Advanced Review

Climate change and poverty: vulnerability, impacts, and alleviation strategies

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Poverty is widely understood to be a key factor that increases the propensity for individuals and households to be harmed by climatic shocks and stresses. This review explores recent literature at the nexus of climate change impacts, vulnerability, and poverty. Within this literature, poverty is increasingly recognized as a dynamic and multidimensional condition that is shaped by the interplay of social, economic, political, and environmental processes, individual and community characteristics, and historical circumstances. While climate change is never seen as a sole cause of poverty, research has identified numerous direct and indirect channels through which climatic variability and change may exacerbate poverty, particularly in less developed countries and regions. Recent studies have also investigated the effects of climate change on economic growth and poverty levels, formation of poverty traps, and poverty alleviation efforts. These studies demonstrate that climate change-poverty linkages are complex, multifaceted, and context-specific. Priority issues for future work include greater attention to factors that promote resilience of poor populations, a stronger focus on nonmonetary dimensions of poverty, investigation of the impacts of climate change on relative poverty and inequality, and exploration of the poverty impacts of extreme climate change.

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INTRODUCTION

The focus on climate-related loss and damages at the 2013 United Nations COP-19 meetings in Warsaw has brought renewed global attention to inequalities associated with the impacts of climate change.[1,2] While the discussion of loss and damages[3] reinforces public awareness that less developed countries and poor populations will suffer most from the impacts of climate change, researchers have long recognized that climate change vulnerabilities, impacts, and responses are deeply entangled within political, social, and economic processes that create and perpetuate poverty.[4–8] In this review article, we examine recent literature at the nexus of poverty, vulnerability, and climate change impacts. Given that poverty is a central theme across a very broad swath of literatures on the human dimensions of climate change including adaptation, human security, food security, and disaster risk reduction, we deliberately limit the scope of this review to studies that specifically focus on: (1) the impacts of poverty on vulnerability to climate change; (2) the impacts of climate change on poverty; and (3) the effects of climate change on poverty alleviation efforts.

Even under this more limited scope, there is a large and rapidly growing set of interdisciplinary literature that explores connections between climate change and poverty. This work is sometimes closely embedded, but often tangential to a much larger body of literature on the nature and causes of poverty. Within these partly overlapping fields, poverty is

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increasingly recognized as a dynamic and multidimensional condition that is shaped by historical circumstances and by the interplay of individual and community characteristics and larger social, economic, political, and environmental processes.[9–12] Although climatic conditions are never seen as a sole cause of poverty, climatic variability and climate change are widely recognized as factors that may exacerbate poverty, particularly in less economically developed countries and regions.[7,8,13] As such, analyses of the impacts of climate change on poverty are generally contingent on recognition that the poor are already vulnerable to harm from climate change. These studies also emphasize that the poor are heterogeneous and that climate change affects some groups more than others, intersecting, often in complex ways, with existing inequalities and patterns of social exclusion.[14,15]

In the next section of the paper, we draw from the broader poverty literature to explore common definitions, approaches, and ways to measure poverty. We then describe how poverty affects vulnerability to climate change, and we discuss recent work on exposure of poor populations to different types of climate stresses. Next, we examine a range of literatures that investigate how climate change affects poverty including different channels of impact, effects of climate change on economic growth, the connections between climate change and poverty traps, and the impacts of climate change on poverty alleviation efforts. We conclude by highlighting directions for future research on climate-poverty linkages.

DEFINING AND MEASURING POVERTY

Conceptualizations of what constitutes poverty, and who should make these determinations, have evolved considerably over time. Some of the earliest studies of poverty focused on the poor quality of life experienced by those with limited economic resources or legal protections.[16,17] Following World War II, economic indicators became, and remain, the dominant means for measuring poverty.[18] However, since the late 1970s and early 1980s, nonmonetary considerations have been reincorporated into the poverty literature, and the focus on deprivations in power, voice, and psychological well-being has become increasingly important.[19–21] In contemporary discussion and theoretical debates on human well-being, scholars and policy makers widely acknowledge that poverty is multidimensional in nature, entailing low income along with other types of severe and chronic disadvantages that are related to, but not entirely dependent upon, monetary considerations.[22–26] This multidimensionality is partly reflected in the widely used Human Development Index (HDI).[27] The HDI, which began to be published by the United Nations Development Programme (UNDP) in 1990, replaces purely monetary measures such as gross national product per capita with a composite statistic composed of indicators for life expectancy, educational attainment, and income. As noted in the next sections, HDI is increasingly used as a poverty metric in the climate change literature.

Fundamentally, the notion of poverty is about the relationship between resources and needs (i.e., do you have sufficient resources to meet your needs?). Three main theoretical approaches are currently used to study poverty. As given in Table 1, these approaches vary in terms of how poverty is defined and measured. Each approach has both benefits and limitations for understanding the drivers of poverty and the lived experiences of the poor. Monetary approaches facilitate easier comparisons across different countries and societies with wide-ranging cultural differences and social values. Approaches that consider human capabilities, relative differences in power structures, and deprivations associated with social exclusion allow for more nuanced assessments of the day-to-day impact of poverty on people's lives.

