(0.234)	(0.349)	(0.289)	(0.028)
Proportion aged 0-14 years	5.108***	3.218***	8.605***	7.897***	-0.489***
	(0.803)	(0.726)	(1.082)	(0.894)	(0.086)
Proportion aged 60 years and over	3.410***	2.314**	8.226***	3.896***	0.043
	(0.907)	(0.820)	(1.222)	(1.011)	(0.097)
Proportion of households in agriculture	0.170***	0.069	0.344***	0.026	0.008
	(0.047)	(0.043)	(0.064)	(0.053)	(0.005)
Proportion of households with insufficient water	-0.115	-0.040	-0.018	0.099	0.018
	(0.107)	(0.097)	(0.145)	(0.120)	(0.011)
Proportion of households with no electricity	0.272	0.251	0.564	-0.525	0.116*
	(0.549)	(0.496)	(0.739)	(0.611)	(0.059)
Δ (Difference between 2009 and 2011)					
Proportion with disability	-1.691*	-0.809	-0.459	-0.749	-0.383***
	(0.801)	(0.724)	(1.079)	(0.893)	(0.086)
Proportion of sick people	0.365+	0.117	-0.903***	0.049	0.016
	(0.192)	(0.174)	(0.259)	(0.214)	(0.021)
Proportion of deaths	-3.045	-1.375	1.490	-0.441	-0.540**
	(1.904)	(1.721)	(2.565)	(2.122)	(0.204)
Problem with poor soil	0.040	-0.013	0.010	0.037	-0.007
	(0.068)	(0.062)	(0.092)	(0.076)	(0.007)
Problem with labor shortage	0.011	0.016	0.145	-0.014	-0.009
	(0.084)	(0.076)	(0.113)	(0.093)	(0.009)
Problem with crop planted	0.140*	0.152*	0.290**	0.106	0.006
	(0.070)	(0.064)	(0.095)	(0.078)	(0.008)
Problem with lack of knowledge	-0.092	-0.132+	-0.214*	-0.011	-0.014+
	(0.075)	(0.068)	(0.101)	(0.083)	(0.008)

Problem with water shortage	0.145*	0.131*	0.249**	0.173*	0.013*
	(0.061)	(0.055)	(0.082)	(0.068)	(0.007)
Problem with inundation	-0.162*	-0.078	-0.033	-0.134	-0.003
	(0.078)	(0.071)	(0.105)	(0.087)	(0.008)
Experience of floods and droughts in 2010					
Log flood index	0.021*	0.002	0.049***	0.011	0.002+
	(0.010)	(0.009)	(0.014)	(0.011)	(0.001)
Log drought index	0.030***	0.024***	0.132***	0.048***	-0.002*
	(0.007)	(0.006)	(0.010)	(0.008)	(0.001)
Flood index x drought index	-0.011***	-0.008***	-0.011***	-0.012***	0.0001
	(0.002)	(0.002)	(0.003)	(0.002)	(0.0002)
Constant	-16.331***	-15.237***	-19.973***	-19.328***	-11.689***
	(0.996)	(0.901)	(1.342)	(1.110)	(0.107)
Observations	34,169	34,165	34,158	34,169	34,170
R-squared	0.02	0.02	0.03	0.02	0.32

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Table A1.2. Difference-in-difference estimates of community welfare (standard errors in parentheses): high education group

	Food expenditure	Non-food expenditure	Agriculture input expenditure	Education expenditure	Income
Socio-economic characteristics in 2009					
Income	0.984***	0.972***	0.765***	0.997***	0.881***
	(0.060)	(0.054)	(0.084)	(0.065)	(0.006)
Proportion with elementary & lower secondary	2.102**	2.576***	5.591***	3.069***	0.023
	(0.666)	(0.601)	(0.934)	(0.726)	(0.069)
Proportion with upper secondary & higher	-0.383	1.470*	-14.645***	0.376	0.234**
	(0.824)	(0.744)	(1.156)	(0.898)	(0.086)
Proportion with other education	-0.280	0.663	-2.785**	0.209	0.104
	(0.658)	(0.594)	(0.923)	(0.717)	(0.068)
Proportion of female headed household	0.532**	0.486**	0.527*	0.245	0.112***
	(0.189)	(0.171)	(0.265)	(0.206)	(0.020)
Proportion aged 0-14 years	9.351***	6.943***	13.611***	13.127***	-0.184+
	(1.029)	(0.928)	(1.442)	(1.121)	(0.107)
Proportion aged 60 years and over	4.915***	2.474**	12.902***	5.271***	-0.222*
	(0.908)	(0.819)	(1.273)	(0.989)	(0.094)
Proportion of households in agriculture	0.034+	0.013	0.072**	-0.003	0.004+
	(0.019)	(0.018)	(0.027)	(0.021)	(0.002)
Proportion of households with insufficient water	-0.268+	-0.103	0.454*	-0.211	-0.005
	(0.141)	(0.127)	(0.198)	(0.154)	(0.015)
Proportion of households with no electricity	0.090	0.382	-1.318	-0.079	-0.086
	(0.645)	(0.582)	(0.905)	(0.703)	(0.067)
Δ (Difference between 2009 and 2011)					
Proportion with disability	-0.226	0.098	-1.065	-0.779	-0.442***
	(0.748)	(0.675)	(1.049)	(0.815)	(0.078)
Proportion of sick people	0.020	-0.009	0.160	-0.179	0.015
	(0.112)	(0.101)	(0.157)	(0.122)	(0.012)
Proportion of deaths	2.791	1.842	1.502	2.996	-0.222
	(1.811)	(1.634)	(2.539)	(1.973)	(0.188)
Problem with poor soil	0.039	0.032	0.178+	-0.013	0.007
	(0.075)	(0.068)	(0.105)	(0.082)	(0.008)
Problem with labor shortage	0.055	0.057	-0.267*	0.034	0.004
	(0.089)	(0.080)	(0.125)	(0.097)	(0.009)
Problem with crop planted	0.015	-0.001	0.227*	0.047	-0.001
	(0.075)	(0.068)	(0.106)	(0.082)	(0.008)
Problem with lack of knowledge	0.081	-0.007	0.154	0.066	0.006
	(0.081)	(0.073)	(0.113)	(0.088)	(0.008)
Problem with water shortage	0.110+	0.150*	0.334***	0.212**	-0.009

	(0.066)	(0.060)	(0.093)	(0.072)	(0.007)
Problem with inundation	0.049	0.036	0.176	0.027	-0.008
	(0.083)	(0.074)	(0.116)	(0.090)	(0.009)
Experience of floods and droughts in 2010					
Log flood index	0.021+	0.008	0.074***	0.031*	0.001
	(0.012)	(0.011)	(0.016)	(0.013)	(0.001)
Log drought index	0.085***	0.071***	0.232***	0.109***	-0.001
	(0.006)	(0.006)	(0.009)	(0.007)	(0.001)
Flood index x drought index	-0.005**	-0.006***	-0.017***	-0.005**	-0.0002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.0002)
Constant	-17.243***	-17.041***	-15.303***	-18.767***	-12.469***
	(1.089)	(0.982)	(1.527)	(1.187)	(0.113)
Observations	34,169	34,165	34,164	34,169	34,170
R-squared	0.02	0.02	0.06	0.02	0.40

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

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The Role of Education on Disaster Preparedness: Case Study of 2012 Indian Ocean Earthquakes on Thailand's Andaman Coast

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ABSTRACT. In this paper we investigate how well residents of the Andaman coast in Phang Nga province, Thailand, are prepared for earthquakes and tsunami. It is hypothesized that formal education can promote disaster preparedness because education enhances individual cognitive and learning skills, as well as access to information. A survey was conducted of 557 households in the areas that received tsunami warnings following the Indian Ocean earthquakes on 11 April 2012. Interviews were carried out during the period of numerous aftershocks, which put residents in the region on high alert. The respondents were asked what emergency preparedness measures they had taken following the 11 April earthquakes. Using the partial proportional odds model, the paper investigates determinants of personal disaster preparedness measured as the number of preparedness actions taken. Controlling for village effects, we find that formal education, measured at the individual, household, and community levels, has a positive relationship with taking preparedness measures. For the survey group without past disaster experience, the education level of household members is positively related to disaster preparedness. The findings also show that disaster-related training is most effective for individuals with high educational attainment. Furthermore, living in a community with a higher proportion of women who have at least a secondary education increases the likelihood of disaster preparedness. In conclusion, we found that formal education can increase disaster preparedness and reduce vulnerability to natural hazards.

Key Words: *disaster preparedness; earthquake; education; partial proportional odds model; Thailand; tsunami*

INTRODUCTION

Although it remains impossible to predict when and where an earthquake will occur, the impacts of earthquake disasters can be reduced by taking a variety of personal safety measures (Turner et al. 1986, Lehman and Taylor 1987, Ramirez and Peek-Asa 2005). Likewise, catastrophes from a tsunami, a massive wave caused by undersea earthquakes, can be mitigated or avoided through effective warning systems. Indeed, the catastrophic loss of the Indian Ocean Tsunami of December 2004 was largely due to the absence of warning systems, lack of knowledge, and lack of preparedness among the populations at risk (Rachmalia et al. 2011).In contrast, in Japan's Tohoku earthquake on 11 March 2011, the effectiveness of local emergency warning systems and disaster preparedness among Japanese citizens saved many lives, despite the short time between the quake and the tsunami. These examples illustrate that personal disaster preparedness is critical to mitigate disaster impacts.

Being prepared for a major disaster is the most effective way to minimize the damage suffered by the affected population (Banerjee and Gillespie 1994). Emergency management officials and disaster planners recognize that for the first 72 hours after an earthquake or other disaster strikes, individuals and families should be prepared for self-sufficiency because services and supplies can be disrupted and emergency assistance might not be immediately available (Russell et al. 1995, Basolo et al. 2009). Preparedness is also associated with successful evacuations during a hurricane (Howell and Bonner 2005, Dash and Gladwin 2007) and improvements in individuals' resilience in coping with trauma (Bravo et al. 1990). Accordingly, the U.S. government has directed resources to improve individual emergency preparedness for both natural and man-made disasters (Eisenman et al. 2006).

Using the Indian Ocean earthquakes on 11 April 2012 as a case study, this paper investigates determinants of emergency disaster preparedness among residents living along the Andaman coast in Phang Nga province, Thailand. The 11 April earthquake not only set off tsunami warnings, but triggered a series of minor secondary earthquakes. The survey was conducted immediately after the Indian Ocean earthquakes and during and just after the period of the minor earthquakes, allowing us to observe disaster preparedness in the moment when that preparedness was being tested by events. We analyze preparedness actions for both the tsunami and earthquakes following the 11 April quakes. In particular, we investigate the association between educational attainment and disaster preparedness, taking into account relevant demographic, socioeconomic, and community characteristics that could influence preparedness actions. We examine how disaster preparedness varies by education at the individual, household, and community levels, and how education interacts with other characteristics in shaping preparedness behaviors. Moreover, given that people in a community interact and exchange information, we argue that living in a community with high average level of education is beneficial in improving preparedness levels.

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This research adds to the literature on disaster preparedness and vulnerability in three ways. First, there have been few studies that focus on the relationship between educational attainment and disaster preparedness, and those that exist do not consider in depth how education can influence preparedness. In this paper we extend beyond the current literature by exploring plausible explanations how formal education can influence preparedness actions. Second, while most studies investigate the influence of individual or household-level education on disaster preparedness, we also consider the influence of community-level education and demographic factors. Third, scientific studies on disaster preparedness have been predominantly conducted in the U.S. There are very few studies on other countries, especially developing countries (Mishra and Suar 2007, Mishra et al. 2010, Ferdinand et al. 2012). We provide new empirical evidence on Thailand, where disaster preparedness has not yet been investigated.

LITERATURE REVIEW AND HYPOTHESES

Preparedness actions are influenced by a broad range of factors. Risk perception is strongly associated with disaster preparedness because individuals must perceive a risk to be motivated to initiate preparedness actions (Sattler et al. 2000, Miceli et al. 2008). An individual's previous experience with a hazardous event can heighten perception of risk and promote preparedness actions (Russell et al. 1995, Lindell and Perry 2000, Tekeli-Yeşil et al. 2010). Other factors that influence preparedness behaviors vary considerably with socioeconomic and demographic characteristics. Individuals of different social groups receive and evaluate risk information differently and have unequal resources to carry out preparedness measures. For instance, there is evidence that women and men differ in the types of preparedness activities they take. Although women are more likely to prepare their families for disaster than men, they are less represented in formal emergency planning organizations (Fothergill 1996). Preparedness increases with age (Sattler et al. 2000, Mishra and Suar 2005), but the very old are less likely to engage in preparation (Heller et al. 2005). In addition to education, socioeconomic factors including income, home ownership, and length of residence in the same location are also positively associated with disaster preparedness (Lindell and Perry 2000, Eisenman et al. 2006, Reininger et al. 2013).

Although many of the factors associated with disaster preparedness, such as age, sex, and race are ascribed characteristics that are determined by nature, characteristics such as income and education are qualities that are dependent on individual initiative and can be achieved over the life course. Because income and education are positively associated with disaster preparedness (Russell et al. 1995, Liu et al. 1996, Lindell and Perry 2000, Bourque et al. 2012), improving a person's socioeconomic level could directly or indirectly increase preparedness activities. We argue that education in particular is a key tool to promote disaster preparedness because highly educated individuals have better economic resources to undertake preparedness actions, and because education may influence cognitive elements and shape how individuals perceive and assess risks, and how they process risk-minimizing information (Menard et al. 2011).

Because preparedness action is closely related to how individuals perceive and act on risk information (Tierney et al. 2001), educated individuals might have more awareness of risks because they are likely to have greater access to information sources and be better able to evaluate the risk information (Jamison and Moock 1984, Rogers 1995, Asfaw and Admassie 2004). There is also evidence that education increases the acquisition of general knowledge that could influence values, priorities, capacity to plan for the future, and ability to appropriately allocate available resources (Thomas et al. 1991, Glewwe 1999, Burchi 2010). The knowledge and competence gained through education thus could be useful when a disaster strikes. This leads to the following hypotheses:

- H1: Education has a positive effect on disaster preparedness by improving income level, which is positively associated with preparedness.
- H2: Education has a positive direct effect on disaster preparedness because education enhances cognitive and risk evaluation skills.

Empirical evidence on the relationship between educational level and preparedness behaviors, however, has not been adequately established. Although some studies find that higher educational attainment enhances disaster preparedness (Edwards 1993, Norris et al. 1999, Murphy et al. 2009, Baker 2011, Menard et al. 2011), numerous other studies report no association between the two factors (Jackson 1981, Faupel et al. 1992, Siegel et al. 2003, Heller et al. 2005, Spittal et al. 2008, Kim and Kang 2010). Generally, education is treated as a control variable and emphasis is not put on understanding how education may influence preparedness behaviors. An exception is the recent study by Menard et al. (2011) that explicitly focuses on establishing the relationship between having a postsecondary degree and disaster preparedness. The study reported that individuals with a college degree are more likely to have an emergency plan and know where to get additional information. Going to college in the U.S. not only increases overall education, but exposes individuals to university emergency systems. Overall higher education and direct experience with an existing emergency system may influence how individuals process risk-minimizing information. Although Menard's study provides evidence on the influence of higher education on disaster preparedness, in the absence of multivariate analysis, it fails to consider confounding factors that can influence both education and preparedness. We fill this gap using multivariate models.

Apart from formal schooling, there is evidence that disaster education interventions can be influential in raising awareness and knowledge of disasters, which in turn can enhance disaster preparedness actions (Faupel and Styles 1993, Tanaka 2005, Page et al. 2008). The link between formal schooling and disaster education interventions has been recognized and disaster-related education has been promoted by some international agencies as a key approach to build disaster-resilient societies (UNISDR 2007, Selby and Kagawa 2012). Nevertheless, there are few empirical studies that consider the interplay between formal education and disaster education in shaping preparedness behaviors. Arguing that formal education can enhance learning skills, the hypothesis formulated here is as follows:

- H3: Disaster-related education increases disaster preparedness and the increase is even greater among highly educated individuals.

Because the majority of studies on disaster preparedness were predominantly carried out in the U.S. and focus on disaster preparedness for hurricanes, the identified associations between various characteristics and disaster preparedness may not apply to all types of disaster and geographical contexts (Kohn et al. 2012). In this paper we provide new empirical evidence on preparedness for earthquakes in Thailand.

CASE STUDY OF 2012 INDIAN OCEAN EARTHQUAKES

2012 Indian Ocean earthquakes

We use the 2012 Indian Ocean earthquakes as a case study of personal emergency preparedness. Earthquakes are rare in Thailand. The country has experienced midsized earthquakes (M5.0 - 5.9) only eight times over the past 40 years (CICC 2012). As a result, preparedness for earthquakes has not been given a priority either at the national or individual level. The 2012 Indian Ocean earthquakes were followed by tsunami warnings and numerous other quakes. The earthquakes consequently put people in the region on high alert and may have triggered preparedness actions among the residents.

On 11 April 2012 at 15:38 local time, a powerful magnitude 8.6 undersea earthquake struck 434 km southwest of the Indonesian province of Banda Aceh in northern Sumatra. It was followed by another major shock (M8.2) at 17:43 local time 200 km to the south, as well as numerous aftershocks (USGS 2012). The Pacific Tsunami Warning Center issued a tsunami watch for countries all along the Indian Ocean rim, from Australia and India to far off Africa. In Thailand, the Department of the Disaster Prevention and Mitigation (DDPM) issued an urgent tsunami warning and evacuation order for people living on the Andaman coast of six southern provinces, the same region that had been hit by the 2004 Indian Ocean Tsunami. Fortunately, a devastating tsunami did not occur because both the initial earthquake and the M8.2 aftershock were a slip-strike earthquake whereby two tectonic plates, Indian and Australian plates, slid against one another horizontally and this lateral movement did not lead to a vertical displacement of water. The tsunami warnings were then lifted several hours later (BBC 2012).

Although a tsunami did not occur, the quakes sparked fear among local residents and tourists, especially in the areas damaged by the 2004 tsunami. This panic was exacerbated by the earthquake of 4.3 magnitude, which struck Phuket with its epicenter at Thalang district five days later, on 16 April 2012, at 16:44 local time. This was followed by a series of more than 26 aftershocks, occurring through 22 April 2012. The Phuket earthquakes might have been triggered by the Indonesian earthquake, as a recent study reports a significant increase in the occurrence of sizable quakes in the six days following 11 April (Pollitz et al. 2012). The Indonesian and the Phuket earthquakes put people living near the southern Andaman coast on high alert because of fear of the tremors and the threat of a repeat of the 2004 tsunami.

DATA AND METHODS

Study area

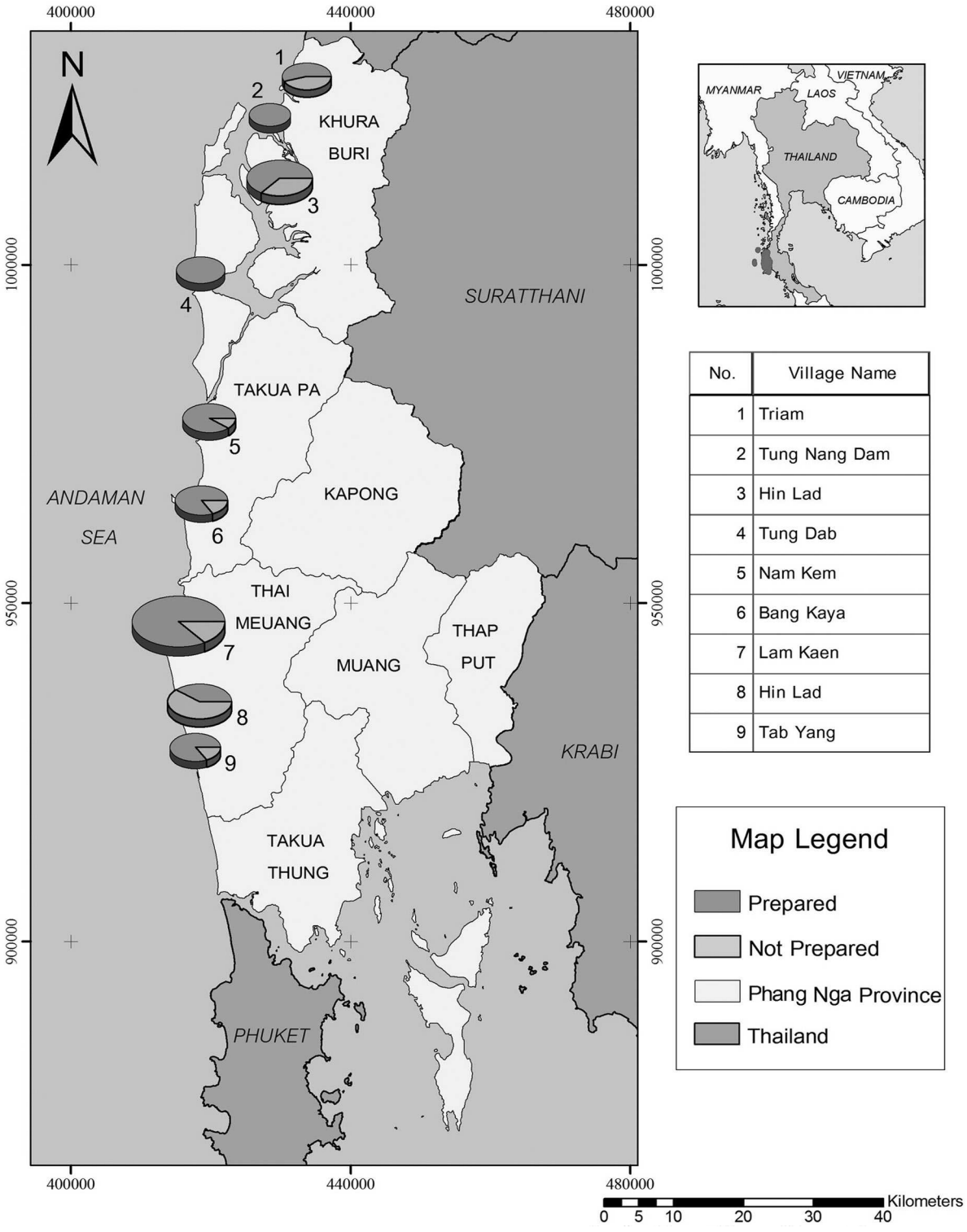
Phang Nga province was chosen for our study because the province suffered the greatest human loss and massive economic impact as a result of the 2004 tsunami. Of the six Thai provinces affected by the tsunami (Nidhiprabha 2010), with a coastline of 240 km, Phang Nga alone experienced 5880 lives lost, accounting for 72% of the total deaths and missing persons in Thailand. Takua Pa District, a popular area for tourists because of its numerous beach resorts, was the most severely hit area in the 2004 disaster, with run-up heights varying between 5 to 10 m (FAO 2005, Römer et al. 2012). Inundation distances reached as far as two kilometers inland in some areas, causing widespread devastation (Thanawood et al. 2006).

