26 Poverty and climate change: Natural disasters, agricultural impacts and health shocks

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The international community aims to eradicate extreme poverty, and to do so in a sustainable manner. This chapter suggests that climate change poses a major obstacle to this challenge. Climate-related shocks and stresses – from natural disasters, to agricultural impacts and health shocks – already prevent households from escaping poverty. Poor people are disproportionally vulnerable to these shocks, because they are more exposed and lose more when affected. Climate change will worsen the situation, making it more difficult to eradicate poverty in a sustainable manner. Many policy options are available to help reduce poor people's risk and vulnerability, including building climate-smart infrastructure, providing universal health coverage, implementing social safety nets that can be scaled-up and rapidly targeted towards people affected by a shock, and facilitating migration. With regards to natural hazards, agricultural impacts and health shocks, climate change makes existing priorities more urgent. If addressed correctly, this urgency can turn into an opportunity to reduce both current poverty and future climate vulnerability, before most of the impacts of climate change materialise.

1 The impacts of climate change: Should we focus on poverty instead of GDP?

Estimates of the economic cost of climate change have always attracted interest and debate among policymakers and the public. These estimates, however, have mostly been framed in terms of the impact on country-level or global GDP, which does not capture the full impact of climate change on people's well-being.

One reason is that such estimates do not reflect distribution. The distribution of climate impacts – that is, which countries, regions and people are hit – will determine their effects on well-being. Three-quarters of global income belongs to North America, Europe, and East Asia; the other regions are economically much smaller, and in particular sub-Saharan Africa, which only generates 2% of global income (World Bank 2015). The location of impacts to GDP therefore matters.

Equally important is the fact that the impacts of climate change will be highly heterogeneous within countries. If the impacts mostly affect low-income people, the welfare consequences will be much larger than if the burden is borne by those with a higher income. Poor people have fewer resources to fall back on and lower adaptive capacity. And – because their assets and income represent such a small share of national wealth – poor people's losses, even if dramatic, are largely invisible in aggregate economic statistics.

Investigating the impact of climate change on poor people and on poverty requires a different approach, focused on people that play a minor role in aggregate economic figures and are often living within the margins of basic subsistence. Such an approach was behind a research programme on 'Poverty and climate change' at the World Bank, and this chapter is based on some of the programme's results (for a comprehensive presentation of the results, see Hallegatte et al. 2016). The research starts from the idea that poverty is not static, and poverty reduction is not a monotonic, one-way process. Over time, some people build assets and move out of poverty while others experience shocks and are pulled into poverty. What we call poverty reduction is the net result of these mechanisms. For instance, Krishna (2006) documents poverty dynamics in 36 communities in Andhra Pradesh, India, over 25 years. Each year, on average 14% of households escaped poverty while 12% of non-poor households became poor, so that,

overall, poverty was reduced by 2% per year. These numbers show that a relatively small change in the flows in and out of poverty has a significant effect on overall poverty dynamics. For instance, increasing the flow into poverty by 10% is enough to halve the rate of poverty reduction.

Climate change can affect the flow of people into poverty. In the Andhra Pradesh sample, drought is a major factor – a household affected by drought in the past was 15 times more likely to fall into poverty (Krishna 2006). Droughts may also result in people falling into poverty traps as a result of asset losses. They often affect human capital, especially for children who may be pulled out of school or suffer permanent health consequences (Carter et al. 2007). Even just the risk of a drought can lead poor people to invest in low-risk but low-return activities, perpetuating poverty (Elbers et al. 2007). An impact of climate change on drought frequency and intensity could therefore hamper poverty reduction, with more people falling into and fewer people escaping poverty.

But droughts and natural hazards are not the only climate-sensitive factors to affect the flows in and out of poverty. Agricultural income and food prices matter, as do health shocks. The next sections investigate the following major channels through which climate change affects poverty dynamics: natural hazards, agriculture and health. Of course, many other factors play a role, but these three channels already have well-documented impacts on poor people and poverty reduction, and will be affected by future climate change.