The literature also identifies two important distinctions regarding poverty, both of which have relevance to understanding the relationship between poverty and climate change. First, impoverishment is often classified according to severity, with a distinction being made between absolute and relative poverty.[30,31] Absolute poverty denotes those who lack sufficient resources to meet their basic needs (e.g., adequate food, safe drinking water, adequate shelter), to an extent which compromises their survival. A commonly employed method for estimating the number of people living in absolute poverty involves the use of income thresholds (e.g., living on less than $1.25/day; living on less than $2/per day). Table 2 illustrates the distribution of populations living in absolute poverty in the developing world in 2008, the year with the most recent rural and urban poverty estimates. The table indicates that poverty remains higher in rural areas, although levels vary considerably across different geographic regions. The percentage of urban dwellers living on less than $1.25/day poverty is also high in Sub-Saharan Africa and South Asia, but tends to be much lower elsewhere. It is also notable that the majority of the world's poor live in what can be considered middle income countries, particularly China, India, and Indonesia.[34] These countries are still classified as 'developing' by the World Bank,[33] and are thus included in the values in Table 2.

TABLE 1 | Three Common Theoretical Approaches to Poverty[18,22,23,28,29]

	Monetary	Capabilities	Social Exclusion/Relational
Definition of poverty	Income (or consumption) falls below a minimum threshold of resources (e.g., poverty line)	Deprivation of a person's abilities to live a life they have reason to value	Individuals or groups are wholly or partially excluded from participating in the society in which they live
Indicator(s)	Monetary metrics (income, consumption, assets)	Multidimensional: freedoms, choices, and opportunities (includes monetary dimension)	Multidimensional: social rules, customary laws, and social networks
Key assumptions	Monetary indicators are a good proxy for other aspects of welfare throughout different societies	Money is a poor proxy for overall well-being. Choices and freedoms have intrinsic value whereas money does not	The factors that allow some people to escape poverty are the same that allow for the exclusion of others
Type of poverty	Absolute and relative	Absolute and relative	Relative and relational
Unit of analysis	Individual (although monetary figures usually collected at household level)	Individual	Individual or group (but poverty is characterized as a social relationship between the poor and the non-poor)
Pros	Monetary measures easily facilitate comparisons across people and places	Accounts for publically provided goods and services; considers cultural differences in what people value	Accounts for distributional issues and inequities; specific attention to unequal power relationships
Cons	Excludes publically provided goods and services (e.g., schools, clinics); neglects power relationships	Difficult to make cross-country comparisons	Difficult to make cross-country comparisons

In contrast to absolute measures, relative poverty focuses on whether or not a person is substantially disadvantaged as compared with other individuals in his or her community, region, or country. Relative benchmarks of poverty are based on what is considered to be the normal standard of living in a particular social context.[35,36] According to this classification, a person's survival may not be at risk but they may still suffer considerable deprivations that make them poor and compromise their ability to be respected in the society in which they live.[37] Within the climate change literature discussed in the next sections, absolute measures of poverty measures are typically used in cross-country analyses and analyses focused on developing countries. Relative measures, though rarely used, are more applicable to developed country contexts, where

TABLE 2 | Global Distribution of Extreme Poverty in Urban and Rural Regions of Developing Countries

	Total Population in Millions (mid-2008)[1]			% of Population Living on Less Than $1.25/Day (2008)[2]		
	Total	Urban	Rural	Total	Urban	Rural
Developing World:	5679	2232	3447	22.7	11.6	29.4
Regional breakdown of developing countries						
East Asia and Pacific	1964	889	1075	14.3	4.3	20.4
Europe and Central Asia	410	233	177	0.5	0.2	1.2
Latin America and Caribbean	570	439	131	6.5	3.1	13.2
Middle East and North Africa	317	180	136	2.7	0.8	4.1
South Asia	1576	500	1076	36.0	29.7	38.0
Sub-Saharan Africa	843	296	547	49.2	33.6	47.1

[1]Total population and urban/rural population shares are from the Population Reference Bureau (PRB).[32] We use PRB figures for population totals and urban and rural population shares. By aggregating country-level data, we reconstruct regional groupings commonly used by the World Bank (WB).
[2]Urban and rural shares of people living on less than $1.25/day are taken from the WB.[33] We use WB figures for percentage of people living on less than $1.25/day. WB and PRB population figures are not an exact match but differ only by an average of 2%.

studies emphasize the effects of climate change on disadvantaged populations.