Given the large-scale impacts from the 2004 event, Phang Nga residents might be expected to improve personal disaster preparedness initiatives. In this study, we assess disaster preparedness in the areas that were issued tsunami warnings on 11 April 2012 by the DDPM. Nine villages were randomly selected as interview sites. These villages varied considerably in terms of population numbers and level of disaster preparedness (see Fig. 1).

Data sources

The analysis is based on two data sources. The data for personal preparedness were obtained from a survey of households located in tsunami high-risk areas in Phang Nga province (see Fig. 1) conducted by the College of Population Studies, Chulalongkorn University between 17 April – 13 May 2012. The survey consisted of face-to-face interviews carried out in the Thai language by trained interview staff and local researchers. For each village, 30% of the households were

Fig. 1. Map of sampled nine villages in Phang Nga province and percentage of respondents undertaking preparedness actions in a village (size of pie chart corresponds with population size).



No.	Village Name
1	Triam
2	Tung Nang Dam
3	Hin Lad
4	Tung Dab
5	Nam Kem
6	Bang Kaya
7	Lam Kaen
8	Hin Lad
9	Tab Yang

selected for an interview through systematic random sampling. In total, interviews were conducted in 563 households with the head of household being the first approached; if not present, the spouse or a household member aged 15 years or older was asked to participate.

The questionnaire contained questions on basic demographic and socioeconomic characteristics of the respondent and the household. A set of questions related to awareness of, response to, and preparedness for the 2012 Indian Ocean earthquakes were also included. Questions regarding experience with the 2004 tsunami, social activities engaged in, and channels of information received were also asked. The final sample consisted of 557 households with valid responses to all questions used in the analysis. The data on basic demographic and education at the village-level was obtained from the 2010 Population and Housing Census, supplied in an aggregated form by the National Statistical Office, Thailand.

Variables

The empirical analysis explored determinants of disaster preparedness actions based on characteristics associated with preparedness behaviors as cited in previous literature. In particular, we investigated the relationships between formal education and disaster preparedness.

Dependent variable

Given the fact that Thailand's southern Andaman coast was on high alert because of the Indonesian and subsequent Phuket earthquakes during the period of the survey, the outcome of interest was whether people living in the high-risk areas were taking any measures to prepare for the earthquakes and the hazards that might follow. The dependent variable was taken from the question which asks: "Have you or your family taken any preparedness actions after the 11 April 2012 Indonesian earthquake?" Response categories were: (1) no preparation; (2) keeping close watch of the situation; (3) preparation of survival kits; (4) planning evacuation procedure and emergency plan with household members; (5) inspection of house structure; and (6) other preparations.

Explanatory variables

1) Education: Following the hypotheses that education could enhance awareness and preparedness for disasters, we measured the relationships between education and preparedness after the Indian Ocean earthquakes at three levels.

- Individual level – the highest level of education of the respondents divided into four categories: (1) no education and elementary; (2) lower secondary; (3) upper secondary; and (4) tertiary
- Household level – the number of household members with at least secondary education
- Village level – proportion of men and women with at least secondary education in the village

2) Disaster-related variables: We included disaster-related variables previously found to be associated with disaster preparedness (Mileti and Fitzpatrick 1992, Faupel and Styles 1993, Heller et al. 2005, Mishra and Suar 2007). These variables were measured at the individual level, including:

- Tsunami experience – coded 1 if the respondent was affected by the 2004 tsunami; 0 otherwise
- Participation in tsunami drills and disaster education – code 1 if the respondent participated in tsunami drills and/or disaster education; 0 otherwise
- Number of information sources – a continuous variable measuring the number of sources of information where the respondents obtained the news about the 11 April 2012 earthquakes and tsunami warnings

Control variables

Control variables included individual, household, village demographic, and other relevant characteristics.

- Individual level – age, sex, occupation, marital status, years of residence in a house
- Household level – household income, number of usual residents, number of members aged 0-5 years, number of household members aged ≥ 60 years, number of disabled members, whether household located on the coast
- Village level – village indicator, proportion of women, proportion of people aged ≥ 65 years

All independent variables included in the multivariate analyses were tested for a potential problem of multicollinearity and no problem was detected.

Statistical techniques

To investigate the determinants of personal preparedness, we performed chi-square analysis comparing the number of preparedness activities undertaken by demographic and socioeconomic characteristics. In the case where the determinants were continuous variables, one-way analysis of variance (ANOVA) was performed to compare means of the relevant variables by number of preparedness activities.

Subsequently, positing that a person's disaster preparation outcome was likely to be a product of individual and household characteristics, as well as the characteristics of the village in which the person lives, we performed multivariate analysis to explore the influence of different factors on disaster preparedness actions at the same time.

Because the outcome variable (number of preparedness measures taken) was not normally distributed, ordinary least squares regression could not be used because the normality assumption would be violated. We then grouped the number of preparation activities into three ordinal categories: no

preparation, one preparation measure, two or more preparation measures. Although ordered logistic regression is an appropriate method for an ordinal response variable, the model is only valid for the data that meet the proportional odds assumption, that is, the coefficients that describe the relationship between any two pairs of outcome groups are statistically the same. For our data, the likelihood-ratio test showed that the proportional odds assumption was violated (Wolfe and Gould 1998). Thus we decided to adopt the partial proportional odds model, which allows the coefficients that violate the proportional odds assumption to vary across logistic equations, i.e., to have different effects on the dependent variable (Peterson and Harrell 1990, Fullerton and Xu 2012).

The partial proportional odds model (PPOM) can be expressed as a generalized ordered logit model:

$$P(Y_i > j) = g(X\beta_j) = \frac{\exp(\alpha_j + X_i\beta_j)}{1 + [\exp(\alpha_j + X_i\beta_j)]} \quad \text{with } j = 1,2 \ldots, M-1 \tag{1}$$

where M is the number of categories of the ordinal dependent variable (3 in our case) and β_j is unique for each j for the coefficients that the proportional odds assumption is violated otherwise $\beta_j=\beta$. For our analysis, M = 3 thus the PPOM is equivalent to a series of binary logistic regressions where categories of the dependent variable are combined. The dependent variable is defined over an increasing number of preparation measures taken: $Y = 1$ for no preparation, $Y = 2$ for one preparation measure taken, and $Y = 3$ for two or more preparation measures taken. In our case, $M = 3$, then for $J = 1$ category *Y1* is contrasted with *Y2* and *Y3* (logit 1); and for $J = 2$ the contrast is between *Y1* and *Y2* versus *Y3* (logit 2). This way each group is compared to groups with higher number of preparation measures.

All statistical analyses were carried out in the statistical software STATA, version 11 and the PPOM is estimated using *gologit2*, a user written program (Williams 2006).

RESULTS

Binary relationships between disaster preparedness and individual, household, and village characteristics

Table 1 describes demographic characteristics of the sample at the individual, household, and village levels. Binary relationships between these characteristics and the number of preparedness measures taken are also presented. As shown in Table 1, the number of preparedness actions carried out differs notably by age and occupation: 28.6% of individuals in the youngest age group, 34.7% of those in the oldest age group, and 44% of those engaged in agriculture did not take any preparedness actions. Disaster-related variables are significantly associated with disaster preparedness. Respondents who were affected by the 2004 tsunami and participated in evacuation drills and disaster education are more likely to be prepared and more likely to undertake more than just one preparedness measure. Individuals with higher number of sources of information on tsunami and earthquakes news are also more likely to be prepared.

Considering household characteristics, demographic composition in a household is related to disaster preparedness, whereby households with a higher number of members aged ≥ 60 years (0.72) and a lower number of members with disability (0.02) are less likely to be prepared. Note that on the average the number of elderly and disabled household members is less than 1 in most households. Preparedness is significantly related with household location: only 14.3% of those living on the coast were not prepared as compared to 38.9% of those whose house located ≥ 1 km from the shore. With respect to village characteristics, respondents living in a village with higher proportion of women had lower rates of taking preparedness actions.

Regarding disaster preparedness and education, there is a weak relationship between individual education and the number of preparedness measures taken. Those with no education or with only elementary education were less likely to be prepared (29.4%). Respondents with tertiary education were more likely to be prepared and to have taken more than one preparedness action (41.2%). The average education level in a village is also highly correlated with disaster preparedness, with the respondents with higher number of preparation activities being more likely to live in a village with a higher proportion of men and women with at least secondary education.

Disaster preparedness considering village effects

In Table 2, we apply the partial proportional odds model (PPOM) to estimate the factors associated with disaster preparedness, taking into account the differences between villages. Models 1 and 2 include a village indicator variable to control for the possibility that disaster preparedness outcome can vary depending on the village in which one lives.

In Model 3, we explore the relationships between village demographic characteristics and disaster preparedness. Note that the village indicators are not included in Model 3 because the models with village indicators are equivalent to a fixed effects estimator where village-level covariates are treated as nuisances and cannot be estimated (Paul et al. 2010). We also exclude the two villages in our original sample where all respondents have taken preparedness actions (see Fig. 1). The analysis in Tables 2 and 3 thus include the sample of 544 subjects.

Our interpretation of the parameter estimates is as follows. The results can be interpreted in the same way as traditional ordered logit models, that is, the change in the log odds of the

Table 1. Summary statistics of individual-, household-, and village-level characteristics and binary relationships between these characteristics and disaster preparedness.

	No preparation	One preparation	Two or more preparations	N	Total
Individual characteristics					
Educational attainment+					
no & elementary education	29.4%	43.4%	27.2%	371	66.6%
lower secondary	23.7%	56.6%	19.7%	76	13.6%
upper secondary	23.7%	40.7%	35.6%	59	10.6%
tertiary	17.6%	41.2%	41.2%	51	9.2%
Status in household					
head of household	28%	44.9%	27.1%	336	60.3%
not head of household	25.3%	44.3%	30.3%	221	39.7%
Years of residence in household	27.93(20.21)	25.33(15.42)	25.58(16.32)	557	26.1(17.09)
Sex					
men	27.9%	47%	25.1%	251	45.1%
women	26.1%	42.8%	31%	306	54.9%
Age**					
< 30 years	28.6%	32.9%	38.6%	70	12.6%
30 - 39 years	20.8%	50.9%	28.3%	106	19%
40 - 49 years	25.2%	53.3%	21.5%	135	24.2%
50 - 59 years	25.4%	41%	33.6%	122	21.9%
60 years and over	34.7%	40.3%	25%	124	22.3%
Marital status					
divorced/separated/widowed	24.1%	51.9%	24.1%	79	14.2%
married	26.2%	44.7%	29.1%	409	73.4%
single	34.8%	36.2%	29%	69	12.4%
Occupation**					
fishery	23.1%	50%	26.9%	52	9.3%
agriculture	44%	44%	12%	75	13.5%
laborer	27.6%	37.9%	34.5%	87	15.6%
general trade/own business	24.2%	44.8%	30.9%	194	34.8%
private employee/civil servant	13.9%	55.6%	30.6%	36	6.5%
economically inactive	25.7%	44.2%	30.1%	113	20.3%
Experience of 2004 tsunami**					
not affected	40.7%	38.9%	20.4%	216	38.8%
affected	18.2%	48.4%	33.4%	341	61.2%
Participated in evacuation drills and disaster education**					
not participated	38%	40.7%	21.4%	332	59.6%
participated	10.7%	50.7%	38.7%	225	40.4%
Number of sources of information**	2.41(1.02)	2.94(1.44)	3.2(1.48)	557	2.87(1.38)
Household characteristics					
Number of members with at least secondary education					
none	29.3%	43.8%	26.9%	283	50.8%
one person	23.8%	46.4%	29.8%	168	30.2%
two or more persons	25.5%	44.3%	30.2%	106	19%
Number of persons in household	3.98(2.21)	3.73(1.95)	3.96(1.80)	557	3.87(1.98)
Number of children aged ≤ 5 years	0.37(0.67)	0.36(0.63)	0.39(0.67)	557	0.37(0.65)
Number of members aged ≥ 60 years**	0.72(0.98)	0.39(0.66)	0.52(0.82)	557	0.52(0.81)
Number of members with disability**	0.02(0.14)	0.03(0.18)	0.08(0.28)	557	0.04(0.20)
Household income					
< THB 10,000	27.8%	46.5%	25.8%	198	35.5%
THB 10,000 - 19,999	26%	46.2%	27.8%	223	40%
THB 20,000 - 29,999	26.4%	42.5%	31%	87	15.6%
THB 30,000 and over	28.6%	34.7%	36.7%	49	8.8%
House location**					
house located on the coast	14.3%	50%	35.7%	70	12.6%
house located < 1 km from the shore	19.9%	48.3%	31.8%	261	46.9%
house located ≥ 1k m from the shore	38.9%	38.9%	22.1%	226	40.6%

(con'd)

Village characteristics					
Percentage of men with at least secondary education**	20.39(6.21)	23.19(6.22)	24.65(7.63)	557	22.85(6.83)
Percentage of women with at least secondary education**	24.9(6.61)	30.39(6.59)	31.23(6.43)	557	29.15(7.04)
Percentage of members aged 60 years and over	5.67(2.41)	5.52(1.79)	5.24(1.74)	557	5.48(1.97)
Percentage of women**	46.14(2.79)	45.13(2.32)	44.4(2.17)	557	45.19(2.50)

Note: Standard deviations are in parentheses. For categorical variables, chi-square tests were performed to test the relationship between that particular variable and disaster preparedness. For continuous variables, ANOVA was applied.
THB = Thai baht
** $p < 0.05$

response variable per unit change in the predictor. Tables 2 and 3 present the results in odds ratio (OR), the exponential function of the regression coefficient ($\exp^{\beta}$). OR > 1 indicates the higher odds of preparedness while OR < 1 indicates the lower odds of preparedness. Unlike the ordered logit models, in the PPOM, multiple coefficients are estimated for each variable that violates the proportional odds assumption. Accordingly, for these variables, two different coefficients are listed. The first coefficient (not in bold) predicts responses for the first logit equation (Logit 1) whereas the second coefficient (in bold) predicts responses for the second logit equation (Logit 2). In Logit 1 the reference group is no preparation; while in Logit 2 the reference group is individuals who have not done any preparation or have taken only one preparedness measure. The percentage change in odds for each unit increase in the independent variable is calculated using the formula: $100 (\exp^{\beta} - 1)$.

The model estimates in Table 2 are presented in a forward stepwise manner. Model 1 investigates the relationships between individual demographic characteristics including disaster-related variables and disaster preparedness. Individual education and marital status appear to be a key determinant of disaster preparedness. Generally speaking, higher levels of education are strongly associated with a higher number of disaster preparedness activities. Likewise, individuals who are married are more likely to be prepared. With respect to disaster-related variables, the experience of tsunami in 2004 and participation in evacuation drills and disaster education are not significantly associated with disaster preparedness, unlike what we found in the binary statistics. The number of sources of information is positively related to the number of preparedness actions taken. An increase in one source of information increases the odds of preparation by 1.35 times. Model 2 includes household characteristics. Household income has no significant relationship with disaster preparedness. Consistent with the binary statistics, the greater the number of household members aged ≥ 60 years, the lower the likelihood of preparation, but this applies only to the first logit equation. Likewise, the greater the number of disabled members, the greater the odds of preparedness. We find a weak positive relationship between education of household members and the number of preparedness activities taken. Model 3 includes village characteristics. In this model, the coefficients for education of household members become statistically significant. It is also found that while 1% increase in the proportion of women in a village reduces the likelihood of preparation by 17%, a 1% increase in the proportion of women with at least secondary education increases the odds of preparation by 11%.

Variation of determinants of disaster preparedness by individual education and previous tsunami experience

It is also of interest to compare whether the effects of the determinants of disaster preparedness vary by individual education and tsunami experience. In Table 3 we estimate the PPOM models splitting the sample by: (1) individual education, defined as individuals with less than secondary education and individuals with at least secondary education; and by (2) individual tsunami experience, defined as individuals not affected by the 2004 tsunami and individuals affected by the 2004 tsunami. Splitting the sample by individual education, Table 3 shows that the predictors of the likelihood of preparation vary considerably by educational level. For respondents with low educational attainment, the main factors influencing disaster preparedness are the number of sources of information and some household demographic characteristics, i.e., the number of the elderly and disabled member. On the other hand, for individuals with higher education, it is evident that their likelihood of taking preparedness actions increases with tsunami experience, participation in evacuation drills, disaster education, and the number of sources of information received. For this group the number of household members with at least secondary education further increases the likelihood of preparation. The odds of undertaking preparatory activities significantly increase by 2.5 and 4.5 times for highly educated individuals living in a household with one, two, or more members with at least secondary education respectively.

Regarding the analysis that splits the sample by tsunami experience, Table 3 reports that for individuals not being affected by the 2004 tsunami, evidently education of the household members is a key driver for taking preparedness actions. For this group, the odds of preparedness for those living in a household with two or more members with at least secondary education is 6.6 times greater than those living in a household where none of the household members possess

Table 2. Odds ratio estimated from partial proportion odds ordered logit models predicting disaster preparedness with village indicators and characteristics.