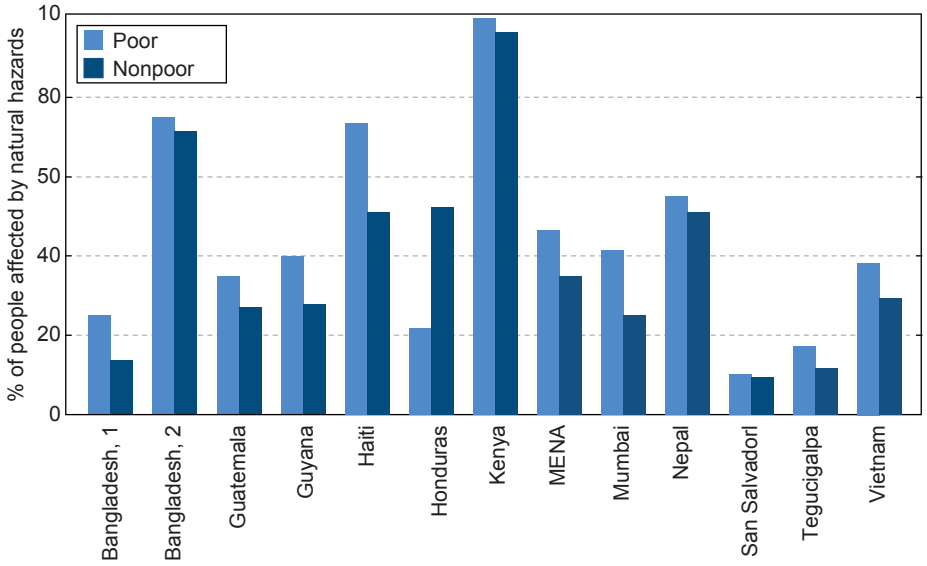
2 Natural hazard impacts

In some regions, natural hazards such as floods, droughts, and extreme temperatures will increase in frequency or intensity as a result of climate change. The exposure, vulnerability, and lack of adaptive capacity of poor people puts them at particular risk.

Regarding exposure, it is often the case that poor people live in risky areas. A number of case studies have examined the exposure of poor and non-poor people to disaster risk, with most finding poor people to be more exposed (Figure 1). For instance, when

large-scale floods hit the Shire River Basin in Malawi in January 2015, the areas with the highest exposure were also the poorest (Winsemius et al. 2015).

Figure 1 Several studies have examined the exposure of poor and non-poor people to natural hazards. All but one case reviewed find poor people are more exposed than non-poor people.



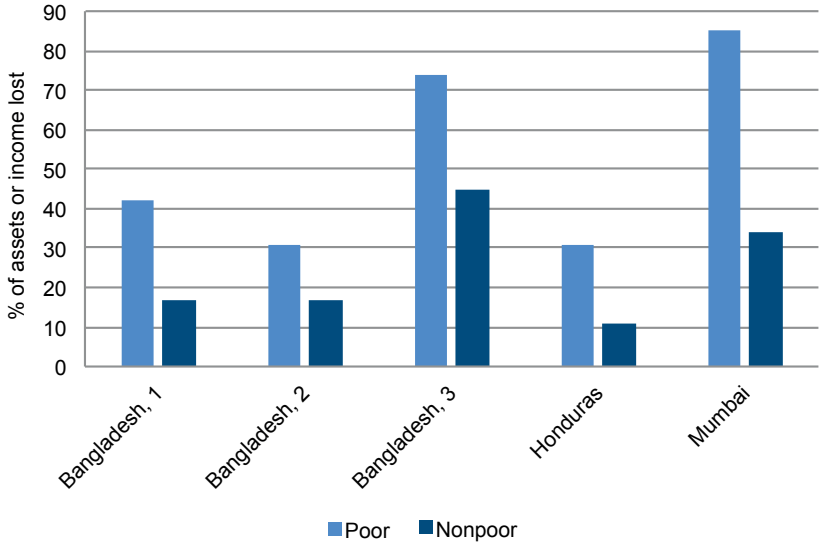
Note: MENA = Middle East and North Africa.
Source: Winsemius et al. (2015).

But the relationship between poverty and exposure to risk is not straightforward. Causality runs in both directions: poor people sometimes choose to settle in risky areas where land is available or affordable; and living in risky areas may make people poor when hazards destroy assets and livelihoods. But poor people are not always more exposed; for instance, flood-prone coastal or river areas benefit from low transport costs that attract firms and opportunities, and the wealthier populations in a country. In these cases, rich people may be the ones most exposed. In-depth analyses find no systematic overexposure of poor people to floods at the national level, although poor people are often the most exposed within a city or a region (Winsemius et al. 2015).

While not systematically more exposed, poor people are certainly more vulnerable when a disaster strikes and lose larger shares of their assets or income. This is because

poor people hold a large fraction of assets in material and vulnerable form (rather than as financial savings in a bank), live in lower-quality housing (such as slums), and depend on lower-quality infrastructure (such as non-paved roads). In the small number of surveys that compare asset and income losses of poor and non-poor people after floods and storms, poor people are found to lose a larger share (Figure 2). With regards to droughts, the fact that poor people are more dependent on agricultural income makes them more vulnerable (see Section 3). In the future, these vulnerabilities will evolve as the share of people in agriculture changes and as differences between poor and non-poor people are reduced (for example, in terms of building quality and access to infrastructure).

Figure 2 Generally, poor people lose a larger percentage of assets or income after floods and storms.



Note: Each study has a different definition of 'poor' and 'non-poor' in their sample. Vulnerability depends on the type of hazard and context in which it occurs; even within the same country (Bangladesh), vulnerability measures vary greatly based on location and severity of flooding. The first three studies use percent of income loss as a metric, while the Honduras and Mumbai cases use asset loss.

Source: Based on Brouwer et al. (2007) for Bangladesh (1); del Ninno et al. (2001) for Bangladesh (2); Rabbani et al. (2013) for Bangladesh (3); Carter et al. (2007) for Honduras; and Patankar and Patwardhan (2014) for Mumbai.