A second important distinction in the poverty literature emphasizes its temporal dimensions (i.e., the length of time an individual spends living in poverty) and considers whether poverty is a chronic or temporary condition. Chronic poverty is used to describe a situation in which a person has been poor for a long period of time, often since birth. Empirical evidence suggests that poverty of an extended duration is hard to reverse, and people who have been poor for five or more years have a higher probability of remaining poor for the remainder of their lives.[27] The chronically poor often pass on their poverty to their children.[38] Temporary poverty generally refers to situations of transience where a person has been poor for less than five years, often as a consequence of an external shock (e.g., unemployment, extreme weather event). Although temporary poverty is often seen as a less serious condition, some research finds that individuals may cycle in and out of poverty for multiple periods over their lifetime.[39] As discussed later, the question of whether climate change contributes to chronic poverty is an important issue for empirical research.

The study of patterns and processes of poverty remains active in many academic disciplines and policy-making arenas. In particular, recent work has led to the emergence of alternative indicators that better capture the multidimensionality and varied facets of poverty, including severity and duration.[40] Qualitative, place-based studies of poverty also remain highly relevant in empirical investigations of the geography of uneven development in urban and rural spaces.[36] Climate change has emerged within these contexts as a new element shaping spatial configurations of poverty, the number of people living in poverty, and the prospects for alleviating deprivation for both people and places.

POVERTY AND VULNERABILITY TO CLIMATE CHANGE

Poverty, however measured, is widely understood to be a key factor that increases vulnerability to climate change.[7,41–45] Like poverty, the concept of vulnerability has different definitions and varying usages across disciplines. Drawing on the consensus definition of vulnerability presented in the recent IPCC report on *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, vulnerability is defined here as the propensity for individuals and households to be adversely affected by climatic and other environmental shocks and stresses.[45] This definition subscribes to the notion that vulnerability has both an 'exposure' component, which primarily reflects location in an area that is subject to climatic hazards, and a 'social' component, which depends on a range of individual and community characteristics as well as economic, cultural, and political factors, which may increase susceptibility to harm and reduce capacity to respond to climatic shocks and stresses.[45] Poorer individuals are expected to have a greater propensity to be harmed by climate change for a variety of reasons: they have fewer assets to help them recover from climate shocks and stresses such as droughts, hurricanes, and floods; their livelihoods are more likely to depend on climate sensitive sectors (e.g., agriculture, forestry, fishing, pastoralism) or on low-income informal or hourly jobs with little protection against climate-related employment disruptions; they are more likely to live in areas with higher exposure to climate extremes and less likely to be insured against such events; they have less access to knowledge and information about adaptation; and, they have fewer alternative livelihood options.[42,46–48]

Physical health and psychological dimensions of poverty may also play a role in influencing both climate change vulnerability and resilience of poor populations. While the terminology of resilience has a variety of meanings in the climate change literature, within the context of poverty, resilience may be understood as the ability of poor individuals and poor communities to recover or 'bounce-back' from climatic shocks and stresses. The poor often experience higher levels of illness, mental stress, stigmatization, shame, humiliation and other burdens that compound monetary disadvantage and hinder their ability to escape poverty, respond to external shocks, or plan for the future.[20,37,40,49,50] Recent research indicates that poverty also drains the cognitive abilities of the poor, contributing to worse financial decision making, in both developed and developing country contexts, because preoccupations with severe budgetary constraints reduce the mental resources to deal with other challenges.[51] These cognitive effects are hypothesized to undermine resilience of poor populations, though further research on this issue is needed.

While monetary poverty or HDI are frequently used as indicators of social vulnerability to climate change,[52–55] researchers emphasize that simply being poor does not make a person or household more susceptible to climatic shocks. Rather, it is typically a combination of many dimensions of poverty, including income, social exclusion, lack of assets and capabilities, as well as a range of contextual factors and external stresses, and, in some cases, failed development policies, that increase vulnerability of poor

populations.[15,56–60] Although case evidence is limited, recent work also suggests that poor individuals and communities can be highly-resilient and display significant capacity to learn from extreme events and take steps to reduce future vulnerability.[61,62]

Within rural, developing country contexts, researchers have documented many additional factors that increase vulnerability of poor individuals and households including limited land ownership, lack of options for livelihood diversification, lack of market access, on-going degradation of local ecological resources such as forests, reliance on cash crops, and globalization of markets.[48,58–60,63–66] For example, increasing commodification of rural life due to economic globalization in Mozambique's Limpopo River Basin has been found to pressure small-scale agriculturalists to abandon traditional strategies for managing climate risks, making them more vulnerable to extreme weather.[64,65]

For the poor in urban areas of the developing world, living and working in hazardous environments, in conjunction with contextual factors such as weak governance and inadequate infrastructure, contribute to vulnerability to climate extremes.[67–73] For example, flood-prone residential locations in Lagos, Nigeria are often chosen by the poor based on availability of low-cost housing, family ties, and economic opportunities.[73] Flooding in these locations is exacerbated by unregulated land use upstream and poorly maintained and insufficient drainage infrastructure.[73] In many cases, poverty intersects with other dimensions of social exclusion such as gender and racial discrimination, further reinforcing vulnerabilities.[74,75] This phenomenon is illustrated by another study of flooding in Lagos, which documents significantly greater negative impacts of urban flooding for low-income women as compared to middle and high-income women.[76] The research demonstrates that, in addition to poverty, gender relations and gender roles, occupational status, and household structure all contribute to greater vulnerabilities for low-income women.[76]