	Model 1		Model 2		Model 3	
	β	s.e.	β	s.e.	β	s.e.
Individual characteristics						
Education (ref: no & elementary)						
lower secondary	0.942	(0.254)	0.976	(0.279)	0.935	(0.266)
upper secondary	1.882**	(0.584)	1.749+	(0.576)	1.642	(0.534)
tertiary	2.327**	(0.787)	2.116**	(0.786)	1.985+	(0.731)
Head of household	0.902	(0.204)	0.886	(0.209)	0.935	(0.218)
Years of residence in household	1.003	(0.006)	1.005	(0.007)	1.006	(0.007)
Women	1.361	(0.298)	1.410	(0.317)	1.349	(0.301)
Age (ref: < 30 years)						
30 - 39 years	0.784	(0.265)	1.180	(0.496)	1.189	(0.494)
			0.510+	**(0.199)**	**0.533**	**(0.206)**
40 - 49 years	0.912	(0.351)	0.937	(0.385)	1.043	(0.419)
	0.436**	**(0.167)**	**0.321****	**(0.131)**	**0.351****	**(0.140)**
50 - 59 years	0.925	(0.345)	0.851	(0.333)	0.915	(0.352)
60 years and over	0.696	(0.291)	1.539	(0.824)	1.603	(0.841)
					0.400+	**(0.216)**
Marital status (ref: single)						
divorced/separated/widowed	1.088	(0.438)	0.995	(0.427)	1.102	(0.467)
married	1.890**	(0.590)	1.964**	(0.648)	1.918**	(0.629)
Occupation (ref: agriculture)						
fishery	0.586	(0.245)	0.636	(0.278)	0.696	(0.300)
laborer	1.094	(0.388)	0.590	(0.244)	0.734	(0.297)
			1.610	**(0.645)**	**1.840**	**(0.726)**
general trade/own business	0.855	(0.270)	0.841	(0.276)	1.038	(0.333)
private employee/civil servant	1.088	(0.480)	1.082	(0.501)	1.344	(0.611)
economically inactive	1.232	(0.418)	1.165	(0.411)	1.307	(0.454)
Affected by tsunami in 2004	1.450+	(0.315)	1.425	(0.325)	1.172	(0.255)
Participated in evacuation drills and disaster education	1.465	(0.359)	1.462	(0.370)	1.340	(0.334)
Number of sources of information	1.354**	(0.092)	1.639**	(0.180)	1.647**	(0.177)
					1.276**	**(0.100)**
Household characteristics						
Number of members with at least secondary education (ref: none)						
one person			1.315	(0.289)	1.511+	(0.323)
two or more persons			1.665+	(0.460)	1.820**	(0.499)
Household income (ref: < THB 10,000)						
THB 10,000 - 19,999			0.959	(0.212)	1.014	(0.218)
THB 20,000 - 29,999			0.830	(0.248)	0.857	(0.252)
THB 30,000 and over			0.939	(0.357)	0.907	(0.341)
Number of persons in household			0.939	(0.060)	0.929	(0.058)
Number of children aged ≤ 5 years			0.910	(0.150)	0.950	(0.156)
Number of members aged ≥ 60 years			0.461**	(0.086)	0.507**	(0.088)
			1.413+	**(0.270)**	**1.445****	**(0.263)**
Number of members with disability			3.805**	(1.802)	3.785**	(1.746)
House location (ref: house located on the coast)						
house located < 1 km from the shore			0.761	(0.216)	0.737	(0.209)
house located ≥ 1 km from the shore			0.864	(0.293)	0.747	(0.244)
Village characteristics						
Percentage of men with at least secondary education					1.024	(0.024)
Percentage of women with at least secondary education					1.114**	(0.032)
					1.023	**(0.031)**
Percentage of members aged 65 years and over					0.978	(0.067)
Percentage of women					0.835**	(0.052)
Village indicators included	yes		yes		no	

(con'd)

Constant_1	0.865	(0.582)	1.011	(0.775)	41.553	(112.455)
Constant_2	0.063**	(0.043)	0.100**	(0.076)	87.689	(242.146)
Log likelihood	-495.90		-470.00		-477.60	
DF	29		45		42	
Pseudo R^2	0.15		0.20		0.18	
N	544		544		544	

Note: Coefficients not in bold indicate the estimate under the proportional odds assumption whereas bold coefficients are variables that violate the proportional odds assumption. The coefficients not in bold are for the first logit equation contrasting no preparation versus one preparation and two preparations or higher. The bold coefficients are for the second logit equation contrast no preparation and one preparation versus two preparations or higher.
THB = Thai baht
** $p < 0.05$, + $p < 0.1$

secondary level education. In addition, individuals with lower secondary qualification also have a greater propensity for preparation compared to those with no education or only elementary qualification. Likewise, the likelihood of preparation significantly increases with the number of sources of information for this group. For individuals who were affected by the 2004 tsunami, the likelihood of being prepared is significantly associated with marital status and household characteristics. The odds of taking preparedness actions for the divorced/separated/widowed and the married are six and eight times greater than for single individuals. Although the number of the elderly in household (applied only to Logit 1) reduces the likelihood of preparation, the number of disabled members increases the propensity to carry out preparedness activities.

DISCUSSION

Our multivariate estimation shows that formal education is positively related to preparedness actions at the individual, household, and village levels. We find that the positive effect of individual and household-level education remain after controlling for household income. This suggests that education has an independent effect from income in increasing preparedness. Thus Hypothesis 1, which states that education increases disaster preparedness through improving income level, is not supported. Subsequently, there is weak evidence that education may increase cognitive ability and risk perception because it is found that being affected by the 2004 tsunami increases the likelihood of preparedness, but this applies only to those with tertiary education. This implies that the highly educated group managed to translate their previous disaster experience into preparedness actions. Hypothesis 2 thus is partially supported.

As predicted in Hypothesis 3, we also observe a strong interaction between individual educational attainment and informal education on disaster preparedness. Participating in evacuation drills and disaster education increases the likelihood of undertaking preparedness actions, but this applies only to the respondents with at least secondary education. It is plausible that highly educated individuals have better learning skills and are better in processing abstract thinking, e.g., in a hypothetical situation like a tsunami drill.

Apart from the effects of individual education, we find that education of household members enhances disaster preparedness, especially among the individuals who were not affected by the 2004 tsunami. Whereas disaster experience can increase disaster awareness and consequently preparedness action (Russell et al. 1995, Sattler et al. 2000, Horney et al. 2008, Tekeli-Yeşil et al. 2010), those who do not have such experience may have difficulty in perceiving the risk associated with a particular natural hazard. Our results nevertheless show that for those without previous tsunami experience, education of household members together with the number of information sources are key factors that drive disaster preparedness. Because information is processed through multiple stages, hearing the information, understanding it, and perceiving its relevance (Nigg 1982), education can shape the degree to which individuals accurately perceive and assess risks and make a decision to take on preparedness actions. In this sense, education may increase risk awareness without having to experience a natural disaster directly.

We also find that individual disaster preparedness differs by demographic and educational composition of the village. In general, the greater the proportion of the female population in the village, the lower the personal disaster preparedness. On the other hand, the greater proportion of women with at least secondary education, the higher the likelihood of taking preparedness actions. This raises a question of why gender and educational composition in a community could affect individual emergency preparedness behaviors. One explanation is that women are more likely to have denser social ties comprising a higher proportion of kin and neighbors than men (Moore 1990, Renzulli et al. 2000), so they might be more likely to exchange information and mutual assistance. However, women usually have fewer socioeconomic resources and less access to formal emergency planning organizations (Fothergill 1996). A community with a higher proportion of females in the population might have lower disaster preparedness because women have less access to

Table 3. Odds ratio estimated from partial proportion odds ordered logit models predicting disaster preparedness with village indicators: samples split by respondents' level of education and experience of the 2004 tsunami.

	Individual educational level				Experience of 2004 tsunami			
	Less than secondary		Secondary and over		Not affected		Affected	
	β	s.e.	β	s.e.	β	s.e.	β	s.e.
Individual characteristics								
Education (ref: no & elementary)								
lower secondary	na.		na.		3.051**	(1.730)	0.728	(0.288)
upper secondary	na.		na.		2.084	(1.120)	1.455	(0.669)
tertiary	na.		na.		1.680	(1.062)	2.547+	(1.304)
Head of household	0.841	(0.246)	1.046	(0.492)	1.195	(0.571)	1.272	(0.528)
							0.470**	**(0.169)**
Years of residence in household	1.005	(0.008)	1.002	(0.016)	1.011	(0.012)	0.998	(0.011)
Women	1.452	(0.411)	1.439	(0.616)	1.179	(0.485)	0.951	(0.388)
							2.737**	**(0.947)**
Age (ref: < 30 years)								
30 - 39 years	0.743	(0.465)	0.661	(0.342)	2.177	(1.485)	0.541	(0.270)
	0.931	**(0.593)**			**0.323**	**(0.232)**		
40 - 49 years	0.317+	(0.205)	0.414	(0.258)	2.907	(2.007)	0.362+	(0.190)
					0.068**	**(0.061)**		
50 - 59 years	0.986	(0.601)	0.765	(0.562)	1.107	(0.813)	0.294**	(0.180)
	1.960	**(1.424)**					**0.919**	**(0.500)**
60 years and over	0.618	(0.459)	0.009**	(0.015)	1.222	(1.223)	0.403	(0.265)
Marital status (ref: single)								
divorced/separated/widowed	0.803	(0.500)	17.624+	(26.386)	0.976	(0.726)	6.106**	(4.745)
married	1.611	(0.898)	5.112**	(3.026)	1.494	(0.796)	7.938**	(4.596)
Occupation (ref: agriculture)								
fishery	0.757	(0.390)	0.254	(0.240)	1.657	(1.793)	0.525	(0.299)
laborer					**0.479**	**(0.328)**	**0.385**	**(0.242)**
	1.189	(0.537)	1.056	(0.860)	3.567+	(2.413)	1.236	(0.732)
general trade/own business	0.923	(0.358)	0.802	(0.554)	1.195	(0.700)	0.472	(0.220)
private employee/civil servant	1.184	(0.873)	0.808	(0.622)	0.888	(0.817)	0.832	(0.523)
economically inactive	1.033	(0.420)	2.468	(2.051)	1.404	(0.818)	0.736	(0.394)
Affected by tsunami in 2004	1.301	(0.374)	2.132+	(0.916)	na.		na.	
Participated in evacuation drills and disaster education	1.337	(0.418)	2.774**	(1.403)	1.316	(0.692)	1.495	(0.478)
Number of sources of information	1.351**	(0.118)	1.580**	(0.234)	2.238**	(0.349)	1.165	(0.110)
Household characteristics								
Number of members with at least secondary education (ref: none)								
one person	1.081	(0.298)	2.482**	(1.098)	2.066+	(0.862)	0.923	(0.273)
two or more persons	1.263	(0.422)	4.500**	(2.667)	6.579**	(4.068)	1.559	(0.580)
Household income (ref: < THB 10,000)								
THB 10,000 - 19,999	0.970	(0.253)	1.066	(0.539)	1.705	(0.739)	0.782	(0.228)
THB 20,000 - 29,999	0.994	(0.381)	0.721	(0.421)	0.691	(0.381)	0.769	(0.307)
THB 30,000 and over	0.961	(0.528)	0.438	(0.310)	0.165**	(0.138)	1.254	(0.640)
			2.542	**(1.724)**	**1.730**	**(1.601)**		
Number of persons in household	0.968	(0.076)	0.870	(0.119)	0.818	(0.115)	0.858+	(0.074)
					1.354**	**(0.205)**		
Number of children aged ≤ 5 years	0.990	(0.204)	0.287**	(0.127)	0.998	(0.291)	0.876	(0.191)
			1.042	**(0.371)**				
Number of members aged ≥ 60 years	0.497**	(0.097)	1.654	(0.763)	0.831	(0.292)	0.575**	(0.125)
	1.221	**(0.263)**					**1.524+**	**(0.342)**
Number of members with disability	4.009**	(2.120)	2.322	(3.082)	3.243	(3.651)	5.173**	(3.162)
House location (ref: house located on the coast)								
house located < 1 km from the shore	1.047	(0.377)	0.533	(0.300)	1.511	(1.122)	0.716	(0.243)
					0.505	**(0.362)**		

(con'd)

house located ≥ 1 km from the shore	1.067	(0.461)	0.859	(0.572)	1.062	(0.758)	0.974	(0.414)
Village indicators included	yes		yes		yes		yes	
Constant_1	1.459	(1.479)	0.417	(0.573)	0.233	(0.304)	9.772**	(11.069)
Constant_2	0.089**	(0.091)	0.023**	(0.031)	0.009**	(0.012)	0.759	(0.806)
Log likelihood	-318.10		-139.20		-157.20		-275.70	
DF	39		38		45		44	
Pseudo R^2	0.18		0.28		0.31		0.19	
N	360		184		216		328	

Note: Coefficients not in bold indicate the estimate under the proportional odds assumption whereas bold coefficients are variables that violate the proportional odds assumption. The coefficients not in bold are for the first logit equation contrasting no preparation versus one preparation and two preparations or higher. The bold coefficients are for the second logit equation contrast no preparation and one preparation versus two preparations or higher.
THB = Thai baht
** $p < 0.05$, + $p < 0.1$

information channels (Katungi et al. 2008) and consequently could not share useful information. However, living in a community with high proportion of highly educated women increases personal disaster preparedness because education can increase access to disaster-related information and socioeconomic resources. The disaster preparedness of other members in a community hence can benefit from such female social networks.

The finding that disaster preparedness increases with the level of education is consistent with other studies in Asia that focus on other types of disaster outcomes. For instance, earlier research has found that communities in Nepal with higher levels of education suffer fewer human and animal deaths because of floods and landslides (K.C. 2013). Likewise, highly educated individuals in Indonesia are reported to cope better with the post-tsunami phase of the disaster, especially over the long run (Frankenberg et al. 2013). These findings show that education can be an important resource to reduce vulnerability to environmental hazards in Asia.

Although in this paper we have provided evidence of the role of education in enhancing disaster preparedness and investigated how formal schooling and informal education interact with disaster experience, it is beyond the scope of this study to identify how formal education can increase preparedness activities through other factors, e.g., risk perception, not observed in this study. Preparedness actions are related to both the perceptions of risk and an individual's capacity to take protective action and responses (Slovic 2000). The perception of risk varies considerably with past disaster experience, as well as demographic and socioeconomic profiles. Educational differences in disaster preparedness might partly be due to how individuals with diverse levels of education perceive risk in different ways based on their cognitive ability. Likewise, formal education may translate into a better ability to understand disaster education. Further study, especially a qualitative one, is required to deepen our understanding of the role of formal education on disaster preparedness.

This current study is not without limitations. First, the study may suffer from a selection bias of the out-migration of individuals or households with certain characteristics from areas at risk to tsunami. In the case of Thailand, however, there is no evidence that a mass exodus of tsunami affected population occurred after the 2004 Indian Ocean tsunami (Naik et al. 2007). Hence, the selection problem seems to be minimal in our study. Second, there was a potential of respondents misreporting their preparedness actions. They might over-report their evacuation plan or preparedness kit due to a social desirability bias, with the respondents wanting to be viewed favorably by the interviewer, or feeling obliged to report that they had the plan or kit prepared in response to the earthquake. Likewise, there was also a possibility of underreporting disaster preparedness because of recall bias, although most of the interviews were carried out shortly after the earthquakes. Because the study does not have information on preparedness from other sources, the data presented here rely solely on the respondents' accounts and report behavior. Lastly, the data do not allow us to identify who actually initiated emergency preparedness actions in a household because the survey interviewed only one respondent per household. We thus control for whether the respondent is a head of household in the analysis as a proxy for decision making power. A future study should attempt to identify who actually implemented preparedness measures in a household to better understand how individual and household characteristics influence disaster preparedness.

CONCLUSION

In this study we provide evidence that education, measured at the individual, household, and village levels, has a significant relationship with disaster preparedness. We distinguish between the effects of formal schooling and disaster-related training on preparedness actions and find that disaster education is effective particularly in the context of participants who have high educational attainment. Formal education may enhance cognitive ability, information processing, and learning skills so individuals with higher education respond

better in hard times, such as when the disaster strikes. Indeed, in the absence of past disaster experience, we find that households with highly educated members are better prepared for the disasters. There is also a spillover effect of education, possibly through communication and information exchange among village members as evidenced by the finding that living in a village with higher proportion of highly educated female members is positively associated with the number of preparedness activities undertaken at the individual and household level.

We show that disaster-related education can enhance personal preparedness, which is crucial in mitigating the disaster risks. However, the effectiveness of such education might be limited only to a subgroup of the population, such as highly educated individuals. Thus, policies that ensure universal access to formal education at least at the secondary level can be beneficial in reducing vulnerability and mitigating disaster impacts.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/6101

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Independent Associations of Maternal Education and Household Wealth with Malaria Risk in Children

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ABSTRACT. Despite evidence that they play similar but independent roles, maternal education and household wealth are usually conflated in studies of the effects of socioeconomic status (SES) on malaria risk. Demographic and Health Survey and Malaria Indicator Survey data from nine countries in sub-Saharan Africa were used to explore the relationship of malaria parasitemia in children with SES factors at individual and cluster scales, controlling for urban/rural residence and other important covariates. In multilevel logistic regression modeling, completion of six years of maternal schooling was associated with significantly lower odds of infection in children (OR = 0.73), as was a household wealth index at the 40th percentile compared to the lowest percentile (OR = 0.48). These relationships were nonlinear, with significant quadratic terms for both education and wealth. Cluster-level wealth index was also associated with a reduction in risk (OR = 0.984 for a one percentile increase in mean wealth index), as was urban residence (OR = 0.59). Among other covariates, increasing child's age and household size category were positively correlated with infection, and sleeping under an insecticide-treated bednet the previous night (OR = 0.80) was associated with a moderate reduction in risk. Considerable variation in parameter estimates was observed among country-specific models. Future work should clearly distinguish between maternal education and household resources in assessing malaria risk, and malaria prevention and control efforts should be aware of the potential benefits of supporting the development of human capital.

Key Words: *Demographic and Health Survey; DHS; malaria; Malaria Indicator Survey; maternal education; MIS; multilevel modeling; socioeconomic factors*

INTRODUCTION

A priori expectations and empirical evidence suggest that maternal education affects child health independently of household resources. Yet most studies of the influence of socioeconomic status (SES) variables on health—whether assessing broad indicators like mortality or disease-specific outcomes—equate the effects of wealth and education on risk, thus blurring the distinction between them. Making this distinction is of critical importance in designing effective and cost-efficient health and development policy for resource-poor nations, and—less well appreciated—it is essential for accurately forecasting the long-run evolution of the burden of disease.

This study examines the association of SES variables with confirmed malaria parasitemia, using data from Malaria Indicator Surveys (MIS) and traditional Demographic and Health Surveys (DHS). The addition of parasitological information to the suite of data collected by DHS offers significant opportunities for improving understanding of how SES relates to malaria risk. This study focuses on the independent associations of household wealth and maternal schooling with malaria in children, in the context of urban versus rural residence. Among these factors, relationships among poverty, urban residence, and malaria risk have been analyzed more often than associations with education. Moreover, the link whereby malaria affects school attendance and educational attainment has been examined in greater depth than the complementary relationship emphasized here—i.e., the effect of maternal education on malaria risk. This study thus provides novel insight in an important area.

Since the turn of the millennium, and increasingly since the call to action by the Bill and Melinda Gates Foundation (2007), a concerted global effort against malaria has achieved major successes, supported by increased funding and ever more sophisticated understandings of the dynamics and operational challenges of malaria control. The scale-up of prevention activities has averted more than 0.8 million deaths in children since 2000 (Eisele et al. 2012). These triumphs have led to loftier goals; e.g., the prevention of all malaria deaths by 2015, progressive regional elimination, and eventually, global eradication (WHO 2011). Yet, while elimination and eradication have emerged firmly back into the global scientific and policy discourse (Feachem and Sabot 2008, Tanner and De Savigny 2008, Malaria Elimination Group 2009, Mendis et al. 2009, Das and Horton 2010, Marsh 2010, Moonen et al. 2010, D'Souza and Newman 2012, Pindolia et al. 2012), technical feasibility studies conclude that we are unlikely to eliminate malaria in high-transmission areas with current capabilities (WHO 2008). Without sustained or increased efforts and funding, regional and global coordination, and an array of novel control tools, malaria is likely to remain viable in areas with high intrinsic transmission rates, particularly in sub-Saharan Africa. In fact, despite recent advances, malaria remains among the most important communicable diseases globally, having caused two-thirds of a million deaths and well over 200 million acute infections in 2010, mostly (80–90%) in sub-Saharan Africa (WHO 2011). International funding for malaria control appears to have peaked in 2010 at ~US$2 billion of the estimated US$5–6 billion per annum needed for elimination (WHO 2011); despite progress, current funding is inadequate for comprehensive malaria control at a global scale (Snow et al. 2010). The recent global financial crisis and competing demands on international financial aid make it doubtful that needed investments will occur or be sustained over the long term. The history of malaria control, of course, is one of significant achievements followed by disease resurgence in areas that lack necessary elements of integrated public health

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infrastructure when economic and financial crises or waning political will have contributed to large-scale reductions in funding for prevention and control (Nájera et al. 2011, Cohen et al. 2012).

It is critical to find and make efficient use of all effective routes for malaria prevention and containment. Malaria control "tool boxes" typically include interventions that directly affect the dynamics of malaria transmission and progression: case management, larval control, insecticide residual spraying, insecticide-treated bednets (ITNs), intermittent preventive treatment in pregnant women, and chemoprophylaxis in travelers or other at-risk groups (Morel et al. 2005). Other interventions, including vaccines (Schwartz et al. 2012) and vector sterilization (Townson 2009), which are on the horizon but not yet available for wide-scale public health action, also directly affect transmission. In contrast, where SES factors influence risk, they generally act indirectly through their effects on other proximal determinants of risk. Moreover, efforts to, say, improve education or decrease poverty are not malaria-specific, may require a much broader set of investments than traditional interventions, and often generate more controversy as well. Yet, to the extent that these factors determine risk, the potential of such efforts to constitute important formal components of larger scale policy for malaria control should be considered in greater detail.

There is no question that SES factors are correlated with malaria risk. Higher standards of living, for example, were instrumental in the large-scale reductions in malaria in North America and Europe during the late 19th and early 20th centuries (Humphreys 2001). Today, the poorest populations worldwide bear a disproportionate number of malaria cases and deaths (Barat et al. 2004). However, causality in the relationship between SES factors and malaria is likely bidirectional. For example, it is probable that malaria causes poverty and vice versa, in reinforcing feedback cycles at the individual, community, and potentially national or regional scales (Somi et al. 2007, Teklehaimanot and Mejia 2008).