In addition, poor people often have more limited access to social protection, a factor that makes them more vulnerable after disasters. A consistent finding across countries is that transfers (from social protection and labour markets) received are much lower for poor

people (ASPIRE 2015). For example, in Colombia, the poorest 20% receive on average US$0.23 per person per day, while the richest 20% receive $4.60. Even after a disaster, ad hoc schemes to provide compensation have not targeted poor people, as evidenced by the 2005 Mumbai floods (Patankar 2015) and the 2011 Bangkok floods (Noy and Patel 2014). With less income coming from transfers and less savings, poor households are more dependent on their labour income for their consumption, making them more vulnerable to shocks and lost days of work (their inability to smooth consumption can even translate into avoidable health impacts, as discussed in Section 4).

It is therefore no surprise that natural disasters have a well-documented impact on poverty (Karim and Noy 2014). For example, at the municipal level in Mexico, Rodriguez-Oreggia et al. (2013) find that floods and droughts increased poverty by between 1.5% and 3.7% from 2000 to 2005. To compound these effects, disasters often result in reduced food consumption for children as well as interrupted schooling, with likely lifelong impacts such as stunting and reduced earning capacity (Alderman et al. 2006).

But looking only at the impact of actual disasters may underestimate the effect of risk on development and poverty. Ex ante, in the presence of uninsured weather risk, poor households engage in low-risk, low-return activities, perpetuating poverty. This ex ante effect, while much less visible, can dominate ex post impacts of disasters (Elbers et al. 2007). While progress has been made in recent years, many poor people remain uninsured and they exhibit lower financial inclusion than non-poor people (FINDEX 2015).

Climate change will worsen the frequency and intensity of natural disasters in some regions (IPCC 2014), but future impacts will depend not only on climate change, but also on the policies and actions implemented to manage risk. Land-use planning – especially in growing cities – is critical to ensure that new development is resilient and adapted to a changing climate (Hallegatte et al. 2013). Early warning systems, hard and ecosystem-based protection against floods, preservation of ground water, and improved building quality for poor people are all policies that can save lives and reduce asset losses. Providing options to poor households to save in financial institutions is critical to protect their savings. Social protection that can be scaled up after a disaster, and targeting instruments that are able to identify affected households and deliver aid in a

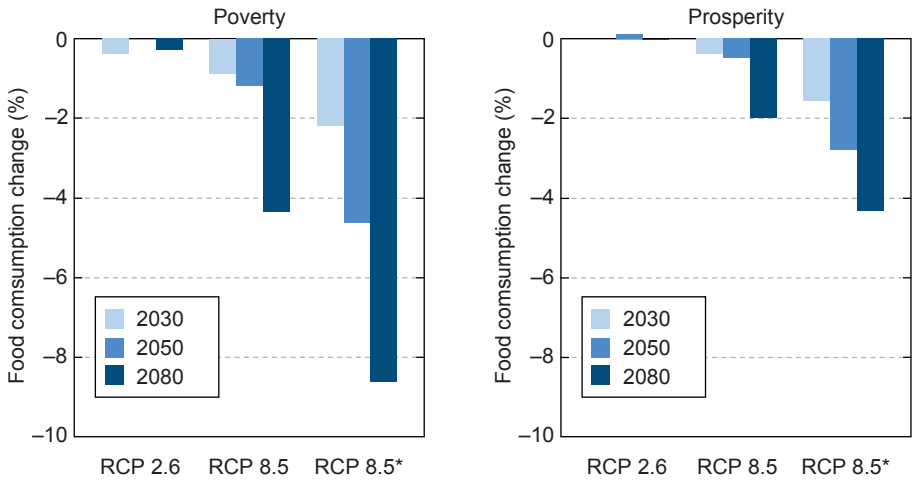
timely fashion to those who need it can help avoid long-term, irreversible consequences and poverty traps (Pelham et al. 2011).

3 Agricultural impacts

Climate change will impact agricultural and land productivity, especially for major crops (wheat, rice and maize) in tropical and temperate regions, with higher emissions pathways worsening the impacts (Porter et al. 2014). Under the most optimistic climate scenario – and with CO_2 fertilization (an effect that suggests plants can improve photosynthesis and productivity with higher CO_2 concentrations) – crop yields may decrease globally by 2% by 2030; but if emissions continue unabated, the reduction could amount to 6% by 2050 and 14% by 2080. And without CO_2 fertilization, the impacts may be even more severe, with yields falling by 10% and 33% by 2030 and 2080, respectively (Havlík et al. 2015). But the global impacts will not be uniform across crops and regions. These impacts are also extremely uncertain – they depend on the extent to which CO_2 fertilization materialises, the availability of water, and the development of new varieties and techniques better suited to future climates.