While most research on the connections between poverty and vulnerability focuses on developing country contexts, studies have also documented greater exposure to climate stresses of relatively poor populations in advanced countries, particularly in the United States.[77–82] Studies of the impacts of extreme climate events including Hurricanes Katrina in New Orleans and Hurricane Sandy in New York and New Jersey demonstrate that poorer populations are more likely to be harmed by these events, though other factors such as lack of institutional capacity, social isolation, and dynamics of local housing markets, also play a contributing role.[83,84] In developed countries, vulnerability of poor populations is often integrally tied to infrastructure and provision of urban services.[85] For example, climate-related disruptions of urban public transport infrastructure have been found to have a disproportionate effect on poor residents of urban areas, who are more likely to hold hourly wage positions and less likely to have alternative transport options during system-wide, weather-related shutdowns.[86]

Recognition that the poor are more vulnerable to climatic shocks and stresses has motivated interest in documentation and quantification of how many poor people are likely to be exposed to harm from climate change. These studies, which emphasize the physical exposure of vulnerable populations,[87] have demonstrated that poor populations, both globally and regionally, are more likely to be exposed to climate hazards and sea level rise than other groups.[81,88] A recent study of exposure to sea-level rise (SLR) in coastal areas of the United States uses the SOVI® index,[77] a composite metric of social vulnerability comprised of numerous social measures including poverty, to demonstrate a disproportionate impact of SLR on disadvantaged populations.[81] The study goes a step further than most vulnerability mapping exercises by showing that the disadvantaged are more likely to live in areas that will not be protected from inundation (i.e., they will be abandoned), as compared to areas where less socially vulnerable groups live.[81] Although fuller consideration of the literature on vulnerability indices and vulnerability mapping is beyond the scope of the present review, recent surveys of that literature have noted that income and multidimensional poverty are frequently used as a component of vulnerability metrics.[42,44,45,52,53]

While aggregate studies that quantify exposure of poor populations, as opposed to poor countries, are limited, many exposure factors can be gleaned from the literature. Rural agriculturalists, for example, are often characterized as among the most vulnerable to climate change and extreme weather.[89–91] In addition to reliance on agriculture and natural resources, particularly in drought-prone regions, other frequently cited indicators of climate change exposure include living in a low-lying coastal zones or an informal urban settlements, and poor nutrition and health status.[42,92–96] · Table 3 shows the number of individuals globally and by region who may potentially be exposed based on indicators including nutrition, housing status, and residence in a low-lying coastal zone. Although global and regional estimates of this type cannot shed light on a wide variety of other factors that influence vulnerability, they nonetheless

TABLE 3 | Potentially Climate-Exposed Populations

	Undernourished[97] (Total Population in Millions, 2007–2009)	Urban Slum Residents[98] (Total Population in Millions, 2012)	Resident of Low-Lying Coastal Zone[96] (Total population in Millions, 2000)
Global	867	N/A	634
Developing World	852	863	527
Selected regional breakdown of developing countries			
East Asia and Pacific	245	724	361
Latin America and Caribbean	50	36	29
South Asia	311	207	135
Africa	220	226	56

provide a rough gage of the present distribution and magnitude of potentially climate-exposed populations for these particular indicators. Modeling of present and future distributions of exposed populations using other exposure indicators, and also taking into account demographic, development, and migration trends, is an active area for new research.[87,99,100] However, the identification of poor populations living within exposed regions remains a key research challenge.[94]

IMPACTS OF CLIMATE CHANGE ON POVERTY

Researchers have theorized numerous direct and indirect channels through which climate change can further impoverish the poor or push individuals into poverty (see Figure 1). Direct channels, which are rooted in long-established impact assessment frameworks, postulate direct connections between biophysical changes, market responses, and poverty outcomes.[101] Indirect channels, often invoked in vulnerability frameworks, hypothesize that chains of causality between climate exposure and poverty are complex and influenced by individual and household characteristics and other factors including decision-making processes, socio-economic conditions, and quality of institutions and governance. Indirect channels also highlight the effects of climate change on factors that are thought to contribute to poverty such as poor health status or political conflict, emphasizing that climate change overlaps, interacts with, and often compounds the effects of other social, economic, and environmental stressors.[101]

In this section, we describe prominent areas of climate-poverty research that are illustrative of each of type of impact channel, including studies of agricultural production and food prices, livelihoods and ecosystems services, health, migration and conflict. While these areas are by no means inclusive of all climate-poverty impact work, they nonetheless illustrate some of the key differences between direct and indirect impact channels. Although we describe the research areas separately, it is important to recognize that impacts are sometimes interrelated. For example, climate-related, higher food prices can contribute to poorer nutrition, affecting susceptibility to infectious diseases to which poor populations are already vulnerable.[102] Higher food prices can also contribute to political instability and conflict, particularly in areas that already have a history of instability and high poverty rates.[103] Similar types of inter-relationships can be identified between health, ecosystem services, and livelihoods, among others.