On the one hand, then, researchers have examined how malaria affects SES factors. At the national level, a widely cited set of studies has associated malaria endemicity with substantially slower economic growth and decreased per capita GDP (Gallup and Sachs 2001, Sachs and Malaney 2002), although the causality of these relationships has been questioned given the inadequacy of data, complexity of interrelationships among social and economic factors and health, and difficulty of extrapolating microlevel results to the macro level (Packard 2009). At the household and individual levels, malaria imposes significant burdens, both direct, in terms of the costs of prevention and treatment, and indirect, in the form of lost wages. Such impacts are, of course, felt more keenly among the poor, for whom they constitute a much greater fraction of available resources (Chima et al. 2003, Teklehaimanot and Mejia 2008). Malaria also affects human capital formation by increasing school absenteeism in areas of high transmission and decreasing school performance subsequent to malaria episodes (e.g., Vitor-Silva et al. 2009). Severe malaria syndromes, including severe anemia and cerebral malaria, can have physiological and neurological sequelae which result in decreased cognitive and reasoning ability, with long-term consequences for intellectual development and productivity (Chima et al. 2003).

This study is more interested in the complementary link; i.e., how SES factors affect malaria risk. Worrall et al. (2005), in a review of a range of microlevel studies, found strong associations between various SES proxies and uptake of malaria prevention and treatment but inconclusive evidence for a causal effect of SES on incidence. Filmer (2005), using DHS data for 22 countries, found a general pattern of lower fever in children with higher household SES (measured by a wealth-based asset index), but results were significant in only three countries; the study did not find a significant association between fever in children and mother's years of schooling. Moreover, the use of fever as a proxy for malaria infection is inexact and can result in considerable misclassification, which thus overestimates the impact of uncomplicated episodes while underestimating the consequences of severe disease (Chima et al. 2003). Since 2010, WHO guidelines have specified that all suspected cases of malaria should be confirmed via microscopy or rapid diagnostic tests (WHO 2010). Some studies have associated SES factors with severe disease; e.g., in Western Kenya, lower household wealth percentile was associated with higher odds of clinically confirmed malarial anemia (Siri et al. 2010). Poverty is clearly associated with other factors linked to malaria risk. For example, the poor are less likely to be able to pay for ITNs or other prevention or to seek or obtain adequate treatment. The poor are also more likely to live in substandard housing, which allows vectors access to sleeping individuals, and thus strongly increases risk (Lindsay and Snow 1988).

Evidence is inconclusive as to the specific effect of adult education on malaria in children. No association was found between educational level of parents or guardians and severe or mild malaria in children in the Gambia (Koram et al. 1995a, b), or between maternal educational attainment and malaria severity or time to reinfection in Gabon (Luckner et al. 1998), febrile episodes in Benin (Rashed et al. 2000), or malaria infection in Equatorial Guinea (Custodio et al. 2009). In contrast, Villamor et al. (2003) found that maternal schooling strongly reduced baseline parasitemia when other indicators of socioeconomic status were controlled for; where mothers had no education, children had 43% higher adjusted prevalence. In Mali, maternal completion of primary school halved the risk of severe malaria in their children, even though most educated mothers (84.2%) did not have adequate knowledge about malaria (Safeukui-Noubissi et al. 2004). In Western Kenya, caretaker's level of education was correlated with child parasitemia and malarial anemia in univariate analysis but not when controlling for other factors (Ong'echa et al. 2006). In Brazzaville, Congo, the odds of presenting with cerebral malaria were 90% higher among children whose mothers had less than a primary school education (Carme et al. 1994). Noor et al. (2006) found that mother's educational attainment was strongly predictive of retail sector ITN use in Kenya; this is one of several studies that have linked schooling with preventive behavior or treatment seeking (see Worrall et al. 2005).

Just a few studies have attempted to evaluate both causal pathways simultaneously. Somi et al. (2007) and de Castro and Fisher (2012) used instrumental variable approaches to account for endogeneity in the relationship between SES and malaria in Tanzania—the former used data from 52 villages within the framework of two major demographic surveillance sites, the

latter from a 2007–2008 special country-wide DHS survey. Somi et al. (2007) found that household SES was negatively and significantly associated with malaria parasitemia, and that parasitemia, in turn, had a significant negative effect on the wealth-based asset index used to measure wealth. That study used education level of the household head as an instrument because it showed no association with parasitemia; education of the mother was not among the variables considered for analysis. In contrast, de Castro and Fisher (2012) found that malaria illness among young children contributed to lower household wealth, but lower household wealth did not contribute to a higher incidence of malaria. Having either a father or mother with secondary or higher education did not influence malaria risk.

Education of the mother, father, or household head is often included as an ancillary variable in studies of malaria risk factors, and the discussion here is not comprehensive. Yet, even a cursory review underscores that education is rarely the primary focus of research. In fact, education (most often measured in terms of educational attainment but more broadly encompassing the accumulation of knowledge, skills, networks, and intangible assets like trust) is often conflated with economics (usually, wealth measured by an asset index but more generally comprising resources available to address household needs). For example, education of the household head may be included in asset-based wealth indices (e.g., Schellenberg et al. 2003), which renders it inaccessible to analysis as an independent risk factor. Implicitly or explicitly, the focus of many studies is on poverty, even where information on education is collected.

In different contexts, it has been shown that the distinction between such indicators is critical in estimating impacts of SES factors on health, that they act along distinct causal pathways, and that equating them can obscure true relationships (Geyer et al. 2006). Thus, DHS data have been used to show that the effect of mothers' educational attainment on child mortality is often of greater significance than the effect of household wealth, when controlling for potential confounders (Fuchs et al. 2010, Pamuk et al. 2011), or that economic development level, household wealth, and maternal educational attainment have strong independent associations with child health, as indicated by weight and height for age (Boyle et al. 2006). Similarly, de Souza et al. (1999) used census and health systems data in Brazil to show that female illiteracy was associated with higher infant mortality. A broad systematic review of global child mortality found that between 1970 and 2009, increased educational attainment in women accounted for more than half of an estimated 8.2 million averted deaths in children younger than 5 years (Gakidou et al. 2010). Various studies have also found that maternal schooling affects infant mortality when controlling for malaria endemicity (Gemperli et al. 2004, Kazembe et al. 2007).

There are a number of mechanisms by which parental educational attainment is likely to affect health (e.g., Fuchs et al. 2010). Schooling may directly provide health-specific information or increase the ability of individuals to acquire and understand such information; it may increase their familiarity with formal institutions, and thus lead to greater trust in and use of health facilities or preventive measures; it is likely to increase the autonomy and empowerment of women; and it has positive effects on income and household resources. Even where such benefits do not accrue, school attendees may develop social networks whose example or intervention can contribute to healthy behaviors. Community-level education may contribute to child health over and above the individual effect of maternal educational attainment through increases in the general empowerment of women, pooled community knowledge, or the imitation of healthy behaviors by less-educated individuals (Pamuk et al. 2011). Offsetting these factors to a certain degree, parental education may actually reduce health in some cases. For example, better educated mothers may be less likely to breast-feed than their less educated counterparts. Better educated parents also face a higher opportunity cost in terms of foregone productivity when choosing to devote time to child-rearing and household maintenance.

This study measures the independent associations of mothers' educational attainment and household resources with malaria using DHS/MIS data. A series of studies has recently used MIS data to map risk of malaria parasitemia in various countries (Gosoniu et al. 2010, 2012, Giardina et al. 2012), but while these studies have evaluated associations with SES (as measured by the DHS wealth index) and, generally, with urban residence, they have not incorporated education in modeling malaria prevalence.

METHODS

Data sources and variables

Since 1985, the Measure DHS project has collected data on demography and health through standardized national surveys (MeasureDHS 2013). The regular DHS survey includes a wealth of information on health behaviors, specific health issues such as anemia, malnutrition, malaria, and HIV, and a range of individual and household-level socio-demographic factors (Rutstein and Rojas 2006). DHS surveys in malaria-endemic areas have long collected self-reported information about fever and malaria-preventive behaviors but more recently have begun to include biomarker data; i.e., laboratory confirmed malaria parasitemia and anemia in children and pregnant women. Since 2006, the new MIS survey, developed in conjunction with Roll Back Malaria and focused specifically on malaria-relevant information, has been administered in endemic areas, primarily in sub-Saharan Africa. Thirty-two MIS surveys and more than 300 DHS surveys have been conducted in more than 90 countries (MeasureDHS 2013).

DHS/MIS surveys are designed to collect data that are representative of the situation of a particular country (ICF International 2012). They use a hierarchical sample design: first, a sample of clusters, usually census enumeration areas, is selected; second, all households within these clusters are enumerated and a second-stage sample of households is systematically identified for interview. Clusters may be chosen so as to achieve sufficient sample size within regional or urban/rural strata; sampling weights, corrected for stratum-specific nonresponse, allow for accurate estimation of population parameters. For surveys that deal with malaria biomarkers, blood specimens are collected for a subset of the overall sample and are tested for anemia and parasitemia. At the national scale, surveys are managed by national implementing agencies in collaboration with Measure DHS. Interviewers receive extensive training and interact with local authorities in identifying selected households and

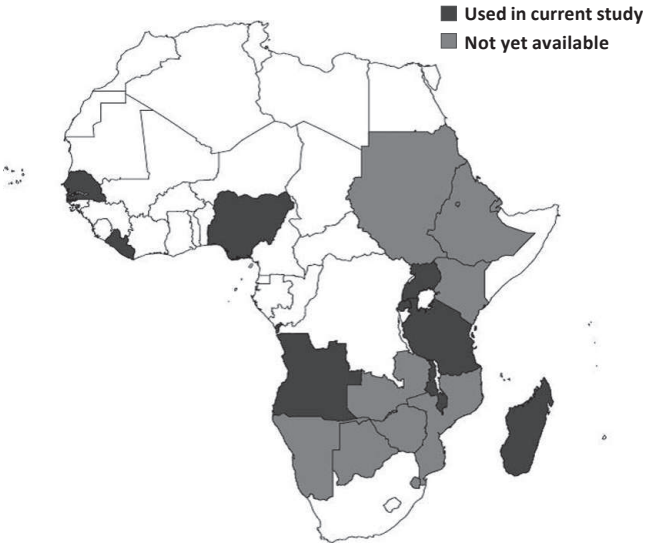
Table 1. Household-level Demographic and Health Surveys (DHS)/Malaria Indicator Surveys (MIS) used in analyses, and sample size (AIS: AIDS Indicator Survey).

Country	Year	Survey type	Number of sampled clusters (N^{clust})	Number of sampled households (N^{house})	Number of sampled mothers (N^{mother})	Number of sampled children (N)
Angola	2011	MIS	240	1840	1981	2900
Liberia	2011	MIS	150	1721	1869	2436
Uganda	2009	MIS	170	2179	2254	3400
Malawi	2012	MIS	140	1472	1501	1896
Rwanda	2010	DHS	492	2801	2848	3699
Senegal	2008–9	MIS	320	1814	2654	3562
Tanzania	2011–12	AIS/MIS	916	4498	4895	6634
Nigeria	2010	MIS	240	2679	3019	4353
Madagascar	2011	MIS	268	3768	3885	5257

administering questionnaires. Confidentiality of information is a major concern: DHS surveys are anonymous, and strict efforts are made to prevent the disclosure of respondent identity.

All currently available MIS or DHS surveys that report confirmed malaria parasitemia in children (Table 1) were obtained. Because all of these data sets originate in sub-Saharan Africa (Fig. 1), most infections are due to *Plasmodium falciparum*, the most lethal malaria parasite (Cibulskis et al. 2011). From these sources, a global data set ($N = 34{,}137$) was created, consisting of records for all children under 5 years of age with a valid malaria parasitemia test and valid information on maternal education and household wealth. All data processing and statistical analysis was performed in SAS 9.2 (SAS Institute Inc., Cary, NC). Fig. 1 was produced using R (R Core Team 2013) in the RStudio Integrated Development Environment (RStudio 2013).

Fig. 1. Map of Demographic and Health Surveys/Malaria Indicator Surveys included, and other surveys with information on malaria parasitemia.



DHS/MIS data contain a multitude of indicators that are potentially related to malaria occurrence, from which a conservative set of explanatory variables (Table 2) was selected. In particular, the main variables of interest—i.e., household wealth, maternal educational attainment, and urban residence—were included a priori. Cluster-level education and wealth were also added to assess the influence of community-level factors. To account for clustering at various scales and the hierarchical nature of data collection, country and identifying numbers for sample cluster and household were retained. Several other variables that have been shown to strongly and consistently affect malaria incidence were added as covariates in order to avoid omitted-variable bias due to confounding. Confounding may arise where a variable is both a cause of the dependent variable and is associated with one or more independent variables. These include child's age—one of the best predictors of parasitemia—and use of ITNs and housing quality, both of which are reliably associated with reduced risk. Household size was also included because it relates strongly to wealth and to malaria in some contexts. For example, it may influence the likelihood of being bitten by a mosquito or the likelihood that nearby vectors have acquired infection. Similarly, sex of the household head was included as potentially indicative of priorities about how household resources are used. Where several available variables were related or assumed to have similar effects, a judgment was made as to which was most relevant to the analysis in order to avoid multicollinearity and limit the number of independent variables. For example, whether the child slept under an ITN the previous night was adopted as more directly reflective of infection risk than whether the household owned bednets or ITNs, or than the number of bednets or ITNs or the time since treatment of ITNs. Moreover, only variables available from all country data sets were considered eligible for inclusion, which eliminated several potentially relevant variables from consideration (e.g., recent insecticide residual spraying, education of the household head, knowledge of malaria transmission and prevention). Some potentially relevant variables were beyond the scope of this study (e.g., geographic locations of interviewed households and associated environmental or epidemiological variables).

Table 2. Contextual, household, and individual variables retained.

Variable
Country
Cluster
Household
Whether household is urban
Household size (i.e., number of *de jure* members)
Quality of housing (i.e., whether windows and ceilings are made of finished materials)
Sex of household head
Mother's age
Child's age
Whether child slept under insecticide-treated bednet during previous night
Mother's educational attainment (highest grade completed)
Household asset-based wealth index constructed from:
Car ownership
Motorcycle ownership
Bicycle ownership
Refrigerator ownership
TV ownership
Radio ownership
Mobile phone ownership
Whether residence has electricity
Whether residence has an improved source of drinking water†
Whether residence has a flush toilet
Number of dwelling rooms in residence
Whether floor of residence is made of finished materials
Cluster-level mean of mother's educational attainment
Cluster-level mean of household asset-based wealth index

†According to the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation definition for improved drinking water sources: http://www.wssinfo.org/definitions-methods/watsan-categories/

Where applicable, the accuracy of country-level distributions for explanatory variables and for malaria parasitemia was assessed through comparison with published summary data for DHS/MIS samples (Ndiaye and Ayad 2009, Uganda Bureau of Statistics and ICF Macro 2010, Cosep Consultoria, Consaúde e ICF Macro 2011, National Institute of Statistics of Rwanda [Rwanda], Ministry of Health [Rwanda], and ICF International 2012, National Malaria Control Program [Liberia], Ministry of Health and Social Welfare, Liberia Institute of Statistics and Geo-Information Services, and ICF International 2012, National Malaria Control Programme [Malawi] and ICF International 2012, National Population Commission [Nigeria], National Malaria Control Programme [Nigeria], and ICF International 2012, Tanzania Commission for AIDS, Zanzibar AIDS Commission, National Bureau of Statistics, Office of the Chief Government Statistician, and ICF International 2013).

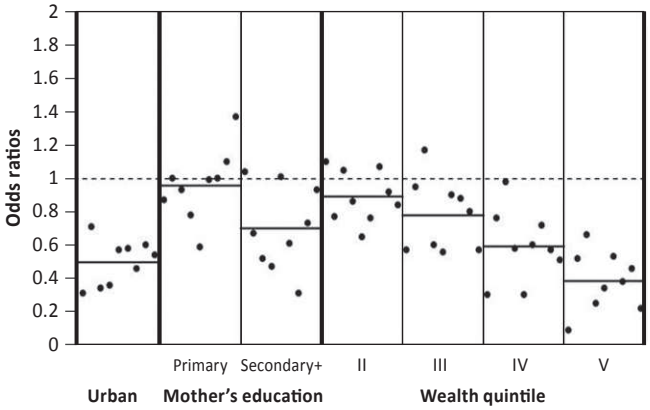
Because the standard DHS wealth index often incorporates variables that are likely to independently affect malaria risk (e.g., bednet ownership, quality of housing) (Rutstein and Johnson 2004), a new asset-based wealth index was constructed for each country, following standard methodology (Filmer and Pritchett 2001). Briefly, principal components analysis (PCA) of household-related variables (Table 2) was used to characterize the underlying distribution of household wealth. PCA identifies linear weighted combinations of variables that explain the largest possible amount of variation in the data; these components capture common information in the original variables, and can be substituted for them to reduce the number of variables under consideration (Vyas and Kumaranayake 2006). When performed using household assets, the first principal component is commonly assumed to represent household wealth, which is difficult to measure directly, and can be indexed in quantiles for this purpose. The internal validity of this index was assessed by examining the proportion of households in each wealth quintile with the corresponding assets (Appendix Table A1.1).

Statistical analysis

Malaria parasitemia was characterized by wealth quintile and standard educational attainment categories (i.e., none, primary, secondary, or higher), along with urban residence and other covariates, for each country (Table 3). Other continuous variables were also categorized to allow for simple stratified analysis. Bivariate associations between parasitemia and other variables were assessed using Pearson's Chi-square test (Pearson 1900).

As a preliminary step in evaluating the independent associations of maternal education and wealth with malaria, these variables were dichotomized—splitting wealth at the median and education at any/no schooling—and parasitemia was compared among the four cross-tabulated groups, overall and stratified by urban residence, for each country (Table 4). This analysis was extended with simple country-level logistic regression models (Aldrich and Nelson 1984), including categorized education and wealth and urban residence (Table 5). Fig. 2 represents these results graphically by illustrating individual country and mean odds ratios for malaria parasitemia in children for urban residence, maternal education, and household wealth.

Fig. 2. Country-specific and mean odds ratios for malaria parasitemia in children for urban residence, maternal education category, and wealth quintile from country-specific reduced (IA) hierarchical logistic regression models.



Multivariate logistic regression models were fit to the global data set to estimate the magnitude of association between risk factors and malaria parasitemia. In particular, because data from DHS/MIS violate the assumption of independence within households, sample clusters, and countries (i.e., because malaria is an infectious condition and because individuals in the same cluster/country are subject to similar contextual risk factors), hierarchical

Table 3. Malaria parasitemia by contextual, household, and individual risk factors: parasite rate (% of population).