Productivity impacts will be transmitted through markets, with very uncertain impacts on food prices; the IPCC suggests that global food prices may vary between -30% and +45% (Porter et al. 2014). Higher food prices would reduce consumption, but modelling exercises show the final effect will depend not only on the change in climate, but also on the socioeconomic context, including GDP growth and access to global food markets. Food security concerns are less in a world with fast economic growth and low poverty (a 'Prosperity' scenario) compared to a world with slow growth and high poverty (a 'Poverty' scenario). For instance, under RCP 8.5 (a high emissions scenario) without CO_2 fertilization, global losses in food consumption are estimated at 2.5% and 4% for 2050 and 2080 in the Prosperity scenario, while the figures are over 4% and 8% in the Poverty scenario (Figure 3).

Figure 3 Impact of climate change on food consumption for three climate scenarios, three time periods and two socioeconomic scenarios (Prosperity and Poverty)



Note: The climate scenarios are: RCP2.6, a low emission scenario; RCP8.5, a high emission scenario; and RCP8.5*, a high emission scenario without the (uncertain) effect of CO_2 fertilization. Impacts are much less severe under the Prosperity scenario.

Source: Havlík et al. (2015).

Any change in food consumption will be particularly severe for poor people, who spend a larger share of their budget on food (62% on average, compared to 44% for non-poor people; see Ivanic and Martin 2014). Poor people in urban areas often have higher shares than rural people, as the latter may produce some of their own food to cover their needs.

Increased food scarcity is likely to translate into more 'food crises' during which food prices rise rapidly, for instance due to weather- or pest-related reductions in production in a major producer country. As illustrated by the spike in 2008, such episodes have a major impact on poverty, and studies suggest that future increases will have significant impacts. In the absence of safety nets and economic adjustments, a number of countries – including Guatemala, India, Indonesia, Pakistan, Sri Lanka, Tajikistan and Yemen – could suffer from an increase in extreme poverty of 25 percentage points if faced with a 100% food price increase, with severe impacts in urban areas (Ivanic and Martin 2014).

But for food producers, an increase in food prices is not necessarily a bad outcome. The final impacts will depend on how changes in prices and in productivity balance (an increase in food prices due to reduced productivity does not automatically lead to increased revenues) and on how increased revenues are distributed among farm workers and landowners (Jacoby et al. 2014). Taking a comprehensive view of farm households (i.e. both their consumption and production), Hertel et al. (2010) argue that such households may benefit from climate impacts if the shock is widespread, farm-level demand for their production is inelastic (while the supply response is low), there are few sources of off-farm incomes, and food represents a relatively small share of expenditures.

In some areas, however, transformational change in the production sector will be required. For instance, in Uganda, coffee production is a central activity, employing more than 2 million people and contributing close to US$400 million to the national economy in 2012. But climate change will make growing coffee increasingly difficult in the next decades, making it necessary for the local economy to restructure around a different crop or sector (Jassogne et al. 2013). Going through such large-scale transformations is highly challenging; in the 1930s, the Dust Bowl eroded large sections of the Great Plains in the US (an area previously renowned for agriculture), and the impacts endured for decades (Hornbeck 2012).

Vulnerability to agricultural impacts will be shaped by the future of poverty and by future market structure and access. Evidence suggests that remote markets have higher price volatility (Ndiaye et al. 2015). Enhancing road infrastructure can strengthen links between rural markets and urban consumption centres, stabilising prices. And the share of their income that people spend on food will decrease as people escape poverty, making the consequences of higher food prices more manageable in the future (if poverty decreases as rapidly as expected, and if poverty reduction reaches the remote rural areas where it is largely absent at the moment) (Ravallion 2014).

4 Health impacts

Health shocks are the leading reason why households fall into poverty (Moser 2008). They affect households through many channels: the direct impact on well-being; the

consequences of the death of a family member; loss of income when a family member cannot work; expenses from care and drugs, especially in the absence of health insurance; and time and resources spent on caregiving.

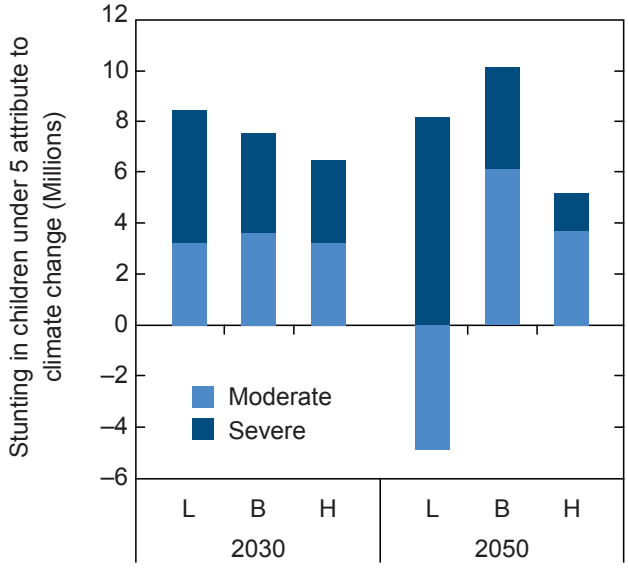
This is why the effect of climate change on health is particularly worrisome.