Direct Channels

Food prices and agricultural production channels have been singled out by many researchers as key, direct avenues through which climate change can affect poverty.[47,91] This work typically utilizes climate model projections, crop production estimates, and economic models to explore how changing climatic conditions, including higher mean temperatures, changes in precipitation patterns, and increased variability, may affect agricultural productivity and food prices.[104–106] The work emphasizes that the urban poor are especially vulnerable to food price increases because they spend such a large share of their income on food,[102,105–107] though some researchers point out that landless rural poor are also highly vulnerable to food insecurity as a result of price increases.[108,109] For rural, agricultural producers, the poverty-related impacts of climate change are more complex. For producers living in a region affected by a climate-related shock, such as a large-scale drought, reduced

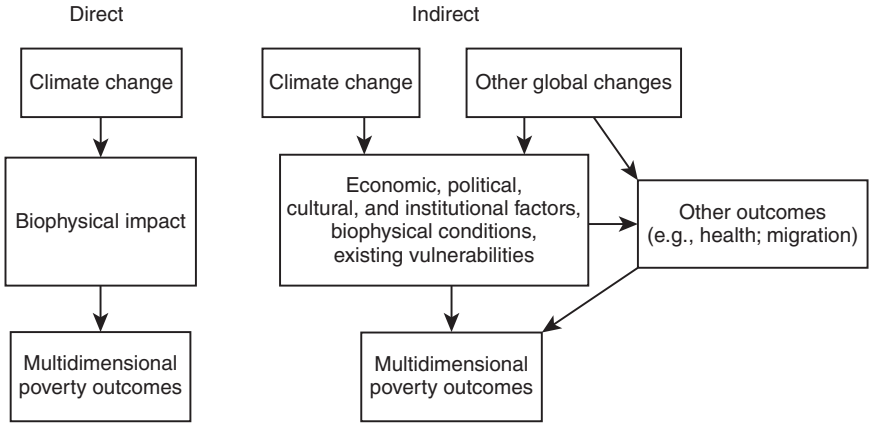

FIGURE 1 | Channels of climate change impact on poverty.

production, and loss of income can directly contribute to food insecurity and poverty. For producers who are not living in an affected region, higher food prices may potentially mean higher market prices for their products, which may help to compensate for higher production and consumption-related costs.[91] While most research in this area focuses on the developing world, climate-related shocks also have the potential to contribute to increased food insecurity within developed countries, though these effects are more likely to be muted by social safety nets.

The varying poverty impacts of climate change are illustrated in a recent study that examines how changes in agricultural productivity under different scenarios of climate change may affect food prices and poverty incidence in a set of 15 developing countries.[104] The research indicates that non-agricultural households, who must buy the majority of their food, will be most adversely affected by climate change. The research also demonstrates that the impacts of climate change are highly uneven across countries, with the largest poverty-enhancing effects occurring among urban and non-agricultural households in low-income countries in Africa and South Asia, but with potentially poverty-reducing effects among agricultural households in some countries in East Asia and Latin America.[104] Another illustrative study explores these issues in Tanzania, examining how weather volatility affects the numbers of people who fall below the poverty line both under present climate conditions and under scenarios of climate change.[106] The study demonstrates that weather volatility increases poverty in the present but suggests that the future climate change impact is uncertain. If climate change increases weather volatility then poverty will increase, but if it decreases volatility then poverty is expected to decrease.[106]

Indirect Channels

Indirect channels of impact are prominent in work that explores livelihood vulnerabilities. This large, interdisciplinary body of literature examines how climatic shocks and stresses including increased likelihood of drought, heat waves, extreme rainfall events, changes in sea ice, and sea level rise are affecting resource-based livelihoods of rural and indigenous populations. The research, which tends to be case study-oriented and focused on households and communities, emphasizes that chains of causality from climate change to poverty impacts are not simply about biophysical effects on the resources, but are mediated by a myriad of social, cultural, and institutional factors operating at multiple spatial scales, which condition capacity to respond to these effects.[48,59,110–115] Although resource dependent societies have extensive experience with and knowledge about coping with climate volatility,[41,116] recent work demonstrates how climate change (coupled with shifting economic landscapes) can exacerbate poverty by undermining traditional coping strategies, such as changing crops and diversifying livelihoods.[60,65,117–121]

In conjunction with impacts on livelihoods, researchers have also begun to explore how climate change can affect ecosystem services upon which poor populations depend. While all human systems are integrally dependent upon ecosystem services, poor individuals in developing countries are more directly dependent on these services than wealthier individuals and those living in developed countries who are able to substitute manufactured capital for natural capital and who rely on fossil fuel energy sources.[122] Many of the key ecosystem services that can be affected by climate change, including soil regulation, water regulation, and biodiversity,[66]

are integral to subsistence crop production, livestock grazing, fishing and hunting, and other livelihood systems. Understanding how climate change may influence relationships between ecosystem services and poverty represents an important area for new research.[66]