	Angola (n^{pop} = 2900; n^{clust} = 240)	Liberia (n^{pop} = 2436; n^{clust} = 150)	Uganda (n^{pop} = 3400; n^{clust} = 170)	Malawi (n^{pop} = 1896; n^{clust} = 140)	Rwanda (n^{pop} = 3699; n^{clust} = 492)	Senegal (n^{pop} = 3562; n^{clust} = 320)	Tanzania (n^{pop} = 6634; n^{clust} = 916)	Nigeria (n^{pop} = 4353; n^{clust} = 240)	Madagascar (n^{pop} = 5257; n^{clust} = 268)
Residence location	***	***	***	***		***	***	***	***
Rural	18.3 (68.6)	53.9 (62.2)	54.0 (88.0)	47.0 (86.9)	2.5 (88.5)	14.5 (64.1)	9.9 (83.9)	55.2 (76.8)	8.8 (94.4)
Urban	1.7 (31.4)	29.7 (37.8)	31.8 (12.0)	14.4 (13.1)	1.1 (11.5)	7.2 (35.9)	3.3 (16.1)	36.8 (23.2)	1.9 (5.6)
Mother's highest level of schooling	***	***	***	***	*	***	***	***	***
None	20.3 (35.1)	49.9 (48.2)	55.7 (21.7)	52.9 (21.2)	3.9 (19.4)	13.3 (69.4)	10.2 (24.3)	57.9 (51.5)	9.5 (27.9)
Primary	10.2 (55.2)	47.7 (30.3)	53.7 (62.5)	44.1 (64.5)	2.0 (72.2)	9.0 (22.8)	8.9 (67.4)	53.7 (19.8)	9.3 (54.3)
Secondary+	3.2 (9.8)	29.2 (21.4)	35.6 (15.8)	21.8 (14.3)	2.1 (8.4)	7.5 (7.9)	3.5 (8.4)	36.4 (28.7)	4.1 (17.9)
Wealth quintile	***	***	***	***	***	***	***	***	***
I (lowest)	23.4 (20.1)	54.1 (19.1)	52.4 (18.3)	57.6 (23.6)	4.2 (23.6)	17.5 (14.9)	11.0 (21.4)	61.0 (21.7)	13.9 (22.6)
II	23.5 (19.9)	50.5 (21.7)	54.6 (21.0)	49.4 (21.7)	2.5 (16.2)	14.0 (16.8)	11.8 (20.7)	59.6 (21.7)	10.8 (20.9)
III	12.1 (21.8)	51.5 (16.8)	57.2 (21.5)	40.9 (20.6)	2.1 (21.0)	15.3 (16.0)	10.1 (19.4)	54.0 (20.7)	7.4 (20.3)
IV	4.3 (19.9)	40.0 (19.7)	52.7 (20.3)	37.9 (20.0)	1.2 (19.8)	8.9 (25.8)	7.9 (18.9)	42.7 (17.7)	5.9 (21.0)
V (highest)	1.1 (18.3)	30.3 (22.7)	38.5 (19.0)	17.3 (14.2)	1.4 (19.5)	8.2 (26.6)	3.0 (19.7)	33.1 (18.3)	1.8 (15.2)
Child's age (months)	**	***	***	***		**	***	***	***
6–11	9.6 (13.3)	25.1(11.5)	34.4 (21.1)	35.0 (9.9)	0.9 (11.2)	6.7 (10.2)	4.3 (12.9)	42.0 (12.4)	4.0 (12.1)
12–23	11.3 (23.6)	34.2 (26.8)	47.6 (20.6)	34.6 (25.8)	2.5 (20.9)	10.2 (23.6)	7.7 (25.1)	46.8 (21.5)	7.1 (19.8)
24–35	12.8 (22.7)	47.0 (20.2)	57.6 (20.0)	44.0 (21.5)	2.0 (23.7)	12.9 (21.5)	8.9 (21.4)	49.9 (20.5)	7.1 (21.9)
36+	15.4 (40.5)	56.0 (41.5)	59.3 (38.3)	48.8 (42.8)	2.8 (44.3)	13.4 (44.8)	10.9 (40.6)	55.7 (45.6)	10.7 (46.1)
Child slept under insecticide-treated bednet	***		**	*	***				**
No	14.9 (73.2)	45.0 (62.5)	53.4 (64.8)	45.6 (39.8)	3.6 (29.4)	11.9 (67.2)	7.7 (26.5)	51.5 (69.1)	6.2 (22.8)
Yes	8.1 (26.8)	44.5 (37.5)	47.5 (35.2)	40.9 (60.2)	1.8 (70.7)	11.8 (32.8)	9.2 (73.5)	49.6 (30.9)	9.1 (77.2)
Finished windows and ceilings	***	***	***	***	**	***	***	***	***
No	17.8 (69.0)	52.2 (66.2)	54.1 (75.2)	50.2 (71.4)	3.0 (54.0)	16.4 (40.7)	11.5 (51.9)	57.3 (61.2)	9.4 (84.4)
Yes	2.5 (31.0)	30.3 (33.8)	42.8 (24.8)	24.2 (28.6)	1.5 (46.0)	8.8 (59.3)	5.9 (48.1)	40.8 (38.8)	3.1 (15.6)
Household size			**				***	**	*
1–4	11.4 (25.3)	41.9 (27.6)	45.8 (26.1)	39.3 (37.6)	2.5 (36.9)	13.3 (3.9)	7.6 (21.3)	47.2 (19.1)	7.9 (28.8)
5–6	14.8 (37.9)	45.2 (33.4)	53.4 (33.2)	45.9 (39.4)	2.4 (35.9)	11.3 (11.0)	6.8 (30.3)	49.2 (29.3)	7.5 (34.4)
7–8	12.6 (22.9)	45.6 (21.7)	53.1 (25.6)	43.0 (18.2)	1.8 (20.1)	11.6 (12.7)	10.4 (22.5)	53.0 (21.4)	8.7 (21.0)
9+	12.2 (13.9)	47.6 (17.3)	53.1 (15.1)	42.3 (4.8)	2.7 (7.1)	11.9 (72.4)	10.9 (25.9)	53.5 (30.2)	10.9 (15.9)
Mother's age (years)						**	*		*
< 20	9.1 (11.1)	35.5 (6.1)	45.6 (4.9)	36.0 (4.8)	2.7 (1.0)	13.2 (4.9)	9.9 (4.8)	54.2 (4.3)	7.9 (7.2)
20–29	12.9 (54.2)	45.9 (52.3)	51.1 (55.6)	42.2 (53.4)	2.4 (46.8)	10.1 (48.7)	9.0 (49.1)	50.1 (47.2)	8.5 (47.4)
30–39	14.6 (28.4)	45.9 (31.7)	51.0 (31.6)	43.2 (34.9)	2.1 (39.2)	14.2 (38.3)	7.8 (36.1)	51.2 (37.7)	7.5 (35.4)
40+	14.5 (6.4)	41.0 (9.9)	57.5 (8.0)	49.4 (7.0)	2.9 (13.0)	10.6 (8.2)	10.9 (9.9)	52.4 (10.7)	11.7 (10.1)
Sex of household head	***	**				***			
Male	11.6 (81.8)	47.0 (70.2)	51.2 (78.1)	43.8 (78.5)	2.3 (78.9)	12.6 (87.0)	8.7 (83.5)	50.9 (92.3)	8.7 (83.4)
Female	19.6 (18.2)	39.5 (29.8)	51.7 (21.9)	38.8 (21.5)	2.5 (21.1)	6.8 (13.0)	9.4 (16.5)	51.0 (7.8)	7.2 (16.6)

Chi-square test: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

multilevel models were constructed using the generalized linear mixed modeling procedure in SAS (Kiernan et al. 2012). Such models are appropriate where data have been collected in nested units, as is the case for DHS/MIS surveys. These models account for the hierarchical nature of the data by adjusting for the correlation of observations within higher level groups and allowing observed variance to be apportioned among group-level and individual effects.

In particular, sampling cluster and household, which were selected from among larger distributions of possible samples or surveys, were included in the model as nested random effects,

Table 4. Malaria parasitemia (%) by any/no maternal education and above/below median wealth, stratified by urban residence.

	Rural				Urban				Total			
Education / Wealth	Low/ Low	Low/ High	High/ Low	High/ High	Low/ Low	Low/ High	High/ Low	High/ High	Low/ Low	Low/ High	High/ Low	High/ High
Angola	23.0	12.3	20.2	8.8	0†	7.0	4.9†	1.1	22.9	10.6	19.4	3.8
Liberia	53.7	52.8	52.8	55.6	42.4	36.3	47.8	22.6	52.5	44.8	51.8	33.2
Uganda	54.8	65.2	53.1	52.5	34.8†	28.7†	61.7†	27.9	54.6	59.0	53.4	47.3
Malawi	60.9	44.8	51.0	37.8	28.3†	2.6†	29.9	11.8	60.1	40.4	49.8	31.7
Rwanda	4.4	3.9	2.4	1.5	0†	0†	2.1†	1.1	4.2	3.6	2.4	1.4
Senegal	17.3	9.5	14.5	9.0	4.1	9.4	6.2	5.8	15.9	9.5	12.1	6.7
Tanzania	11.2	10.8	11.3	7.6	4.0†	2.2†	11.9	2.5	11.0	10.2	11.4	6.0
Nigeria	61.5	51.6	57.6	46.4	58.6	41.7	52.4	29.2	61.2	49.9	57.0	38.8
Madagascar	12.6	6.8	12.4	5.3	16.2†	0	1.9†	1.9	12.6	6.6	12.3	4.9

†Less than 50 observations in cell

while other variables (Table 2), including country, were modeled as fixed effects. Accordingly, the models allowed the intercept to vary randomly at the cluster and household levels. Variance inflation factors (Velleman and Welsch 1981) were examined to test for potential multicollinearity.

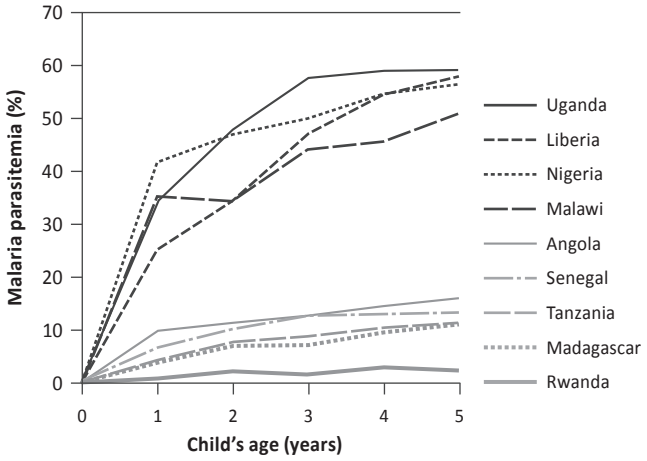
First, a minimal (IIA) model was estimated (Table 6), with education and wealth included as continuous variables and dummy variables used for urban residence and survey country. To this were sequentially added cluster-level SES variables (IIB), nonlinear (i.e., polynomial) SES terms (IIC), and other covariates (IID). Both stratified analysis and Box-Tidwell tests suggested nonlinear effects for education and wealth. The Box-Tidwell test adds a continuous variable along with its Box-Tidwell transformation (x * log [x]) to the logistic regression model. A significant effect for the transformed variable indicates violation of the assumption of linearity (Box and Tidwell 1962). Thus, quadratic (x^2) terms and interactions (i.e., education * wealth, education * urban residence, and wealth * urban residence), either of which can result in nonlinear effects, were evaluated. Because initial examination of variance inflation factors when higher order terms were incorporated indicated significant multicollinearity, wealth percentile and years of education were centered around their grand means, and these terms were regenerated; subsequently, no major multicollinearity was observed (i.e., all variance inflation factors were less than 4.0). An incremental approach was adopted, which involved adding quadratic terms, assessing significance and model fit, and then assessing any added effect of interactions. In fact, no interactions were found to have significant additional effects, and they were left out of the final model.

RESULTS

Exploratory data analysis

Table 3 shows bivariate associations between malaria parasitemia in children and explanatory variables. Of these, links with wealth, maternal schooling, and housing quality were significant in all countries, with trends in the expected directions; i.e., increasing wealth and maternal education were associated with lower levels of infection, as was living in a house with finished windows and ceilings. Malaria prevalence decreased with urban residence and increased with child's age (Fig. 3) in all countries, as expected. These relationships were statistically significant in all countries but Rwanda, where the extremely low prevalence (~2%) may play a role. Other covariates were significantly associated with prevalence in only some contexts. In seven of nine countries, children who slept under an ITN the previous night had lower parasitemia than those who did not, yet these differences were significant in only four countries. In Madagascar, parasitemia was significantly higher among such children, a surprising result which may reflect the mass distribution of nets to households in vulnerable regions. Household size was statistically significant in four countries; in each of these, and indeed in most countries, prevalence increased with the number of residents. No consistent patterns were observed for mother's age or sex of the household head, though each of these was significantly associated with risk in one-third of sampled countries.

Fig. 3. Prevalence of malaria parasitemia by child's age and country.



A simple way to assess associations of malaria with education and wealth is to look at parasitemia across different strata of these variables. Table 4 shows this relationship, both overall and delineated by urban/rural residence. For the complete sample, results were largely as expected. In almost every case, infection was highest where maternal education and household wealth were low, and was lowest in the high/high category, with high wealth and education each independently associated with decreased risk.

Table 5. Odds ratios for malaria parasitemia in children from country-specific (IA) logistic regression models.

Variable	Angola (n = 2900)	Liberia (n = 2413)	Uganda (n = 3400)	Malawi (n = 1896)	Rwanda (n = 3699)	Senegal (n = 3562)	Tanzania (n = 6612)	Nigeria (n = 4353)	Madagascar (n = 5257)
Urban residence	0.32***	0.71***	0.34***	0.36***	0.57	0.58***	0.46**	0.60***	0.54*
Mother's highest level of schooling (vs. none)									
Primary	0.87	1.00	0.93	0.78	0.59*	0.99	1.00	1.10	1.37*
Secondary+	1.04	0.67***	0.52***	0.47***	1.00	0.61	0.31***	0.73***	0.93
Wealth quintile (vs. lowest)									
II	1.10	0.77*	1.05	0.86	0.65	0.76	1.07	0.92	0.84
III	0.57***	0.95	1.17	0.60***	0.56	0.90	0.88	0.80*	0.57***
IV	0.30***	0.76*	1.00	0.58***	0.30**	0.60**	0.72*	0.57***	0.51***
V	0.09***	0.52***	0.66***	0.25***	0.34*	0.53***	0.38***	0.46***	0.22***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

There were two exceptions. In Uganda, among those with low maternal education, high wealth was associated with higher childhood infection than was low wealth; in Tanzania, among those with low wealth, high education was associated with marginally higher infection. In both cases, the differences in rates were small and nonsignificant. In the disjoint cases (low/high, high/low), high wealth was usually associated with a greater decrease in parasitemia than was high education. In seven of nine countries, the reduction in parasitemia associated with having both high wealth and high education exceeded the sum of the reductions from either alone.

A considerably more complex situation occurred when stratifying by urban residence. In urban areas, eight of nine countries deviated from the expected relationship; i.e., the high/high and low/low classes were not associated with the highest or lowest parasitemias, respectively. In most countries, small urban sample sizes and/or low rates of infection likely accounted for these patterns. In rural areas, observed values were more consistent with expectations, with a few exceptions. In rural Ugandans, among children with low education, high wealth was associated with higher prevalence than lower prevalence (65.2% versus 54.8%). Among residents of rural Liberia, those with high education and wealth had the highest parasitemia, though the difference was small. Across residence strata, high wealth was more often (six of nine countries) associated with a greater decrease in parasitemia than was high education.

Table 5 shows odds ratios (ORs) for infection for urban residence, mother's educational attainment categories, and wealth quintiles from simple country-specific models (IA). The mean odds ratio for urban residence was 0.50; i.e., children living in urban areas experienced 50% lower odds of malaria infection relative to rural residents. Maternal schooling and household wealth were associated with monotonic decreases in odds of infection, as clearly shown in Fig. 2, although education was less often statistically significant than wealth. All significant odds ratios were less than 1.00, except in Madagascar, where completion of primary school was (surprisingly) associated with a 37% increase in risk, relative to no schooling. Being in the highest wealth quintile was associated with lower parasitemia, on average, than either high educational attainment or urban residence.

Global logistic regression models

The global hierarchical models estimate associations that are substantially similar to country-specific estimates. Model IIA included fixed effects for only urban residence, individual-level education and wealth, and country of survey, all of which were highly significant. Model IIB added cluster-level educational attainment and wealth; all variables remained highly significant except for community-level education, which was borderline significant. The magnitude of the associations of risk with individual-level SES and urban residence was reduced. Model IIC added polynomial terms for individual-level education and wealth, which further reduced the magnitude of correlations with urban residence and the other education variables. Because none of the interaction terms among the three main variables of interest (i.e., education * wealth, education * urban residence, and wealth * urban residence) attained statistical significance with the quadratic terms in the model, they were excluded from this and subsequent models. Model IID added covariates; both individual and cluster-level education lost significance, though education remained strongly associated with risk at the individual level because of the polynomial term. Child's age was, as expected, very strongly associated with risk (Fig. 3), while ITN use, but not housing quality, was associated with significant reductions in parasitemia. Increasing household size was significantly associated with increased risk, but mother's age and sex of the household head showed no significant relationships. Urban residence was associated with a large reduction in the odds of infection of close to 40%, while having slept under an ITN the previous night accounted for a moderate reduction of 20%.

DISCUSSION

In this sample derived from DHS/MIS data, maternal education, independently of household resources, was strongly associated with childhood malaria risk. Evaluated at the endpoints of their

Table 6. Odds ratios and confidence intervals for malaria parasitemia in children from global hierarchical logistic regression models: minimal (IIA), incorporating cluster-level socioeconomic status factors (IIB), incorporating higher order terms (IIC), and full, incorporating all covariates (IID).

	IIA	IIB	IIC	IID
Urban residence	0.34 (0.28, 0.40)***	0.48 (0.40, 0.57)***	0.53 (0.44, 0.63)**	0.59 (0.50, 0.71)***
Mother's educational attainment (years) (EDU)	0.939 (0.925, 0.954)***	0.959 (0.942, 0.976)***	0.978 (0.960, 0.996)*	0.990 (0.971, 1.009)
EDU^2	–	–	0.993 (0.990, 0.996)***	0.993 (0.990, 0.996)***
Wealth percentile (WLT)	0.986 (0.984, 0.988)***	0.991 (0.989, 0.994)***	0.991 (0.989, 0.993)***	0.990 (0.987, 0.992)***
WLT^2	–	–	1.000 (1.000, 1.000)***	1.000 (1.000, 1.000)***
Cluster-level educational attainment (mean years)	–	0.967 (0.935, 1.001)	0.979 (0.948, 1.011)	0.980 (0.947, 1.015)
Cluster-level wealth percentile (mean)	–	0.985 (0.981, 0.990)***	0.985 (0.981, 0.990)***	0.984 (0.979, 0.988)***
Child's age (months)	–	–	–	
6–11				REF
12–23				2.22 (1.88, 2.62)***
24–35				3.70 (3.12, 4.37)***
36+				5.00 (4.25, 5.87)***
Child slept under insecticide-treated bednet	–	–	–	0.80 (0.72, 0.88)***
Finished windows and ceilings	–	–	–	0.93 (0.81, 1.07)
Household size	–	–	–	
1–4				REF
5–6				1.11 (0.97, 1.27)
7–8				1.16 (0.99, 1.35)
9+				1.46 (1.24, 1.73)***
Mother's age (years)	–	–	–	
< 20				REF
20–29				1.05 (0.85, 1.30)
30–39				0.92 (0.74, 1.14)
40+				1.07 (0.83, 1.38)
Female head of household	–	–	–	1.09 (0.95, 1.24)
Country				
Angola	REF	REF	REF	REF
Liberia	33.71 (24.63, 46.12)***	33.80 (24.86, 45.97)***	28.13 (21.48, 36.82)***	41.20 (30.27, 56.07)***
Uganda	28.69 (21.26, 38.71)***	32.20 (23.85, 43.48)***	25.24 (19.47, 32.71)***	40.15 (29.74, 54.20)***
Malawi	12.84 (9.61, 17.15)***	13.90 (10.36, 18.64)***	11.63 (8.91, 15.17)***	16.68 (12.38, 22.48)***
Rwanda	0.12 (0.08, 0.16)***	0.13 (0.09, 0.18)***	0.12 (0.09, 0.17)***	0.15 (0.10, 0.21)***
Senegal	0.95 (0.74, 1.22)	0.99 (0.76, 1.28)	1.07 (0.84, 1.37)	1.01 (0.77, 1.32)
Tanzania	0.63 (0.59, 0.81)**	0.72 (0.56, 0.93)*	0.65 (0.51, 0.82)**	0.82 (0.63, 1.07)
Nigeria	27.1 (20.18, 36.27)***	28.62 (21.34, 38.37)***	25.34 (19.55, 32.83)***	31.91 (23.86, 42.67)***
Madagascar	0.35 (0.28, 0.45)***	0.38 (0.30, 0.49)***	0.39 (0.31, 0.49)***	0.73 (0.57, 0.94)*

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; $n = 34{,}043$

ranges, the magnitude of the association between higher maternal education and lower malaria risk in children was smaller than the equivalent association for household resources, yet it was still substantial and statistically significant. Controlling for other factors, completion of six years of primary school by the mother was associated with a reduction in the odds of malaria infection in her child of about 27% (OR = 0.73), whereas an increase from the lowest wealth percentile to the 40th (equivalent to the lower end of the middle wealth quintile) correlated to a 52% reduction in risk (OR = 0.48). The absolute values of these figures appear to lie within the range observed in previously published data, although precise comparisons are difficult because the measures used and outcomes vary widely across studies. For example, Somi et al. (2007) found a one-unit increase in asset-based wealth PCA score—where the range of PCA scores across all individuals was 11.1—to decrease parasitemia by 4%. Siri et al. (2010) estimated a 10% increase in wealth percentile to be associated with a 20% reduction in risk of malarial anemia risk in an urban area. Importantly, it was not possible to evaluate the role of paternal education because these surveys do not specifically identify fathers. Yet this variable is likely to also play a major role, especially where fathers are ultimately responsible for health-seeking decisions. Prior work has shown that paternal schooling may be a strong predictor of investment in children—in some contexts, a better predictor than maternal schooling (e.g., Behrman and Rosenzwieg 2001). To some extent, the effects attributed in this study to maternal education are likely be partly the result of paternal education, with which it is usually highly correlated. A variable linking children to data on their fathers would be a useful addition to future MIS studies.

The inclusion of higher order terms is rare in analyses of socio-demographic or contextual risk factors for malaria, yet such relationships are quite likely. A small increase in resources may make a great deal of difference to a poor household in terms of its ability to provide in ways that reduce a child's malaria risk, while a similar increase may make little difference for wealthy

households that already make use of available malaria prevention and treatment opportunities. In the same vein, a few years of education at the primary level, in addition to (perhaps) providing knowledge about malaria, are likely to boost basic life skills, familiarity with and trust in the public health system, self-reliance, and a host of other factors that affect risk, whereas a few extra post-secondary years may be of lesser import. Conversely, there may be certain thresholds of educational attainment or wealth below which increases have little effect on ability or propensity to mitigate risk. Similarly, interactions among wealth, education, and urban context are to be expected. For example, the ability of individuals to make use of their knowledge and skills should, in fact, depend on their economic resources, and vice versa. The extent to which mothers are able to capitalize on education or wealth may depend on the distance to or the absolute availability of prevention or control measures or other factors which may vary significantly across levels of urbanization. In this study, small but significant nonlinearities were observed in the associations between the logit of malaria parasitemia and wealth and education. In particular, risk decreased with increasing SES terms but also with the squared terms, implying that the effects of these factors (to the extent that these reflect causal relationships) increase at higher levels. Nonlinear effects can result from interactions or from polynomial relationships of the outcome with particular independent variables, or both. This model attributes these to the latter, but a different model selection process might specify a greater role for interaction terms. Nevertheless, observed effect sizes were small, and the main results were relatively insensitive to the choice of higher order terms.