Impacts can occur through increased natural disasters, which have well-documented health effects. Disasters directly impact health through fatalities and casualties, particularly in low-income and lower-middle-income countries, which account for only a third of all disasters but more than 80% of all deaths (UNDP, UNICEF, OXFAM and GFDRR 2014). After a disaster, health conditions worsen when there is inadequate food, water and sanitation. The health effects also surge when affected poor households cannot smooth consumption – a drop in income often translates into reduced food intake, with potentially long-term effects on child development, affecting for example future strength, cognitive capacity and earning potential (Alderman et al. 2006).

As well as from disasters, health impacts also occur from environmental disruptions to crop productivity and food availability (Smith et al. 2014). One example is under-nutrition, which is not only influenced by crop productivity and food availability, but also by water quality and access to sanitation. Climate change is expected to increase stunting, with up to 10 million additional children stunted under a base case economic growth scenario in 2050 (Lloyd et al. 2011, Hales et al. 2014) (Figure 4). Some regions will be particularly affected, with cases of severe stunting possibly increasing by up to 23% in sub-Saharan Africa and 62% in South Asia (Lloyd et al. 2011). These trends are all the more alarming considering that moderate stunting increases the risk of death by 1.6 times and severe stunting by 4.1 times (Black et al. 2008).

Climate change will also change patterns of vector-, soil- and waterborne diseases, introducing them into new areas (Smith et al. 2014). The combined effects of temperature fluctuation, coastal salinity, humidity, heavy rainfall, flooding and drought can contribute to outbreaks of diseases such as schistosomiasis, cholera, malaria and diarrhoea (Cann et al. 2013, Hales et al. 2014).

Figure 4 Additional number of children aged under five years stunted due to climate change in 2030 and 2050 under low growth (L), base case (B) and high growth (H) socioeconomic scenarios.



Source: Hales et al. (2014).

All of these diseases affect poor people more than the rest of the population, and children more than adults. They also have an impact on income and economic growth. These micro-level impacts translate into lower macroeconomic growth; Gallup and Sachs (2001) find that countries with intensive malaria grew 1.3% slower than other countries in the period 1965-1990.

Estimates suggest that 3% of global diarrhoea cases can be attributed to climate change, and the frequency of malaria cases may increase by up to 10% by 2030 in some regions (WHO 2009). Higher temperatures are one reason for this: a study in Lima, Peru, found a 4% increase in hospital admissions for diarrhoea for each 1°C temperature increase during warmer months, and a 12% increase for every 1°C increase in cooler months (Checkley et al. 2000).

We can only begin to measure the global burden of disease from climate change, but observed patterns are worrisome. A recent synthesis of five key aspects – under-nutrition, malaria, diarrhoea, dengue and heat waves – estimates that under a base case

socioeconomic scenario and a medium/high emissions scenario, approximately 250,000 additional deaths per year between 2030 and 2050 will be attributable to climate change (Hales et al. 2014).

But the future burden of disease will depend on development. Despite rising temperatures in the twentieth century, malaria rates dropped significantly. This is because socioeconomic trends – urbanisation, development, and improvements in health facilities – matter much more for controlling malaria than climate impacts (Gething et al. 2010). Development objectives such as achieving universal health coverage by 2030 could contribute greatly to adapting to climate change impacts on health. In fact, the recently released Lancet report on health and climate change declared that responding to climate change could be "the biggest global health opportunity of the 21st century" (Watts et al. 2015).

5 How can we achieve low-carbon resilient development?

While climate change impacts poverty, poverty reduction reduces vulnerability to climate impacts. The previous discussion highlights some of the benefits that development and poverty reduction can bring in terms of climate vulnerability. For instance, better social safety nets, improved access to financial institutions and insurance, and reduced inequality would mitigate the impact of disasters, and especially the irreversible impacts on children's health and education. Improved connection to markets – with better infrastructure and appropriate institutions – would protect consumers against large food supply shocks, and help farmers access the technologies and inputs they need to cope with a different climate. Basic services – for example, improved drinking water and sanitation and modern energy – can also help protect against some of the impacts of climate change, such as waterborne diseases and environmental degradation. And access to health care has been improving with development and growth in most countries, with the benefits being exemplified by reductions in child mortality and malaria.

Most importantly, development and climate mitigation need not be at odds with each other. Evidence suggests that raising basic living standards for the world's poorest will have a negligible impact on global emissions (Rao et al. 2014, Fay et al. 2015). Initiatives

such as the UN's 'Sustainable Energy for All' can improve access to electricity and at the same time be compatible with a warming limit of 2°C (Rogelj et al. 2013). Making mitigation and poverty eradication compatible will require a sequenced approach where richer countries do more, special attention is given to the impacts of land-use-based mitigation on food production, and complementary policies (e.g. cash transfers) are introduced to protect poor people against negative side-effects of mitigation (Fay et al. 2015). In many cases, it will also require richer countries to support poorer countries to provide technologies and financing instruments.

The impacts of climate change will increase over time. There is therefore a window of opportunity to reduce poverty now and thereby reduce vulnerability tomorrow. Any climate agreement that aims to be workable and effective should have this goal of reducing vulnerability in mind, and be designed in a way that contributes to development and poverty eradication.