Impacts on physical and mental health represent another avenue through which climate change can indirectly contribute to impoverishment. Diseases that disproportionately affect the poor such as malaria, dysentery and cholera are expected to increase as a result of climate change,[69,123–125] potentially contributing to reduced productivity and loss of income for affected populations. In addition to its physical toll, climate change also affects psychological health.[126–128] These effects on mental health and well-being may include personal experience of loss or injury from an extreme event, exposure to media coverage of these events, and stress and anxiety over potential future impacts.[126] Research also indicates that climate change can undermine culture and identity, important elements in the literature on psychological dimensions of poverty, by decreasing the viability of traditional livelihoods and social support networks.[129–131]

Other mechanisms through which climate change may indirectly contribute to impoverishment are through its connection to political instability, conflict, and migration. Evidence suggests that climate change can act as a threat multiplier, increasing the likelihood of political instability and violent conflict, particularly in regions with a history of prior conflict.[103,117,125,132–135] Instability and conflict can, in turn, further exacerbate poverty.[9] Regarding migration, the same direct and indirect channels that contribute to poverty, including damage to assets, livelihoods, and ecosystem services, can also motivate migration.[136–139] In many cases, rural out-migrants will end up living in informal settlements in urban areas where they are exposed to new types of climatic risks.[103] While migration can be understood as a positive adaptation to climate change, the poorest of the poor are often unable to migrate and may end up trapped in environmentally degraded areas.[103,140] Other climate-migration-poverty linkages are also conceivable, such as the possibility that food price increases may indirectly exacerbate rural poverty by reducing remittances sent home by urban wage laborers.

As discussed in the next sections, economic growth is yet another critical avenue through which climate change may affect poverty. The slowing of economic growth or shifts in the pattern of growth as the result of climate change may have significant impacts on both poverty rates and poverty alleviation efforts.

CLIMATE CHANGE, ECONOMIC GROWTH AND AGGREGATE POVERTY

Despite recognition of the myriad channels through which climate change can exacerbate poverty, research that attempts to quantify the impacts of climate change on economic growth and poverty typically emphasizes impact channels that run through the agricultural sector, often looking directly at the sector or focusing on countries or groups of countries, particularly in sub-Saharan Africa, where agriculture dominates the economy.[104–106] In this section, we consider two types of studies that explore the connections between climate change, economic growth and poverty, including: (1) integrated modeling assessments; and (2) econometric studies of climate variability and poverty rates. These economic studies, which have been reviewed in detail elsewhere,[47,141] typically draw upon absolute, monetary definitions of poverty or poverty headcounts.

Integrated modeling assessments entail use of computable general equilibrium (CGE) models, which are run under scenarios with and without climate change in order to provide estimates of the net effects of climate change on economic growth, income, and poverty.[47] A recent study of Zambia, which uses a dynamic computable general equilibrium model to examine the effects of climate variability and change on economic growth and household income poverty,[142] illustrates this line of work. The study finds that current climate variability reduces economic growth in Zambia (by 4% over 10 years), pulling 2% more of the population below the poverty line.[142] Notably, the study results also indicate that the impact of current climate variability on economic growth exceeds the expected damage from even the worst case scenarios of climate change-related shifts in variability over the next few decades.[142] Other recent CGE modeling efforts reveal negative effects of climate change on economic growth in developing countries or groups of developing countries; these effects are expected to exacerbate poverty, though direct poverty impacts are not necessarily computed.[143,144]

Econometric studies explore how past changes in climate have affected growth and poverty at the national, regional, and household levels, with past effects sometimes used to project future impacts. Recent studies in this vein have demonstrated significant effects of climate variability and extreme events. For example, a study of the impact of climate variability on economic growth and poverty headcounts in

sub-Saharan Africa finds that severe variability, especially severe drought, has had a consistently negative effect on economic growth.[145] Severe variability is found to increase the poverty headcount of populations living below $1/day, but results are less consistent for populations living on less than $2/day. A study examining the impacts of natural disasters on HDI and different poverty metrics at the municipal level in Mexico shows that floods and droughts consistently reduce HDI and increase all metrics of poverty.[146] Another study of rural Mexico shows that both rainfall and temperature shocks affect consumption expenditures of rural households, but that these effects are most pronounced for households living in arid regions of the country.[147]

Econometric studies have also explored the effects of climate variability and change on economic growth in developing countries. Although these studies do not directly quantify a poverty impact, they nonetheless illustrate significant climate effects on aggregate growth. For example, a study exploring the connections between temperature and economic growth using a panel of 125 countries over the period from 1950 to 2005 finds that higher temperatures have a negative effect on economic growth, but only within the lowest income countries.[148] A study focused on rainfall finds similar results, demonstrating that lower rainfall since the 1960s in sub-Saharan Africa has been a significant determinant of weaker economic growth for countries located in this region.[149] Significant rainfall effects were not observed in other developing country groupings.[149]