The model specified in this study improves upon previous uses of DHS data to evaluate the association of malaria risk with SES factors by incorporating confirmed parasitemia rather than self-reported fever (as in Filmer 2005) and by separating out the independent effect of education. It complements prior studies with DHS (Fuchs et al. 2010, Pamuk et al. 2011) that have demonstrated a significant association of maternal education, independent of wealth, with infant mortality. In the latter, education was generally found to be more reliably and strongly associated with health than was wealth, whereas the current results suggest the opposite. It may be that infant mortality encapsulates such a range of disease syndromes and potential risk factors that the ability of mothers to flexibly apply knowledge and skills is more important than for malaria, where interventions are generally well defined but often costly. Moreover, the dramatic acceleration in efforts to combat malaria in the African continent over the past decade would, in some cases, have saturated surveyed populations with information on malaria causes, prevention, and treatment, yet in some situations, schooling may confer a relative advantage through the transmission of just such knowledge (e.g., malaria education modules or general instruction on health and hygiene). In such contexts, these "direct" benefits of maternal education would have been dampened (though more distal effects, such as increased self-reliance, would not have been affected).

This study also presents novel information from DHS/MIS on associations of cluster-level maternal education and household wealth with malaria parasitemia. In particular, cluster-level wealth was found to have a slightly stronger association with risk than was individual-level wealth, which potentially bespeaks the role of community-level infrastructure or services. Cluster-level education exhibited a similar inverse relationship with malaria risk, as did individual-level education, but this did not attain significance in the model. This work should be considered preliminary for various reasons. First, different ways of parameterizing community-level education, incorporating all adults rather than just women, or all women rather than just mothers, would likely yield different results; such alternative parameterizations would speak to different hypotheses about the role of community-level knowledge. Second, cluster means are based on relatively few respondents, with a small fraction (7.8%) containing less than five individuals. Because some households contained multiple respondents, cluster-level means will in some cases have been constructed from just one or two households. Analyses based on larger aggregations might arrive at conclusions that differ from or supplement those found in this study for individuals and clusters. The main reason that the elucidation of community-level (or broader geographic) effects has not been undertaken is that the selection of areas over which to evaluate areal associations is not straightforward. Aggregating clusters in a way that accurately reflects endemic, environmental, cultural, economic, or policy boundaries requires a greater knowledge of local context than is available to a secondary analysis of DHS/MIS data. Ideally, it requires access to fine geographic data on sampling locations, maps of endemicity, and detailed local knowledge about, for example, school systems, health catchment areas, geographic aspects of public health action, consumption patterns, and tribal, neighborhood, or other cultural boundaries. This would be a useful area for future work.

As expected, urban residence was strongly associated with malaria risk: urban residents were about 40% less likely (OR = 0.59) to be infected, after controlling for other factors. Broad evidence exists for the reduction of malaria prevalence in cities (Robert et al. 2003, Keiser et al. 2004, Hay et al. 2005). An effort to relate *P. falciparum* prevalence to urban extents at the global scale found the median parasite rate in urban areas to be about 40% that in rural areas (Tatem et al. 2008), and two other studies using MIS data estimated similar odds ratios for urban residence: 0.42 in Tanzania (Gosoniu et al. 2012) and 0.43 in Senegal (Giardina et al. 2012), though this relationship was statistically significant only in the former. These reductions are greater than those observed in the final model in this study but are similar to what is seen in the reduced model (OR = 0.34). It may be that the variables representing community-level wealth and/or housing quality capture some of the variation that would otherwise be attributable to urban residence. The country-specific regressions estimated in this study show substantial variation in the association of malaria with urbanization across countries (OR = 0.32–0.71) (Table 5). An important way forward in further specifying the effect of contextual risk factors will be to link the GPS locations of sampled clusters to continent-wide maps of population distribution and malaria endemicity.

When controlling for other factors, sleeping under an ITN was associated with ~20% reduction in the odds of malaria parasitemia prevalence. This is close to the level observed in a study that used very similar DHS/MIS data to that presented here. Lim et al. (2011) found a pooled mean reduction in prevalence of 24% in children who slept under an ITN. The small difference in estimated effect may arise from the inclusion of different countries/surveys in the overall data set (e.g., Lim et al. [2011]

used data for Zambia but not Malawi, Nigeria, or Madagascar in estimating effects on parasitemia prevalence) or the specification of different covariates (e.g., Lim et al. [2011] used the original DHS wealth index and did not include housing quality). In the final model, housing quality (i.e., the presence of finished walls and ceilings) was not significantly associated with risk—a surprising result, given a priori expectations and the strong relationships observed at the bivariate level. It may be that the cluster-level wealth variable captured some of the variation that would have otherwise been attributable to housing quality. ITNs and quality housing both act as barriers to transmission while sleeping in the household; however, ITNs also act by killing resting mosquito vectors, so it is consistent with theory that this association is larger in magnitude.

A significant association of malaria risk with increased household size was observed, particularly at the largest sizes. Children from households with nine or more individuals were almost 50% more likely (OR = 1.46) to have malaria. The effect of household size is likely complex: a greater number of individuals per sleeping room may reduce the chances of an individual being bitten by a mosquito but may also decrease an individual's likelihood of having access to a bednet. Generally, larger households have more resources at their disposal; however, since malaria is infectious, the presence of more people in close proximity may lead to a higher probability of locally infected mosquitoes, and thus transmission. Risk may also depend on the composition of household members or on the number of people in particular age groups rather than overall household size. For example, in a multilevel analysis in Ethiopia, Peterson et al. (2009) found the number of children aged 5–9 years was a strong predictor (IRR = 1.66) of household risk. Unlike some previous studies, no significant associations were found for mother's age or the sex of the household head, nor did their inclusion appreciably affect estimates for associations with wealth or education.

This study identified strong independent associations of education with malaria risk when using confirmed malaria parasitemia in a range of countries across sub-Saharan Africa and when controlling for other SES factors. Education is valuable in its own right as a critical element of self-determination, human rights, and social justice, but this study provides more evidence that it also is an important determinant of health. It is worth noting that the effects of education on malaria prevalence extend beyond simply the acquisition of knowledge. Indeed, other studies (e.g., Safeukui-Noubissi et al. 2004) have noted that education lowers malaria risk even where specific knowledge is lacking. Likely, education encompasses less tangible factors such as self-sufficiency, motivation, and confidence, which can lead to improved outcomes on a broad front.

There are important reasons to consider the effects of education on malaria prevalence and incidence. For one, policies to promote education are often substantially different from those aimed at reducing poverty or at controlling malaria in the short term, yet such policies may yield important cobenefits for malaria control. Indeed, other work has shown that rising standards of living, including education and consequent shifts in occupation, are in many contexts a precursor—if not a precondition—for malaria elimination (Humphreys 2001). Second, the provision of education has an inertia, inculcating skills and intangible factors in the recipient that have a persistency that does not exist for other interventions (Lutz 2009). Malaria control is too often envisioned as a response to immediate or short-term needs, and resurgence often follows the reduction or cessation of activities. Economic resources, too, are subject to considerable variation at household, community, and national scales, whereas education, once attained, is long lasting (though skills and knowledge may eventually wane), with effects that are felt for decades—even when funding ceases. Given the current shortfalls in funding for global malaria control and the lingering effects of the global financial crisis, it makes sense to add measures that act over the long term to the arsenal of malaria control tools—with due consideration, of course, for cost-effectiveness, the time horizon of expected benefits, and potential opportunity costs. Third, among research needs that have been identified as being critically important as countries move to lower prevalence is a better understanding of distributional aspects of malaria (Marsh 2010); it seems likely that maternal education significantly influences such distributions. Finally, beyond the potential for maternal education as a policy lever for combating malaria, our results suggest the utility of including it as a factor in projections of future endemicity and health costs. In other contexts, it has been shown that taking account of educational attainment in multistate projection models of specific health outcomes leads to significantly different conclusions about the health and needs of future populations (Batljan et al. 2009, Loichinger 2012). If the current climate of optimism and relatively high funding does not lead to the highly anticipated elimination of malaria in much of the world, it may well be that ensuring education for women yields substantial and lasting reductions in prevalence in some situations.

Among the main limitations of this work are the potential for unobserved or excluded variables or endogeneity to generate spurious findings, misspecification in variable construction or ascertainment, unmodeled dependence among observations, and differential recall of information by sampled subgroups.

As with most observational studies of SES factors, endogeneity (i.e., a situation where the values of some factors in the system are partially or wholly determined by the state of other system variables) is almost inevitably a feature in the data used in this study. Each of the three main variables of interest (education, wealth, urban residence) can plausibly be caused, in part, by the other two. Education may affect earning potential and residential preferences; household wealth can determine the ability to pay for education and afford housing. Urban versus rural residence may affect the quality of schooling, salaries, and cost of living. Furthermore, each may affect and be affected by malaria prevalence. Other covariates, such as bednet use or housing quality, are also likely to be endogenous—i.e., on the causal chain from SES to malaria risk. When endogeneity is present, unidirectional studies are likely to overstate the influence of risk factors. This is a problem that has been less extensively considered in the epidemiologic than in the economic literature, and more detailed work on this problem in the context of malaria risk is called for.

In particular, more studies along the lines of Somi et al. (2007) and de Castro and Fisher (2012) are needed to evaluate the direction of causality in the relationships between SES and

malaria, but, as the results of this study suggest, this should be assessed for maternal education in addition to (and separately from) wealth. Moreover, it is not clear that the particular instrumental variables used in prior studies are appropriate for most contexts. For example, Somi et al. (2007) used education of the household head and region of residence as instruments for SES, and de Castro and Fisher (2012) used variables related to household size. From the perspective of this study, none of those would be appropriate due to their associations with malaria risk. It is unclear what set of exogenous variables from DHS/MIS surveys might serve as appropriate instruments that would be valid across all the country contexts examined, and such approaches are more likely to be fruitful in narrower contexts. Yet, comparative cross-sectional studies can still have utility, even when endogeneity is present, by drawing attention to important relationships and by suggesting hypotheses that need further development, as is done in this study.

Although reverse or simultaneous causality is likely in the data used in this study, it is probable that causality in the expected direction also applies; i.e., it is reasonable to suppose that household wealth, which reflects assets built up over the long term rather than instantaneous availability of funds, precedes and influences acute infection in the child. This is even more true for maternal educational attainment, which in most cases will have predated the child's birth, and it is also true for urban residence and housing, and potentially for many other factors. Yet, to the extent that infection in the child reflects risk to other members of the household, the long-term pattern of infection may indeed influence SES factors in this context. Moreover, unobserved factors almost certainly complicate the relationship between education and risk. Innate parental ability, for example, may influence both likelihood of attending school and actions to prevent malaria in children.

Considerable potential for misclassification exists within the DHS/MIS data. Wealth, in particular, is difficult to measure or even accurately to conceptualize in comparative studies. It is not necessarily clear whether the resources most likely to affect health are the immediate availability of funds for acute care or long-term assets and stability, which affect nutrition, education, and many other factors. Moreover, assets owned vary considerably from country to country and from rural to urban areas, such that indices that attempt to capture multiple settings likely misclassify a substantially large proportion of households. The wealth-based asset index, nevertheless, has become a standard tool for cross-country comparisons. Results using asset indices compare favorably with direct measures of household consumption or other economic indicators (Filmer and Scott 2012) and are usually much easier to obtain. Aggregating household wealth at the cluster level based on the responses of mothers may also lead to misclassification of the community resources that are most likely to influence child risk; therefore, alternative parameterizations, as well as larger aggregations, should be explored. Educational content and quality, too, vary across countries and regions within countries, such that equating years of schooling for all respondents is likely to be misleading. It would be of interest to consider more comparable outcomes such as literacy, numeracy, or malaria-specific knowledge; the latter, in particular, was not possible in this study because not all the DHS/MIS data sets included such questions. ITN use may have substantially different implications depending on the specific measure used (e.g., sleeping under an ITN the previous night versus household ITN ownership), though Lim et al. (2011) found nearly identical effects for these two predictors when they used DHS/MIS data. Housing made of finished materials may or may not have open eaves, which allow for mosquito entry and thus infection (Lindsay and Snow 1988). Despite the potential for misclassification, an effort has been made, where possible, to show that the results presented here are plausible and comparable to previous work.

A potentially greater problem is misspecification of the model through the failure to include all relevant variables. The goal in this study was to demonstrate the independent association of maternal education with malaria risk, and a conservative set of explanatory variables was adopted for simplicity and clarity, and to maximize the number of observations relative to independent variables. Yet, a wide range of other variables that affect malaria risk are potentially available in some DHS/MIS data sets, and others could be associated through Geographic Information System/Remote Sensing analyses or the collection of national-level health system, education, or economic data. Among variables of potential interest are community-level endemicity and environmental factors, recent household insecticide residual spraying, behavioral factors related to malaria prevention and control, and economic or policy factors at regional or national scales. Further work should incorporate these variables for a wider range of DHS/MIS surveys. Indeed, a major limiting factor in this analysis was the availability of only 13 of the 32 studies that have collected data on malaria parasitemia (Fig. 1—several countries have completed more than one survey). The timely release of other data sets relevant to malaria risk is critical to conducting effective research. Other variables of potential importance were not included or easily derivable from DHS/MIS data—for example, paternal education or frequency of travel to high-risk areas, which has been identified as a significant risk factor in some contexts (Siri et al. 2010).

The hierarchical multilevel model employed in this study accounts for the nonindependent nature of data collected at cluster and household levels, and for the fixed effects of country of survey. However, within households, some mothers contributed more than one child to the survey sample. This source of variation is unmodeled in this study, and could lead to biased parameter estimates. Most of this variation is likely accounted for by the incorporation of household-level random effects.

Finally, there is the possibility that differential recall or reporting of SES factors between the more and less educated/wealthy could bias the results. Those with a better understanding of the causes of malaria or more direct exposure to, for example, information campaigns, may be more likely to identify factors that contribute to illness in their families, which could lead to an overestimation of the effect of risk factors in this context. Such an effect may have contributed to the unusually high prevalence observed among those with high education but low wealth in Uganda, though small sample sizes probably played a role.

CONCLUSION

The main finding of this study is that maternal education and household wealth are each independently associated with lower malaria parasitemia in children, though the magnitude of the relationship tends to be larger for household wealth. Urban

residence was associated with a greater reduction in risk than was any other factor, with malaria risk in urban dwellers ~40% lower than in rural dwellers. ITN use was associated with moderately decreased risk, but no significant effect was found for high-quality housing. Large household size (9+) was associated with a significant increase in malaria prevalence in children. These findings have important implications for projections of the long-term prevalence of disease and for the policy discourse surrounding malaria control and prevention. Future research on socioeconomic determinants of malaria risk should clearly distinguish between the effects of education and wealth, seek to establish the causality of the relationships involved, and evaluate the extent to which interactions among these factors and others like endemicity and community-level variables affect risk. DHS/MIS data can be useful in this regard, especially as more MIS studies are released for research purposes, but other data that evaluate quality of education and examine the multiple pathways via which SES factors affect risk are needed.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/6134

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Appendix 1. Asset-based wealth index

For each country, we validated the principal components-based wealth index by examining the proportion of households in wealth quintile categories with the assets used to construct the index.

A1.1: Proportion of households with particular indicator assets, by wealth quintile category.

	Wealth Category		
Country/Variable	Quintiles I & II (poorest)	Quintiles III & IV	Quintile V (wealthiest)
Angola			
Asset ownership (proportion)			
Car	0.0000	0.0336	0.4594
Motorcycle	0.0828	0.2041	0.1623
Bicycle	0.1431	0.1154	0.1710
Refrigerator	0.0000	0.0629	0.7478
TV	0.0086	0.5487	0.9793
Radio	0.2224	0.8002	0.9499
Mobile phone	0.0474	0.7020	1.0000
Access to utilities/infrastructure (proportion)			
Electricity	0.0069	0.2989	0.9568
Improved drinking water source	0.1397	0.6555	0.8100
Flush toilet	0.0129	0.2127	0.6269
Characteristics of living residence			
Number of dwelling rooms (*mean*)	1.560	1.930	2.287
Floor of finished materials	0.0052	0.4057	0.9793
Liberia			
Asset ownership (proportion)			
Car	0.0000	0.0000	0.0813
Motorcycle	0.0000	0.0229	0.2262
Bicycle	0.0000	0.0033	0.1012
Refrigerator	0.0000	0.0054	0.0747
TV	0.0000	0.0011	0.2544
Radio	0.1841	0.5854	0.8239
Mobile phone	0.0299	0.6746	0.9235
Access to utilities/infrastructure (proportion)			
Electricity	0.0000	0.0033	0.1096
Improved drinking water source	0.5313	0.7854	0.8809
Flush toilet	0.0040	0.0621	0.3855
Characteristics of living residence			
Number of dwelling rooms (*mean*)	1.508	1.937	2.622
Floor of finished materials	0.1045	0.4477	0.8434
Uganda			
Asset ownership (proportion)			
Car	0.0000	0.0000	0.0637
Motorcycle	0.0000	0.0235	0.2695
Bicycle	0.2329	0.6843	0.5309
Refrigerator	0.0029	0.0103	0.1244
TV	0.0000	0.0037	0.3230
Radio	0.3857	0.8389	0.9146
Mobile phone	0.0323	0.6505	0.9246

Access to utilities/infrastructure (proportion)			
Electricity	0.0000	0.0118	0.3204
Improved drinking water source	0.6231	0.7670	0.8822
Flush toilet	0.0000	0.0000	0.0442
Characteristics of living residence			
Number of dwelling rooms (*mean*)	1.648	2.076	2.298
Floor of finished materials	0.0022	0.1112	0.8483
Malawi			
Asset ownership (proportion)			
Car	0.0000	0.0000	0.0712
Motorcycle	0.0000	0.0039	0.0501
Bicycle	0.3607	0.4862	0.4512
Refrigerator	0.0000	0.0026	0.2375
TV	0.0000	0.0052	0.6280
Radio	0.1777	0.6579	0.9499
Mobile phone	0.0265	0.5793	0.9551
Access to utilities/infrastructure (proportion)			
Electricity	0.0000	0.0013	0.4670
Improved drinking water source	0.6379	0.8689	0.9551
Flush toilet	0.0000	0.0000	0.0897
Characteristics of living residence			
Number of dwelling rooms (*mean*)	1.512	1.965	2.285
Floor of finished materials	0.0027	0.1887	0.8865
Rwanda			
Asset ownership (proportion)			
Car	0.0000	0.0000	0.0343
Motorcycle	0.0000	0.0000	0.0395
Bicycle	0.0366	0.1779	0.4690
Refrigerator	0.0000	0.0000	0.0514
TV	0.0000	0.0027	0.2537
Radio	0.2469	0.8383	0.9447
Mobile phone	0.0379	0.5490	0.9407
Access to utilities/infrastructure (proportion)			
Electricity	0.0000	0.0067	0.4214
Improved drinking water source	0.5342	0.8094	0.9037
Flush toilet	0.0000	0.0000	0.0396
Characteristics of living residence			
Number of dwelling rooms (*mean*)	1.850	2.285	2.591
Floor of finished materials	0.0000	0.0646	0.6192
Senegal			
Asset ownership (proportion)			
Car	0.0105	0.0161	0.0610
Motorcycle	0.0056	0.0862	0.2741
Bicycle	0.1252	0.2726	0.2177
Refrigerator	0.0000	0.0147	0.6175
TV	0.0168	0.4688	0.8862
Radio	0.6273	0.9222	0.9753
Mobile phone	0.4916	0.9636	0.9648
Access to utilities/infrastructure (proportion)			
Electricity	0.0189	0.4569	0.8872
Improved drinking water source	0.5734	0.6629	0.9110
Flush toilet	0.0637	0.4386	0.7389

Characteristics of living residence			
Number of dwelling rooms (*mean*)	3.879	5.418	6.503
Floor of finished materials	0.1400	0.5902	0.7925
Tanzania			
Asset ownership (proportion)			
Car	0.0008	0.0034	0.0673
Motorcycle	0.0034	0.0566	0.2343
Bicycle	0.4295	0.7341	0.6053
Refrigerator	0.0000	0.0008	0.2308
TV	0.0041	0.0189	0.5058
Radio	0.3363	0.7998	0.8516
Mobile phone	0.2089	0.9086	0.9764
Access to utilities/infrastructure (proportion)			
Electricity	0.0000	0.0057	0.4966
Improved drinking water source	0.3202	0.5634	0.8423
Flush toilet	0.0004	0.0095	0.3432
Characteristics of living residence			
Number of dwelling rooms (*mean*)	2.225	2.897	2.980
Floor of finished materials	0.0038	0.1988	0.9026
Nigeria			
Asset ownership (proportion)			
Car	0.0069	0.0533	0.3345
Motorcycle	0.2291	0.5223	0.5398
Bicycle	0.2781	0.2915	0.2632
Refrigerator	0.0006	0.0584	0.6318
TV	0.0259	0.5338	0.9648
Radio	0.4496	0.8562	0.9578
Mobile phone	0.1929	0.8797	0.9813
Access to utilities/infrastructure (proportion)			
Electricity	0.1382	0.5790	0.9237
Improved drinking water source	0.3788	0.5848	0.7115
Flush toilet	0.0178	0.0968	0.4322
Characteristics of living residence			
Number of dwelling rooms (*mean*)	2.421	2.970	3.157
Floor of finished materials	0.2596	0.7225	0.9295
Madagascar			
Asset ownership (proportion)			
Car	0.0000	0.0015	0.0646
Motorcycle	0.0000	0.0010	0.1159
Bicycle	0.0468	0.2347	0.4767
Refrigerator	0.0000	0.0000	0.1216
TV	0.0000	0.0059	0.6125
Radio	0.2330	0.5296	0.8661
Mobile phone	0.0000	0.1545	0.8367
Access to utilities/infrastructure (proportion)			
Electricity	0.0000	0.0142	0.6762
Improved drinking water source	0.0000	0.5516	0.8063
Flush toilet	0.0000	0.0132	0.1491
Characteristics of living residence			
Number of dwelling rooms (*mean*)	1.182	1.504	1.980
Floor of finished materials	0.0000	0.1555	0.7626

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Vulnerability to Weather Disasters: the Choice of Coping Strategies in Rural Uganda

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ABSTRACT. When a natural disaster hits, the affected households try to cope with its impacts. A variety of coping strategies, from reducing current consumption to disposing of productive assets, may be employed. The latter strategies are especially worrisome because they may reduce the capacity of the household to generate income in the future, possibly leading to chronic poverty. We used the results of a household survey in rural Uganda to ask, first, what coping strategies would tend to be employed in the event of a weather disaster, second, given that multiple strategies can be chosen, in what combinations would they tend to be employed, and, third, given that asset-liquidation strategies can be particularly harmful for the future income prospects of households, what determines their uptake? Our survey is one of the largest of its kind, containing over 3000 observations garnered by local workers using smartphone technology. We found that in this rural sample, by far, the most frequently reported choice would be to sell livestock. This is rather striking because asset-based theories would predict more reliance on strategies like eating and spending less today, which avoid disposal of productive assets. It may well be that livestock is held as a form of liquid savings to, among other things, help bounce back from a weather disaster. Although, we did find that other strategies that might undermine future prospects were avoided, notably selling land or the home and disrupting the children's education. Our econometric analysis revealed a fairly rich set of determinants of different subsets of coping strategies. Perhaps most notably, households with a more educated head are much less likely to choose coping strategies involving taking their own children out of education.