But not all development pathways reduce climate risks in the same way. Of course, low-carbon development mitigates climate change and reduces risks over the long term, benefiting everybody, particularly the poorest. In addition, resilient development would go further in reducing the impacts of climate change. But what does it entail? From our analysis, a few recommendations emerge:

- **Planning for a different (and uncertain) climate**. Many investment and policy decisions have long-term consequences. The effect of transport infrastructure on urban form and economic activity can be observed over long timeframes, sometimes even after the infrastructure has become obsolete (Bleakley and Lin 2010). Policies such as urbanisation plans, risk management strategies, and building codes can influence development for just as long. Therefore, to ensure development is adapted not only to present but also to future conditions, plans must consider the performance of investments and decisions in the short and long term.

  But doing so is challenged by deep uncertainty – we cannot predict future climate conditions precisely, we do not know which technologies will appear, and we are unsure about socioeconomic conditions and future preferences. There is a risk of locking development into dangerous pathways, for instance by urbanising impossible-to-protect flood plains or by specialising in agricultural production at

risk of climate change. To avoid this, the planning process needs to investigate a large range of possible futures, and to make sure it does not create unacceptable risks when climate change and other trends are accounted for, especially if these changes differ from what is considered most likely today (Kalra et al. 2014). Such a robust approach leads to strategies that include safety buffers (e.g. adding safety margins around what areas are considered prone to flooding today), promoting flexibility (e.g. select solutions that can be adjusted over time as more information becomes available), and increasing diversification (e.g. developing the economic sectors that are less exposed to risk).

- **Improving access to healthcare**. Helping households manage health risks is already a priority, considering the role of these shocks in maintaining people in poverty. Climate change only makes this task more urgent and more important. Skilled health staff, with the right equipment and drugs, need to be available in all areas. But even if health care is available, the ability to afford health care is essential – about 100 million people fall into poverty each year due to having to pay for healthcare (WHO 2008). Increasing healthcare coverage and decreasing out-of-pocket expenses is a smart investment for development and poverty reduction, and would be an efficient tool to reduce climate change vulnerability. Doing so is possible at all income levels. For instance, Rwanda invested in a universal health coverage system after the 1994 genocide, with premature mortality rates falling precipitously, and life expectancy doubling (Binagwaho et al. 2014). Climate change does not dramatically change the challenges for the health sector, but emerging issues and diseases increase the importance of monitoring systems that can identify and respond quickly to new – and sometimes unexpected – emergencies.
- **Provision of well-targeted, scalable safety nets**. Safety nets can help manage weather shocks. During the 1999 drought in Ethiopia, the poorest 40% of the population lost almost three-quarters of their assets (Little et al. 2004). Today, Ethiopia's Productive Safety Net Program supports 7.6 million food-insecure people and builds community assets to counteract the effects of droughts. The programme has improved food security, access to social services, water supply, productivity, market access, and ecosystems (Hoddinott et al. 2013). Safety nets can also play a critical role in avoiding irreversible losses from under-nutrition,

but only if scaled-up and deployed quickly after shocks and targeted to the poorest and most vulnerable (Clarke and Hill 2013). In addition, the increasing impacts of natural disasters makes it essential for safety nets to be able to identify quickly those in need, and to scale-up and retarget support after a shock or disaster (Pelham et al. 2011).

Further, trends in climate conditions and risks mean that some places will become increasingly less suitable for development. As a result, temporary and permanent migration is an important risk-management tool, and can be an adaptation option. Independently of climate change, migration plays a key role in the ability of poor households to escape poverty by capturing opportunities for better jobs, higher pay, and improved access to services and education. Climate change may trigger more migration – for instance, if opportunities disappear because of climate impacts (for the example of coffee in Uganda, see Jassogne et al. 2013) – but may also impair migration, for example through increased conflict and exclusion (for an extended review, see Adger et al. 2014). Given the importance of mobility as an instrument for poverty reduction, it is critical that social protection does not lock people into places or occupations from which it will become harder for them to escape poverty. Portability of social protection (geographically and in terms of occupation) is therefore made even more important by a changing climate.

With regards to natural hazards, agricultural impacts and health shocks, climate change only makes existing priorities more urgent for many countries. If addressed correctly, this urgency can turn into an opportunity to reduce current poverty and future climate vulnerability simultaneously. Of particular importance are the high economic and health impacts that climate change could have on children. Without action to move towards low-carbon, resilient development now, we may lock ourselves into a future of increased intergenerational transmission of poverty.

References

Adger, W.N., J.M. Pulhin et al. (2014), "Human security", in *Climate Change 2014: Impacts, Adaptation, and Vulnerability* (see IPCC (2014a) in the introduction to this book for the report's full reference).

Alderman, H., J. Hoddinott and B. Kinsey (2006), "Long term consequences of early childhood malnutrition", *Oxford Economic Papers* 58(3): 450–474.

ASPIRE (2015), ASPIRE Database, World Bank, Washington, DC (http://datatopics.worldbank.org/aspire/).