CLIMATE CHANGE AND POVERTY TRAPS

In addition to immediate and direct effects on income and other poverty metrics, climate change can also have longer-term effects on poor households and communities, contributing to the creation or exacerbation of poverty traps. Within the development literature, poverty traps are defined as self-reinforcing mechanisms that create significant barriers to escaping poverty, and include, for example, market failures or institutional inefficiencies in state governance, legal systems, or social norms that have an adverse impact on the acquisition of physical or human capital.[150] The various mechanisms that reduce incentives for the poor to invest in poverty-alleviating factors, such as education or the adoption of new technologies, interact with and contribute to unproductive or inflexible asset portfolios. These conditions are thought to prevent growth and prosperity creating a 'trap' that cannot be overcome without external assistance,[151] though some scholars contest this notion.[152]

A number of studies have theorized mechanisms through which climate shocks and stresses may contribute to poverty traps at both the household and regional levels. Households may fall into poverty traps as the result of the adoption of coping or defense strategies that reduce risk but also limit opportunities to escape poverty such as selling assets, taking children out of school, and reducing consumption.[39,153–155] Poverty traps may be created at a regional scale under circumstances where destruction of assets from extreme events and diversion of resources toward costly adaptation measures such as coastal defense structures permanently reduces economic output in affected regions.[156]

Empirical evidence on climate-induced poverty traps is, however, quite mixed. In the case of Honduras, for example, one study indicates that following Hurricane Mitch in 1998, the poorest households experienced long lasting, durable effects, suggesting the existence of poverty traps for the least well-off households.[154] Another study, although finding some evidence to support the existence of poverty traps, particularly for poor households that follow defensive economic strategies, finds no significant poverty trap effect as a direct result of Mitch.[155] A third study raises critical questions about the very premise that climate shocks create poverty traps, suggesting instead the climate shocks may, under some circumstances, create opportunities to enhance local resilience.[61] The study shows that household and community responses following Hurricane Mitch led to institutional changes that enhanced resilience such that later flooding had much more limited effects on households and livelihoods.[61] Enhanced resilience is documented by comparing the damage to crop production, agricultural infrastructure, and human health following Mitch and to the damage from two tropical depressions in 2008 in which floodwaters reached heights that were comparable to Mitch.[61] The resilience-enhancing changes documented in the study included shifts in agricultural production areas away from risky floodplain, changes in land tenure which reduced incentives to clear primary forests, and diversification of income-generating strategies.[61] While the varying results among the three studies may be partly explained by differing methodologies and sample populations, their contradictory findings nonetheless suggest that more work on climate-poverty trap connections is needed.

Recent studies in Mozambique have also suggested that climate shocks can, under some circumstances, have positive social and economic impacts

that may potentially benefit poor populations.[157,158] This work, which examines the effects of cyclones on household income, finds that Tropical Cyclone Japhet was associated with increasing incomes for some small and medium scale farmers, most likely because it brought rains to an area that was undergoing a drought. However, households in the area affected by Tropical Cyclone Delfina were found to experience substantial declines in household per capita income.[157,158] Other work explores the question of whether extreme events can have positive impacts via a 'productivity effect', whereby damaged physical capital is replaced by newer capital leading to greater future productivity.[159] This work demonstrates through application of a non-equilibrium economic growth model with embodied technological change that rebuilding after a disaster with newer capital can protect against future disaster losses, but that disasters do not increase economic growth.[159] Their modeling results also suggest that climate shocks can contribute to poverty traps within poor regions in those cases where disaster damages repeatedly exceed local reconstruction capacity.[159]

CLIMATE CHANGE AND POVERTY ALLEVIATION

Poverty alleviation is arguably the most important strategy to reduce the impacts of climate change on the poor. Poverty reduction would make the poor and otherwise marginalized less vulnerable and more resilient to many of the impacts of climate change identified earlier.[4,64,65,160–162] Yet climate change and extreme weather could also reverse past poverty reduction achievements, and hinder future poverty alleviation efforts.[47,143,163,164] In this section, we briefly consider how climate change may affect poverty alleviation efforts.

There is broad recognition that climate change threatens conventional approaches to poverty alleviation.[165–168] For example, traditional strategies to increase incomes of the rural poor and the GDPs of many developing countries entail the promotion of cash crops for export. Yet export-based development strategies can also increase climate-related risks in the agricultural sector, which, in turn, may undermine the intended benefits. For example, household-level research in Mozambique finds that, during 2002–2005, a period characterized by a series of severe weather events, agricultural export-based development strategies contributed to increased inequality among small- and medium-scale farm households.[169] Other work suggests that engagement with agricultural commodity markets has more negative effects on poorer households (both urban and rural) in developing countries when extreme weather reduces crop yields and exerts upward pressure on food prices.[109] Many of the other key pillars of poverty alleviation, including investment in infrastructure to improve food security, transportation networks, health service provisions, market access, and access to basic necessities such as adequate shelter, potable water, and energy sources, can also be compromised by climate change.[165,170,171] As noted earlier, the potential climate change impacts on human health are likely to be more severe for poorer populations and regions already experiencing high disease burdens and resource scarcity, placing additional strains on public health facilities and services in these areas.[123]