Key Words: *coping strategies; covariate risk; education; extreme weather; poverty trap; small-scale farming; Uganda; vulnerability*

INTRODUCTION

Extreme weather events often have severe impacts on lives and livelihoods in the developing world, and climate change is predicted, with varying degrees of confidence, to increase the frequency and intensity of extreme weather in the future (IPCC 2007). It is therefore of great interest to investigate how vulnerability to extreme weather can be reduced.

One aspect of vulnerability is the way in which households cope in the aftermath of a weather disaster. A variety of coping strategies may be employed, from reducing current consumption, for example, reducing expenditure and food intake, to disinvestment, for example, disposing of assets such as land and livestock, and also, reducing investment in educating children. Disinvestment strategies are especially worrisome because by eroding the household's capital stock now and in the future, they erode the capacity of the household to generate income, which may eventually lead to chronic poverty.

We used the results of a household survey in rural Uganda to inquire into the nature of coping strategies used after an extreme weather event and their drivers. Our survey is one of the largest of its kind, containing over 3000 observations garnered by local workers using smartphone technology. As part of a much larger survey, we constructed a hypothetical scenario in which our respondents were exposed to a large drought/flood, which rendered them unable to rely on formal support from the market or state, or from local remittances. We asked them to state which coping strategies they would expect to employ in this scenario.

This enabled us to investigate three things. First, we investigated the nature of the coping strategies most frequently employed, i.e., do respondents turn most often to strategies that reduce current consumption but avoid disinvestment? Or are they in fact more likely to disinvest, and in what? Second, given that multiple strategies can be chosen, we investigated what combinations would tend to be employed. This gave us further insight into the propensity of surveyed households to disinvest, i.e., are disinvestment strategies chosen alongside consumption-reduction strategies, or in isolation? Finally, using the wealth of socioeconomic information that we collected in other parts of the survey, we investigated what determined the uptake of disinvestment strategies that could be particularly harmful for the future income prospects of households.

NATURAL DISASTERS, VULNERABILITY, AND COPING STRATEGIES

The ultimate impact of a natural disaster on a household depends on the household's vulnerability to its effects. In the literature on vulnerability, it is often conceptualized as a function of three elements, i.e., exposure, sensitivity, and

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adaptive capacity (Adger and Winkels 2007). Depending on the unit of analysis, e.g., the individual, the nation, etc., these elements can take on somewhat different meanings, although the basic scope of the framework remains the same.

For our purposes, exposure depends on the physical characteristics of the natural hazard, including its magnitude and the frequency of occurrence. This makes sense when the unit of analysis is a particular household in space and time, but otherwise exposure clearly also depends on who lives where, the value of their assets, and so on. Sensitivity, in the household context, denotes the extent to which it can absorb the impacts of the disaster without suffering long-term harm. Adaptive capacity represents the ability of the household to evolve to cope with a changing exposure to natural disasters. Therefore, when one takes a snapshot of household circumstances at a particular point in time, adaptive capacity reduces sensitivity, and it is convenient to look at the two together.

In terms of exposure, it is well known that Africa, especially sub-Saharan Africa, experiences a large number of droughts and floods, and although there is considerable uncertainty, there is some evidence from predictive modeling studies to suggest that extreme weather will become more frequent in the future because of anthropogenic climate change (Boko et al. 2007, IPCC 2007). In terms of sensitivity and adaptive capacity, it is also widely understood that the impacts of natural disasters are disproportionately large in the developing world, especially in Africa, most especially rural Africa. Our interest, however, is more fine grained and concerns differential vulnerability to extreme weather within the rural developing world, in particular between households living in a broadly similar socioeconomic context, i.e., rural Uganda.

One of the proximate determinants of vulnerability is the choice of strategies households make to manage natural disaster risks. Strategies for managing natural disaster risks are usually divided into ex ante and ex post (Mechler 2004). Our interest is in ex post coping strategies. As with ex ante strategies, these can be grouped into formal, i.e., market-based or publicly provided, and informal, i.e., self-organized on the individual or household/group levels.

When coping with the aftermath of a natural disaster, a household faces a form of portfolio-choice problem. The portfolio could include everything from reducing spending and eating less, through begging and borrowing, migration, selling physical assets, taking children out of school either to work or live elsewhere, to relying on state-based disaster relief, remittances, or insurance payouts.

Rural households in developing countries, however, have in most cases a very limited portfolio, including reducing current spending on food and other items, if possible given the constraints set by subsistence, and disposing of assets such as livestock and land. One of the reasons for this limited choice set is the unavailability of formal strategies because of weak public services and a lack of penetration of market-based instruments because of, for example, a lack of institutions to provide finance or a lack of collateral. Another reason for the limited choice set is the nature of the disaster, i.e., in many cases, the disaster affects the majority of individuals simultaneously, a covariate risk, and therefore informal insurance structures, e.g., family and social networks, do not provide effective relief either.

This unfortunate combination of circumstances can mean that, in the event of a covariate natural hazard, the poorest households may resort to coping strategies tipping them toward chronic poverty, sometimes conceptualized as a poverty trap (Barrett et al. 2006). A poverty trap exists if a household's assets fall to a level below which income growth cannot be supported, and this approach is used to explain low growth paths after disaster events (Carter and Barrett 2006). A lack of productive assets is seen as the most significant driver of the poor falling into vicious circles of extreme poverty (Carter et al. 2007). Therefore, in the context of coping with natural disasters, the key issue is whether a household will need to liquidate productive assets or equivalently reduce the rate of investment in assets, providing it with a means of survival in the short run, but eroding its capacity to earn income and for livelihoods in the longer run.

We are interested in what coping strategies households would employ in the aftermath of a (covariate) natural disaster, and what determines the choice of coping strategies involving various kinds of disinvestment. Within the subset of coping strategies that are likely to damage long-term prospects by disinvesting, we include a focus on strategies involving the disruption and curtailment of children's education. Theories of growth recognize the increasing role of human-capital formation in the development process, in particular a shift in the course of development from demand for skills acquired on the job to skills acquired through formal education (Galor 2011).

It may be assumed that the rational approach to coping with a natural disaster for a household is to first choose those coping strategies that do not erode the household's productive assets now and their accumulation for the future, and resorting to disinvestment only when absolutely necessary. Corbett's (1988) well-known review of the literature on coping with famine interprets various case studies as saying exactly this (see also Ravallion and Chen 1997, Ellis and Mdoe 2003), and it is consistent with Banerjee's (2000) explanation of poverty as vulnerability.

Recent empirical literature yields contrasting and nuanced findings. There is some specific evidence that coping strategies that reduce human-capital investment by sending children to work rather than to school are avoided for as long

as possible (Flug et al. 1998), and this is consistent with the idea that they fall low in the priority-ordering of strategies. However, other studies find that this does not hold true for the poorest households, for whom the immediacy of coping outweighs future returns to human-capital investment (Jacoby and Skoufias 1997, Duryea 1998, Skoufias and Parker 2002). The notion clearly emerges that coping-strategy choice depends on household circumstances.

Similarly, there is mixed evidence on how we should consider the sale of livestock as a coping strategy. Some studies find that selling livestock is one of the first coping strategies households turn to because livestock are held as a form of liquid savings for, among other things, coping with natural disasters (Dercon 1998, Kinsey et al. 1998). Other studies find that the sale of livestock plays a marginal role in coping with extreme weather, or is only employed if households do not have access to other methods of risk-sharing, such as formal credit (Fafchamps and Gavian 1996, Kazianga and Udry 2006), which is actually rather uncommon in many rural parts of sub-Saharan Africa. Two factors that may bear upon the reliance on selling livestock are, first, the extent to which households need to augment cash income as opposed to food consumption, and second, the type of natural disaster, i.e., sale of livestock makes more sense when the environmental shock is a drought or flood because the shock reduces available grazing land and some or all of the livestock could be lost anyway.

In the process of looking at what coping strategies are employed, these studies also offered up clues about the determinants of choice. Unsurprisingly, household income/wealth is seen to play quite a strong role, and this is corroborated by other literature on differential vulnerability (Wisner et al. 2004). Other studies, however, stress that social and demographic factors such as ethnicity, gender, age, and seniority within the community may also be at play (Anderson and Woodrow 1998, Eade 1998). Further clues are provided by the literature on climate vulnerability at the global level, which has stressed the contribution to vulnerability from low incomes, a lack of livelihood diversification, a lack of infrastructure, including infrastructure that provides resilience to extreme weather, such as water storage and flood defense, limited access to credit and insurance, and weak social safety nets (Stern 2007). In the context of credit and social safety nets, one way to cope that may still be operable after a covariate natural disaster is through remittances. As mobile banking has taken hold throughout sub-Saharan Africa, remittances have surged (Blumenstock et al. 2011, Jack and Suri 2011).

We contribute to the literature on coping strategies by reporting relevant results from one of the largest surveys of household disaster-risk management in the developing world, implemented using novel smartphone technology with the help of a network of local community knowledge workers. We provide new evidence on which coping strategies are used most frequently. In particular, we add to the literature pointing to the importance of selling livestock as a means of recovering from a disaster, but we also focus on how often households fall back on disinvestment in the education of children, and the associated causes. The effect of natural disasters on household investment in children's education has not been studied extensively to date.

SURVEY DESIGN

The survey, on which our results are based, was conducted in two districts of Uganda. Oyam district is in northern Uganda, bordering the recently war-torn Gulu region. The town of Oyam lies at 02°14′04″N and 32°23′06″E, at an altitude of 900 m. The second district is Kapchorwa, in the east of Uganda, bordering Kenya and encompassing Mt. Elgon. The town of Kapchorwa lies at 01°24′00″N and 34°27′00″E. The two regions were chosen to capture intracountry variation in disposable income, as well as geographic location. Nevertheless, the economies of both regions are based primarily on subsistence agriculture. Figure 1 maps the study areas in the context of Uganda.

Fig. 1. Study areas: Oyam (02°14'04"N and 32°23'06"E) and Kapchurwa (01°24'00"N and 34°27'00"E).

Farming methods in these two areas are traditional, not encompassing much technological advancement. Only 1% of the households we sampled own a borehole, for example, and mechanized ploughs and active irrigation are seldom used.

Most farming families in our sample have a source of secondary income, including small shop ownership, participation as an educator in a local school, working for NGOs on a local level, money-lending within the community, and renting personal assets, such as car batteries to charge neighbors' phones. Few of the households we sampled have access to formal credit.

The survey (Muth and Helgeson 2011) consisted of 125 questions, asking about the household's socioeconomic circumstances, its attitudes to natural disaster risks, and the courses of action it would take in the event of a disaster. In the latter two cases, it was the stated opinions of the head of the household that were sought. Two small games were integrated into the survey to measure, in an indirect way, the respondents' risk preferences. Such an approach is a hybrid of what is known, in the field of economic valuation, as a stated-preference approach, whereby respondents are directly asked to report their preferences, and a revealed-preference approach, whereby preferences are deduced from real behavior (Pearce et al. 2006). The advantage of the latter is that problems created by the generally hypothetical nature of stated-preference questions, and other aspects of the interview context, can be avoided. However, real behavior is complex and difficult to disentangle into the constructs of interest because in many cases the relevant real behavior simply does not exist or cannot be measured. We make use of the results of one of the games, which we further explain in Appendix 1. Finally, a series of literacy and numeracy questions tailored to a developing-world context were asked in the survey with the results used as a control for other responses.

The survey was administered in the field by the Grameen Foundation's network of community knowledge workers (CKWs). A CKW is a local person who is familiar with the realities of the farmer's daily life, including agricultural practices and typical financial arrangements. A CKW speaks the local language/dialect and lives in-country, often on an income similar to that of the farmers with whom she or he works. One hundred and fifty CKWs in the two regions were equipped with smartphone technology. The survey tool took the form of a software application. Responses were gathered from each survey respondent by a CKW and remotely transmitted to a central database. Before administering the survey, we held two training sessions with CKWs in each study region, as well as a pilot study, again in both Kapchorwa and Oyam.

There were a total of 3258 usable responses in the dataset, 1858 were from households in the Kapchorwa region, and 1400 from Oyam. One hundred and nineteen responses were dropped from the dataset (53 from the Kapchorwa region and 66 from Oyam), either because they were incomplete and key pieces of information were missing, or because responses were judged by the authors to be implausible and likely the result of mistakes in data entry, misunderstandings between the respondent and the CKW, or similar errors. During the survey process, there was a nonresponse rate of about 6% reported by the CKWs. The main reason given for nonresponse was that potential respondents were busy farming.

The mean age of the household head was 40.4 years, with a standard deviation of 13. The mean number of household members in addition to the survey respondent was 4.9 (s.d. 2.9). The average land holding was 5.1 acres (s.d. 70.7), but more than 60% of the sample farmed less than 2 acres of land and nearly all owned the land they farmed. The skew in the distribution of the size of land farmed is thus clear.

It was rare that our households shared land, and only 20% did so for any part of the growing season. Fifty-two percent of the sample generated more than half of their total household income through farming (Table 1) and 80% had surplus crops to sell on the market. Table 2 outlines the survey sample's educational attainment in terms of years of schooling.

Table 1. Percentage of household income from farming activities.

Region	Percent income from farming			
	0-25%	25-50%	50-75%	75-100%
All	19.4	18.1	27.7	33.2
Kapchorwa	20.3	19.5	26.7	32.0
Oyam	18.1	16.3	29.1	34.9

Table 2. Years of schooling of the household head.

Region	Educational level attained by household head (percentage of sample)			
	No formal education	Primary school	O-level equivalent	Above O-level
All	18.78	45.76	26.30	9.15
Kapchorwa	20.61	38.37	31.16	9.85
Oyam	16.36	55.57	19.86	8.21

The majority of farmers obtained funds in a time of disaster from friends and family, although if the disaster was covariate then this was only of value if the help was obtained from outside the community. As expected, the proportion of those receiving remittances from outside their village was correlated with the percentage of those with close family living outside their village. Looking at the opposite flow, upward of 70% of the sample sent remittances outside the village on a regular basis, 23% by means of mobile money.

As mentioned, we used a game, involving coins, to gauge risk aversion in the context of farming. The results were measured in terms of the coefficient of relative risk aversion, the standard measure of risk aversion in economics (Gollier 2001). The results of this game are presented in Table 3 because we will

later make use of them in our econometric analysis, albeit the interpretation of the variable must be at the ordinal level of measurement.

Table 3. Risk aversion.

Region	Coefficient of relative risk aversion (higher means more risk averse)				
	< 0.1	0.1-1.3	1.3-3.2	3.2-5.0	> 5.0
All	13.96	7.61	30.73	12.32	35.38
Kapchorwa	18.42	8.74	31.16	13.91	27.77
Oyam	7.82	6.06	30.14	10.12	45.86

PREVALENCE OF COPING STRATEGIES

Respondents to our survey were presented with a scenario in which they fall victim to a hypothetical natural disaster, most plausibly a drought or flood, which is covariate, in the sense that all households in the area are affected and thus respondents are told to assume there would be no form of help, e.g., remittances, available from family or friends close by. They were presented with twelve coping strategies and asked to choose as many as they would expect to employ in such a situation. It was possible to choose none. Table 4 lists these coping strategies and the frequency of responses for each strategy across the whole sample, and in Kapchorwa and Oyam regions individually. Our list of coping strategies was initially developed by reviewing the literature. We also conducted background qualitative field interviews in both Kapchorwa and Oyam to check the relevance of our set of strategies to the local context.

Table 4. Coping strategies that would be used after a disaster event.

Coping Strategy	Frequency (percentage of total)		
	Total Sample	Kapchorwa	Oyam
Reduction of food intake	738 (23)	419 (23)	323 (23)
Borrow food	624 (19)	379 (20)	251 (18)
Reducing expenditures	1250 (38)	697 (38)	558 (40)
Sell livestock	2196 (68)	1290 (70)	913 (65)
Begging	327 (10)	179 (10)	153 (11)
Sell household items	336 (10)	182 (10)	157 (11)
Sell land or home	95 (3)	40 (2)	59 (4)
Take children out of school	67 (2)	33 (2)	41 (3)
Send children to live elsewhere	38 (1)	29 (2)	16 (1)
Migrate	44 (1)	37 (2)	10 (1)
Change profession	294 (9)	157 (9)	138 (10)
Send children to work	178 (6)	81 (4)	99 (7)

The results across the two regions were very similar. Thus, we can say with some confidence that conditional on the scenario we presented region-specific factors were unimportant in determining the frequency of uptake of coping strategies. What was particularly interesting about the results was the frequency with which the sale of livestock was chosen. It was by a large margin the most frequently chosen coping strategy, i.e., 68% of the pooled sample would use it, compared to 38% for the next most popular strategy, reducing expenditures. To some extent, this was to be expected, because livestock is a commonly held asset among sampled households, i.e., 91% of households reported owning livestock. In addition, the sale of livestock may not undermine the household's productive base as much as some other strategies, such as selling land or one's home, or disrupting the children's education, especially in conditions where the livestock may not be able to graze well for some time. This high frequency of livestock ownership and willingness to cope via livestock sale supports the claim that farmers in the rural developing world use livestock as a form of liquid savings (Dercon 1998, Kinsey et al. 1998). We cannot make that claim definitively, however, because our survey response categories did not distinguish between the sale of surplus livestock that may have been accumulated during times of relative plenty precisely for insurance against natural disasters, and the sale of livestock required for subsistence.

On the other hand, it was surprising that strategies involving reducing current consumption or augmenting it through other means were not chosen more frequently. This runs somewhat counter to the literature on coping strategies, which suggests they are chosen in sequence such that the disposal of productive assets is resisted until other possibilities have been exhausted (Corbett 1988). These include the reduction of food intake, chosen by 23% of the pooled sample, borrowing food (19%), reducing expenditures (38%), begging (10%), and perhaps some forms of migration, e.g., temporarily for work (only 1%).