Baez, J., L. Lucchetti, M. Salazar and M. Genoni (2014), "Gone with the Storm: Rainfall Shocks and Household Wellbeing in Guatemala", World Bank Policy Research Working Paper, Washington, DC.

Binagwaho, A., P. E. Farmer, S. Nsanzimana, C. Karema, M. Gasana et al. (2014), "Rwanda 20 years on: investing in life", *The Lancet* 384: 371–375.

Black, R. E., L. H. Allen, Z. A. Bhutta, L. E. Caulfield, M. de Onis et al. (2008), "Maternal and child undernutrition: global and regional exposures and health consequences", *The Lancet* 371: 243–260.

Bleakley, H. and J. Lin (2010), "Portage: path dependence and increasing returns in US history", NBER Working Paper No. 16314, Cambridge, MA.

Brouwer, R., S. Akter, L. Brander and E. Haque (2007), "Socioeconomic vulnerability and adaptation to environmental risk: a case study of climate change and flooding in Bangladesh", *Risk Analysis* 27(2): 313–326.

Cann, K. F., D. R. Thomas, R. L. Salmon, A. P. Wyn-Jones and D. Kay (2013), "Extreme water-related weather events and waterborne disease", *Epidemiology and Infection* 141(4): 671–686.

Carter, M. R., P. D. Little, T. Mogues and W. Negatu (2007), "Poverty Traps and Natural Disasters in Ethiopia and Honduras", *World Development* 35(5): 835–856.

Checkley, W., L. D. Epstein, R. H. Gilman, D. Figueroa, R. I. Cama et al. (2000), "Effects of EI Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children", *The Lancet* 355: 442–450.

Clarke, D. J. and R. V. Hill (2013), "Cost-Benefit Analysis of the African Risk Capacity Facility", SSRN Scholarly Paper No. ID 2343159, Rochester, NY.

del Ninno, C., P. A. Dorosh, L. C. Smith and D. K. Roy (2001), "The 1998 Floods in Bangladesh Disaster Impacts, Household Coping Strategies, and Response", Research Report No. 122, International Food Policy Research Institute, Washington, DC.

Elbers, C., J. W. Gunning and B. Kinsey (2007), "Growth and Risk: Methodology and Micro Evidence", *World Bank Economic Review* 21: 1–20.

Fay, M., S. Hallegatte, A. Vogt-Schilb, J. Rozenberg, U. Narloch and T. Kerr (2015), *Decarbonizing Development: Three Steps to a Zero-Carbon Future*, Washington, DC: The World Bank.

FINDEX (2015), Global Financial Inclusion Database, World Bank (http://www.worldbank.org/en/programs/globalfindex).

Gallup, J. L. and J. D Sachs (2001), "The economic burden of malaria", *American Journal of Tropical Medicine and Hygiene* 64(1-2 Suppl.): 85–96.

German Space Agency (2015), "January 2015 flood extent of Malawi Event", Cologne.

Gething, P. W., D. L. Smith, A. P. Patil, A. J. Tatem, R. W. Snow and S. I. Hay (2010), "Climate change and the global malaria recession", *Nature* 465: 342–345.

Hales, S., S. Kovats, S. Lloyd and D. Campbell-Lendrum (2014), *Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s*, Geneva: World Health Organization.

Hallegatte, S., C. Green, R. J. Nicholls and J. Corfee-Morlot (2013), "Future flood losses in major coastal cities", *Nature Climate Change* 3: 802–806.

Hallegatte, S., M. Bangalore, L. Bonzanigo, M. Fay, T. Kane, U. Narloch, J. Rozenberg, D. Treguer, and A. Vogt-Schilb (2016), "Shock Waves - Managing the Impacts of Climate Change on Poverty", Washington, DC: World Bank,

Havlík, P., H. Valin, M. Gusti, N. Forsell, M. Herrero et al. (2015), "Climate change impacts and mitigation in the developing world: Integrated assessment of agriculture and forestry sectors", forthcoming in the World Bank Policy Research Working Paper series, Washington, DC.

Hertel, T. W., M. B. Burke and D. B. Lobell (2010), "The Poverty Implications of Climate-Induced Crop Yield Changes by 2030", *Global Environmental Change* 20(4): 577–85.

Hoddinott, J., J. Lind, G. Berhane, F. Flintan, S. Gidey et al. (2013), "Impact Evaluation of the PSNP and HAPB 2012", Institute for Development Studies, Brighton.

Hornbeck, R. (2012), "The Enduring Impact of the American Dust Bowl: Short- and Long-Run Adjustments to Environmental Catastrophe", *American Economic Review* 102: 1477–1507.

IPCC (2014) "Summary for Policymakers", in *Climate Change 2014: Impacts, Adaptation, and Vulnerability* (see IPCC (2014a) in the introduction to this book for the report's full reference).

Ivanic, M. and W. Martin (2014), "Short- and Long-Run Impacts of Food Price Changes on Poverty", SSRN Scholarly Paper No. ID 2484229, Rochester, NY.