It might be argued that food intake and expenditures cannot be reduced because households are already at subsistence level, and further reductions in consumption would present potentially severe consequences for lives. There may certainly be some truth to this, especially if the disaster is severe, but 81% of households in our sample were able to sell surplus crops on the market under normal circumstances, i.e., they were above subsistence prior to the shock. Moreover, this does not explain the reluctance to beg and borrow. It remains striking that sale of livestock was reported so much more frequently than reducing consumption, or augmenting it through borrowing or begging.

More consistent with the literature is the finding that coping strategies that more unambiguously erode the household's stock of productive assets, were seldom chosen. Among these were strategies involving disrupting the children's education, i.e., taking children out of school, sending children to live elsewhere, and sending children to work, suggests that, across the board, households do indeed take education seriously and

Table 5. Principal components analysis loadings.

Component	1	2	3	4
Sell land or home	0.141105	0.37362	-0.066	0.437837
Sell livestock	-0.15134	0.22887	0.621184	0.229587
Change profession	0.048482	0.008033	-0.69758	0.021163
Beg	0.254222	0.212041	-0.12513	-0.3422
Take children out of school	0.270276	0.348158	-0.01925	0.369079
Send children to live elsewhere	0.230579	0.413378	0.101	-0.27516
Sell household items	0.326232	0.190426	-0.06193	0.041663
Migrate	0.232515	0.245374	0.136839	-0.53162
Eat less	0.42126	-0.39377	0.127547	0.039524
Borrow food	0.440882	-0.09887	0.122783	-0.03415
Send children to work	0.321157	-0.02363	-0.10315	0.371403
Reduce Expenditures	0.358498	-0.45721	0.17997	0.032845
% Variance Accounted for by Component	17.98	11.26	9.82	9.28

treat it as a long-term investment, as theories of household capital formation would suggest (Barham et al. 1995).

Because households could choose several strategies, as they can in a real disaster situation, it is of further interest to examine the response data for frequently chosen combinations. We employed a principal components analysis (PCA) to do this. PCA is a commonly used method in exploratory data analysis for identifying, among other things, how variables cluster in a dataset. We wanted to identify whether there were clusters of coping strategies that were frequently chosen together and, if so, what strategies comprised these clusters. One can thus think of a component as an overarching strategy choice, which is realized through choosing specific coping strategies.

Figure 2 displays the results of the PCA in terms of a scree plot (Cattell 1966), which plots the principal components of the dataset against their eigenvalues, a measure of the amount of variance in the dataset explained by each component. Highly clustered datasets yield scree plots in which the eigenvalues drop off very steeply from the first component, quickly flattening out. In addition, Kaiser (1960) proposed a well-known criterion for the interpretation of PCA results, such that only those components whose eigenvalues are greater than one are retained.

What is striking about Figure 2 is how gently the scree plot falls away, especially from the second component onward. The eigenvalue of the first component is also relatively low because it is not unusual to see eigenvalues of well over five in highly clustered datasets. Thus, there appears to be relatively little clustering of coping strategies in the survey data. This hints at a heterogeneous set of strategy combinations chosen by the sample households, and/or at few households choosing combinations at all. Were it the case that certain combinations of strategies were frequently chosen, we would have expected to see the relevant components explain more of the sample variance.

Fig. 2. Scree plot of eigenvalues for principal components analysis of coping strategies.

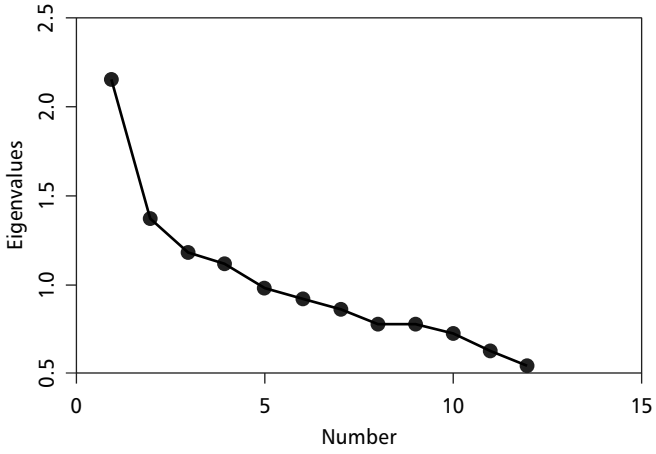

Table 5 presents the component loadings, whereby a loading is the correlation between the variable and the component on the first four components whose eigenvalues are greater than one. The higher the loading, the higher the association between a strategy and the overall component, i.e., the overarching strategy. Consistent with the lack of clustering indicated by Figure 2, the loadings are generally small. There is some weak evidence that strategies involving reducing current consumption are sometimes chosen together because the first component has higher loadings on borrowing food, eating less, and reducing expenditure. The second component has higher loadings on sending children to live elsewhere and taking children out of school, which are similar strategies, seldom chosen overall (see Table 4). Perhaps the strongest result is for the third component, which has a very strong loading on selling livestock, but very weak loadings on all other strategies, indicating that this most popular strategy tends to be chosen in isolation.

Besides the lack of variance accounted for by the principal components and what this indicates about the survey responses, one of the main conclusions we can draw from the PCA is that the component structure is rather at odds with the popular theory that strategies are chosen in typical sequences (Corbett 1988). Were that the case, the sequences should have been evident in the results.

DETERMINANTS OF ASSET LIQUIDATION

Of the 12 coping strategies presented to respondents, 6 could fall into the category of capital disinvestment, i.e., sell livestock, sell household items, sell land or home, take children out of school, send children to live elsewhere, and send children to work. Within this subset, by far the most readily adopted would be the sale of livestock, with 68% of the sample willing to do so. Therefore, even though it is unclear to what extent sale of livestock affects the household's future prospects, on weight of numbers alone, it is of interest to analyze what determines the choice of this strategy, either in isolation or in combination with any other strategies. To do this we constructed a binomial variable, LivestockLiq, which took the value of 1 for those households indicating a willingness to utilize the coping strategy of livestock sales. Clearly, only households that own livestock can sell it, so we accounted for this by restricting the sample to livestock-owning households, reducing the sample by only 290 households.

We also focused on the choice of disinvestment strategies that would take children out of the educational system. Given the rising importance of human-capital formation to development, and notwithstanding the continuing importance of practical learning-by-doing in the labor markets of less-developed economies, these strategies can be particularly important in affecting long-run vulnerability. We developed the binomial variable, AssetLiqChild, which took the value of 1 for those households indicating willingness to take children out of school, send children to live elsewhere, and/or send children to work.

These two variables, LivestockLiq and AssetLiqChild, were used as dependent variables in a regression analysis of our survey data to shed light on which socioeconomic and attitudinal factors determined their uptake by households. Note that because of the rather weak clustering of strategies, we did not take forward the principal components into this analysis.

Research on household vulnerability to natural hazards has previously emphasized the importance of capital assets (Wisner et al. 2004, Carter and Barrett 2006), so we included measures of (1) the household's built and financial capital and (2) its human capital. Because neither of these forms of capital is directly observed, we used proxies for them based on relevant literature and what our survey made available.

For built/financial capital, we used the acreage of land owned by a household as our proxy measure (Acres). Previous literature has suggested that there is a strong relationship between access to land and household income, certainly in eastern and southern Africa (Jayne et al. 2003). Human capital is straightforwardly captured via the ordinal-level variable education, which summarizes the respondent's years of schooling. The data for this variable, in Table 2, shows that the majority of respondents (64%) leave formal education at the end of elementary/primary school at the latest, a further 26% of respondents leave school at the ordinary level, i.e., O-level, and only 9% of respondents remain in school thereafter to complete advanced-level secondary education. Natural capital stocks are stressed in the literature, but we excluded them in this study because it was assumed that environmental conditions were the same in a given period for all households sampled. Social capital is also stressed in the literature, but social capital is notoriously hard to measure, and in our scenario it is social capital that exists beyond the local level that is of interest because the natural disaster scenario is covariate. We included one explanatory variable that partially captures social capital beyond the local level.

We included several other explanatory variables relating to the household's wealth and income. None of these were highly correlated with the others, and each promised to control for a rather different effect, so we included them in our models.

First, we included the share of household income from farming (IShare). This was an ordinal-level variable ranging from 0 (0-25%) to 3 (75-100%), which mapped to intervals that respondents could choose in the survey. Two households with the same income, and perhaps also wealth, but with differing degrees of dependence on farming for income, might be expected to rely to a different extent on livestock sale in the event of a drought or flood; for example, more diversified households may be less reliant on selling livestock because they have other coping strategies within their feasible set.

Second, we included a dummy variable indicating whether a household was engaged in subsistence farming or whether it was able to sell surplus crops to the market (Surplus). This may, for example, affect whether a household has a reduction in food intake or expenditure within its feasible set. It may also affect the relative impact on a household of a disaster that affects crop yields. Note that for interpretation of the results, the coding of this dummy variable was 0 for a surplus and 1 for no surplus.

Third, we specified the dummy variable (FamRem), which indicated whether the household was a net recipient of remittances from outside of its village, or a net provider beyond the village. This was first and foremost an indicator of the household's financial position, i.e., we assumed net providers were in a stronger position, all else being equal, but because remittances also depend on social capital, it can be seen to

partially capture super-local social capital stocks as well. About 47% of households received more in remittances from outside the village than they provided, although 34% were net providers. The remainder neither sent nor received remittances.

That there could be connections between the choice of coping strategy and attitudes to risk, especially those held by the head of the household, is intuitive. To gauge the effect of risk perceptions, we included the outcome of our coin game for each respondent (CoinRisk). The coin game provided us with a measure of household risk aversion, specifically as it applies to agricultural planning. In this model, we used an ordinal variable to indicate if a respondent was relatively more risk averse. The higher the variable value for a given household, the more risk averse it was. We also controlled for the age of the household head via the variable Age, and we controlled for the size of the household (FamSize). A particular concern in any regression model is bias resulting from unobserved variation. This is more difficult to counter in cross-sections than in panel datasets, but we included two variables to deal with it. Possible regional differences were incorporated in the model by specifying a region-level dummy variable (Region) that took on different values depending on whether the respondent was located in Oyam or Kapchorwa. More importantly, we exploited detailed local data on where the responses were garnered to specify 34 dummy variables at the sub-county level. The estimation technique is probit. Table 6 summarizes the regressors.

Table 6. Explanatory variables of differential vulnerability.

Variable	Name	Scale of measurement
Region	Region	Categorical
Educational status	Education	Ordinal
Acres owned	Acres	Ordinal
Age	Age	Continuous
Family size	FamSize	Continuous
Income share from activities outside farming	IShare	Ordinal
Surplus crop sold on the market	Surplus	Categorical
Risk aversion	CoinRisk	Ordinal
Remittances	FamRem	Categorical

Table 7 (column i) presents the estimated probit model for willingness to sell livestock. It shows good explanatory power overall. A number of key explanatory variables were individually significant in the model. Of these, IShare and Surplus were significant at better than the 1% level, the former positive, the latter negative. In particular, households with a higher share of income from farming were more likely to sell livestock after a natural disaster, as were those households that grow surplus crops to sell on the market. In both cases, the most likely explanation is that the variable reflects vulnerability to natural disasters and that greater vulnerability leads to a greater reliance on the sale of livestock to cope. IShare was indicative of the diversification of household employment, which has been shown to be associated with lower levels of vulnerability (Wisner et al. 1994). Furthermore, diversification has been argued to act as a safety valve for the rural poor by providing a broader set of feasible coping strategies from which to choose (Ellis 2000). Households that have surplus output to sell on the market (Surplus) lose not only their own source of food when a natural disaster wipes out crops, but they also lose potential income from market sales, burdening them with a greater need to cope overall. It might be objected that households selling surplus crops on the market are better off and therefore less vulnerable to natural disasters because their farms are more productive, but recall that we control in various ways for household income and wealth.

Table 7. Probit models of the determinants of strategies to (i) sell livestock and (ii) taking children out of education.

Variable	(i) LivestockLiq	(ii) AssetLiqChild
Region	-6.52	-3.14
Education	0.03	-0.16 ***
Acres	-0.001	-0.000
Age	0.004 *	0.006 *
FamSize	0.025 **	0.042 ***
IShare	0.098 ***	-0.009
Surplus	-0.314 ***	0.016
CoinRisk	-0.161 **	0.170
FamRem	0.050	-0.005
Number of Ob	2788	2935
Log likelihood	-1471.59	-726.440
Pseudo R^2	0.134	0.166

FamSize and CoinRisk had significant positive effects on willingness to sell livestock, albeit only at the 5% level. The greater the family size, the more likely it is that the household will sell livestock to cope, which could again reflect a positive association between family size and vulnerability, i.e., the larger the family the more mouths there are to feed. Together with the significant coefficients on IShare and Surplus, the picture is thus building that the sale of livestock is a strategy commonly turned to by households more vulnerable overall to natural disasters. This picture is in turn consistent with the notion that livestock is held as a liquid asset to form a first line of defense in coping with such shocks, although it is also consistent with the notion that more vulnerable households cannot cope by reducing consumption alone, or by using other strategies that avoid disinvestment, i.e., livestock is only sold once the returns from other strategies have been exhausted. Yet we know that such strategies are used less frequently, and we did not find evidence that they were employed in combination with selling livestock.

The positive coefficient on CoinRisk indicated that, the more the head of the household was risk averse, the less likely it

was that livestock was sold as a means to cope. This could reflect a number of considerations because the dynamic relationship between coping strategies and income risk for particular households is extremely difficult to know. It could also reflect a correlation between CoinRisk and income/vulnerability because it is widely thought that relative risk aversion decreases with household income (see Rosenzweig and Binswanger 1993 for classic evidence on farmers' risk aversion).

Age was significant at the 10% level and positive, indicating that households in which the household head was relatively older were more likely to sell livestock as a means of coping. It is probable that age encompasses an underlying effect not accounted for directly in our model. By way of one possible explanation, in many rural societies age correlates with changes in the role played within the wider community (Lipton and Maxwell 1992). The older the household head, the higher the cost to his reputation from borrowing or begging, for example. With increasing age may also come reduced mobility, ruling out coping strategies involving migration, for instance. Neither our financial-capital nor human-capital proxies were significant in this model.

The probit model with the dependent variable AssetLiqChild is shown in Table 7 column (ii). As mentioned previously, this type of coping strategy unambiguously reduces the household's investment in capital (human capital) that would likely reap returns in the future. The estimated model shows good explanatory power overall. Education was significant at the 1% level and negative, indicating that, the higher the educational attainment of the household head, the less likely they were to risk compromising their children's educational attainment. It may well be that those with higher educational attainment placed more value on investment in human capital per se because, within our sample, there was no significant correlation between education and built/financial capital wealth.

By contrast, FamSize was significant at the 1% level and positive, indicating a higher propensity to disrupt the children's education after a natural disaster when the family size is greater. This is intuitive because households that have more people to care for are more likely to take up coping strategies that may endanger future prospects, but stabilize household prospects in the immediate term. With increased family size, in particular increased numbers of children, we can also hypothesize an effect at the margin, whereby the cost to future prospects of having one less child in formal education is lower. There was a weak, i.e., significant at the 10% level, positive association between Age and AssetLiqChild, which may again reflect factors linked with age.

DISCUSSION

Our survey results suggest that the sale of livestock is by far the most frequently chosen coping strategy after a weather disaster. This runs counter to some previous studies indicating that the sale of livestock plays a minor role in coping with extreme weather (Fafchamps and Gavian 1996, Kazianga and Udry 2006), and to the thrust of the literature on choosing coping strategies in sequence (Corbett 1988), such that a reduction in current consumption is always attempted prior to liquidating any assets. We found that strategies involving reducing current consumption or augmenting it by borrowing/begging would be used fairly seldom. Conversely our results support the argument that livestock is held as a form of liquid savings, one possible use of which is to recover from a shock (Dercon 1998).

Our findings reveal a fairly rich set of determinants of different subsets of coping strategies. We chose to focus on drivers of the choice to cope via the sale of livestock, given its prevalence, and the reduction of children's education, given its potential importance. Our findings point out the impact of initial vulnerability on the propensity to disinvest, where initial vulnerability is represented by a lack of income diversification, a large family size, and in the case of selling livestock, whether surplus crops are sold on the market, and hence, how much of a shock the weather event is to household income. However, our findings also point out attitudinal and social factors (thus consistent with Anderson and Woodrow 1998, Eade 1998), notably the effect of educational attainment on educational aspirations for children, attitude to risk, and albeit weakly, age.

There are some limitations to our study, chiefly that our survey questions, being hypothetical in nature, could yield answers affected by various forms of bias. However, the fact that the survey was administered by local CKWs, who had a pre-existing relationship with the respondents, built on trust, helped to combat this issue. Also, in the areas researched, large covariate weather shocks, i.e., involving loss of at least half a crop, occurred at least once every four years, so respondents were familiar with the issues in question. Furthermore, in neither region is there formalized agricultural insurance, which also serves to make the scenario realistic.

Though our regression models have good explanatory power, the issue of endogeneity, principally through omitted variables, is one that we need to be aware of. We account for this as best we can by (1) specifying a rich set of regressors, none of which is highly correlated with other regressors, and (2) by including dummy variables at the subcounty and regional levels to account for unobserved variations.

Responses to this article can be read online at:
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Appendix 1. The coin game.

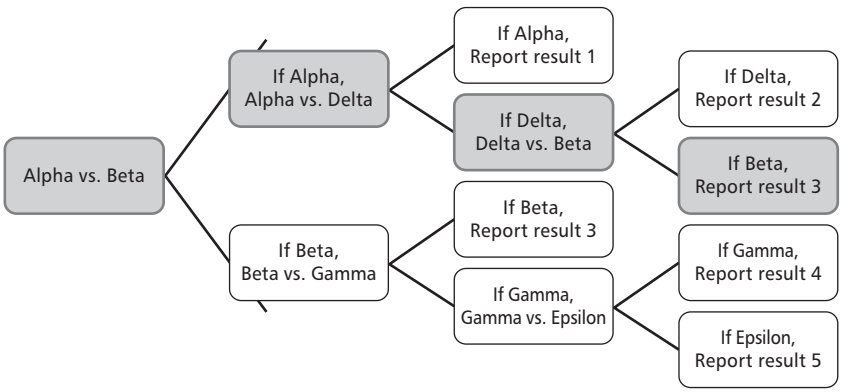
The coin game is a way to quickly measure the risk aversion of a single subject through binary-choice iterations. The game is designed in a triple-bounded dichotomous-choice structure. The subject is given two coins and told each coin represents a crop he could choose to grow in the coming season. One flip of the coin will decide the size of the harvest his crop yields. The participant is allowed to examine and handle the coins, which are metal tokens (see Figure A.1), and is then asked to choose which crop he will plant (dichotomous choice). One coin offers a yield of 5 on either side, thus being risk-free, while the other coin offers yields of 9 on one side and 3 on the reverse, thus involving risk. For consistency, in describing administrations of the game, the former coin is referred to as 'Alpha', while the latter is called 'Beta'. The yields are expressed in arbitrary units, with icons representing crops to minimize any cultural or linguistic skew in the results.

Figure A.1. The coins.

The Choices Offered in Round One of the Coin Game

After the subject chooses between Alpha and Beta in the first round, he is provided in a second round with a choice of two new coins. The choice of coins depends on the coin chosen in the first round, according to the decision tree in Figure A.2. It is possible to go through three rounds (triple-bounded), as illustrated by the shaded pathway in the figure.

Figure A.2. Constant-relative-risk-aversion decision tree.



Note that maize was chosen as the crop to display on the coins, as it is familiar to nearly all farmers in Uganda.

The game itself is a version of a classic risk-aversion classification exercise. To analyze the game output, we use the framework of constant relative risk aversion. Under constant relative risk aversion, the utility of consumption u(c) is given by the following function:

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}$$

where σ is the coefficient of relative risk aversion, a parameter controlling the curvature of the utility function, which measures risk aversion.

Where the player chooses the 9:3 coin (Alpha) rather than the 5:5 coin (Beta) in the first round of the game, his choice is mathematically equivalent to an inequality between probabilities where the participant prefers one probability to the other. The choice of the 9:3 coin can be represented by:

$$5^{1-\sigma} = \frac{1}{2}(9^{1-\sigma} + 3^{1-\sigma}) \rightarrow \sigma_{9:3}$$

As the context of each decision is a choice between two coins and the probabilities of any given outcome at any given time are equal, this follows for all other values in the opportunity set, e.g.:

$$\therefore 5^{1-\sigma} = \frac{1}{2}(8^{1-\sigma} + 4^{1-\sigma}) \rightarrow \sigma_{8:4}$$

and

$$\therefore \ 5^{1-\sigma} = \frac{1}{2}(10^{1-\sigma} + 2^{1-\sigma}) \rightarrow \sigma_{10:2}$$

This method allows the player to be quickly categorized according to the variance he will tolerate with two choices at a mutual probability of 0.5. The coins represent variances of the following values (each of which represents a comparison of a coin's two sides expressed as a fraction): 1, 1/2, 1/3, 1/5, 1/11.

Hence, the participants are classified into five categories of risk aversion.

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