Jacoby, H.G., M. Rabassa and E. Skoufias (2014), "Distributional Implications of Climate Change in Rural India: A General Equilibrium Approach", *American Journal of Agricultural Economics* 97(4): 1135–1156.

Jassogne, L., P. Lderach and P. van Asten (2013), *The Impact of Climate Change on Coffee in Uganda: Lessons from a case study in the Rwenzori Mountains*, Oxford: Oxfam.

Kalra, N., S. Hallegatte, R. Lempert, C. Brown, A. Fozzard et al. (2014), "Agreeing on Robust Decisions: New Processes for Decision Making under Deep Uncertainty", World Bank Policy Research Working Paper, Washington, DC.

Karim, A. and I. Noy (2014), "Poverty and natural disasters: A meta-analysis", Victoria University of Wellington, School of Economics and Finance.

Krishna, A. (2006), "Pathways out of and into poverty in 36 villages of Andhra Pradesh, India", *World Development* 34(2): 324–404.

Little, P., P. Stone, T. Mogues, P. Castro and W. Negatu (2004), "'Churning' on the Margins: How the Poor Respond to Drought in South Wollo", BASIS Brief No. 21, University of Wisconsin- Madison.

Lloyd, S. J., R. S. Kovats and Z. Chalabi (2011), "Climate change, crop yields, and undernutrition: development of a model to quantify the impact of climate scenarios on child undernutrition", *Environmental Health Perspectives* 119: 1817–1823.

Moser, C. O. N. (2008), *Reducing Global Poverty: The Case for Asset Accumulation*, Washington, DC: Brookings Institution Press.

Ndiaye, M., E. d'Hôtel and L. C. Tristan (2015), "Maize price volatility: does market remoteness matter?", World Bank Policy Research Working Paper, Washington, DC.

Noy, I. and P. Patel (2014), "Floods and spillovers: Households after the 2011 great flood in Thailand", Working Paper Series No. 3609, Victoria University of Wellington, School of Economics and Finance.

Patankar, A. (2015), "The exposure, vulnerability and adaptive capacitiy of households to floods in Mumbai".

Patankar, A. and A. Patwardhan (2014), "Estimating the Uninsured Losses due to Extreme Weather Events and Implications for Informal Sector Vulnerability: A Case Study of Mumbai, India", accepted for publication in *Natural Hazards*.

Pelham, L., E. Clay and T. Braunholz (2011), "Natural disasters: what is the role for social safety nets?", Overseas Development Institute, London.

Porter, J.R., L. Xie et al. (2014), "Food security and food production systems", in *Climate Change 2014: Impacts, Adaptation, and Vulnerability* (see IPCC (2014a) in the introduction to this book for the report's full reference).

Rabbani, G., S. H. Rahman and L. Faulkner (2013), "Impacts of Climatic Hazards on the Small Wetland Ecosystems (ponds): Evidence from Some Selected Areas of Coastal Bangladesh", *Sustainability* 5: 1510–1521.

Rao, N. D., K. Riahi and A. Grubler (2014), "Climate impacts of poverty eradication", *Nature Climate Change* 4: 749–751.

Ravallion, M. (2014), "Are the World's Poorest Being Left Behind?", NBER Working Paper No. 20791), Cambridge, MA.

Rodriguez-Oreggia, E., A. De La Fuente, R. De La Torre and H. A. Moreno (2013), "Natural Disasters, Human Development and Poverty at the Municipal Level in Mexico", *Journal of Development Studies* 49(3): 442–455.

Rogelj, J., D. L. McCollum and K. Riahi (2013), "The UN's 'Sustainable Energy for All' initiative is compatible with a warming limit of 2°C", *Nature Climate Change* 3: 545–551.

Smith, K.R., A. Woodward et al. (2014), "Human health: impacts, adaptation, and co-benefits", in IPCC (2014), *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, Cambridge, UK: Cambridge University Press (see the Introduction to this volume for the report's full reference).

UNDP, UNICEF, OXFAM and GFDRR (2014), "Disaster risk reduction makes development sustainable", conference paper, UN Development Programme.

UNOSAT (2015), "January 2015 flood extent of Malawi Event", United Nations Institute for Training and Research.

Watts, N., W. N. Adger, P. Agnolucci, J. Blackstock, P. Byass et al. (2015), "Health and climate change: policy responses to protect public health", *The Lancet*.

WHO (2009), *Global Health Risks: Mortality and burden of disease attributable to seletected major risks*, Geneva.

WHO (2008), *The World Health Report 2008 - primary Health Care (Now More Than Ever)*, Geneva.

Winsemius, H., B. Jongman, T. Veldkamp, S. Hallegatte, M. Bangalore and P. J. Ward (2015), "Disaster risk, climate change, and poverty: assessing the global exposure of

poor people to floods and droughts", forthcoming in World Bank Policy Research Working Paper series, Washington, DC.

World Bank (2015), *World Development Indicators*, Washington, DC.

World Bank and National Statistical Office of Malawi (2013), "Malawi Poverty Map", Washington, DC.

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