Climate change also threatens newer poverty reduction initiatives such as tourism-based development. Tourism has gained widespread popularity among governments and international donors as a means for alleviating poverty in rural regions of the developing world,[172,173] particularly in areas with charismatic wildlife species and dramatic landscapes that appeal to Western tourists and conservationists.[174] However tourism-based development is highly vulnerable to climate change and weather-related shocks.[175–178] For example, a recent study of Malaysia finds that catastrophic flooding led to severe declines in tourism revenue due to declining tourism arrivals and the destruction of tourism accommodation facilities and attractions, with resultant negative impacts on local livelihoods reliant on the industry.[179] The study authors recommend that tourism infrastructure should be incorporated into flood recovery plans in order to ensure sustainability of the sector's contribution to economic development.[179]

Funding for poverty alleviation is also potentially threatened by climate change, as funds are diverted from development efforts and toward climate adaptation.[95] The projected costs of climate adaptation efforts (e.g., proposals and strategies intended to reduce the impacts of climate change on poor populations) are likely to dwarf development budgets.[180] While detailed discussion of adaptation policies is beyond the scope of this review, many have argued that adaptation-enhancing interventions can be complimentary to poverty reduction efforts and have recommended careful mainstreaming of adaptation into existing development and poverty alleviation plans.[95,167,181–185] Under the best circumstances, poverty alleviation efforts designed with climate change in mind could directly dovetail with measures that will enhance adaptive capacity,

including diversification of livelihoods, improved access to credit, and strengthening of traditional communal systems of mutual support. However, adaptation policies and actions may also have significant, unintended consequences for poor and lower income populations.[79,186] For example, land grabbing by governments or foreign interests, premised on a need to ensure food security in the face of climate change, can cut off access to traditional land resources, particularly in cases where land tenure and private property rights are lacking.[102] Without appropriate, participatory governance strategies, adaptation can run counter to poverty alleviation efforts, enhancing marginalization of vulnerable groups[62,186,187] Good governance is, in fact, a key tenet for all types of poverty alleviation strategies, and much more work is needed to gauge effective models for harmonizing climate adaptation, participatory governance, and poverty alleviation.

CONCLUSION: PRIORITIES FOR FUTURE RESEARCH

Examination of recent literature at the nexus of poverty, vulnerability, and climate impacts reveals that the connections between climate change and poverty are complex, multifaceted, and context-specific. While the poor are more likely to be exposed to climate shocks and stresses and have fewer resources to adapt, some poor communities display high levels of resilience. The climate change research community has produced detailed knowledge of why the poor can be expected to be more vulnerable to the impacts of climate change, but much less is known about factors that promote and enhance resilience. Additional research on characteristics and conditions that allow poor communities and individuals to respond, recover and 'bounce forward' from climate stresses and extreme events is an important area for further study. Researchers have also articulated many channels though which climate change can contribute to impoverishment, yet most empirical work, particularly at the aggregate level, has focused on food and agriculture. Other avenues of impact between climate change and poverty outcomes, such as mental health, ecosystem services, migration, political instability, and conflict have received only limited attention in the literature. Further investigation of the potential effects of climate change on economic growth and poverty traps as well as options for aligning adaptation strategies and poverty reduction, is also needed.

As research moves forward in these and other areas, an important takeaway from the broader poverty literature is the need to incorporate alternative conceptions and metrics of poverty. Despite acknowledgement that poverty has many dimensions, much of the climate change literature uses poverty lines or other set monetary metrics, missing the 'near poor'—those living just above the poverty line - and the relative poor. Non-monetary facets of poverty such as social exclusion, stigmatization, and shame have also received little attention in the climate change literature. Furthermore, while most attention to climate change and poverty mechanisms focuses on the developing world, there is also a need for exploration of climate-related reductions in income within the developed world. Within the United States, for example, socio-economic stress resulting from Hurricane Katrina has had persistent effects on the health status of otherwise vulnerable populations,[188] which may have significant long-term poverty implications. It is likely that Hurricane Sandy, which damaged or destroyed more than 650,000 housing units in the US Northeast,[189] will also contribute to increased poverty, particularly for lower-income households who experienced major damage to their homes and did not have flood insurance coverage.

Another important area for further work entails new theorizations of poverty and development that can accommodate conceptions of enhanced quality of life within a context of finite resources and climate change. Conceptualizations of poverty have evolved considerably over time, and many contemporary notions of development view progress in human well-being not simply in terms of increasing personal income or national economic growth, but as the creation of an enabling environment for people to enjoy long, healthy lives that they have reason to value.[19,190,191] However, much of the theoretical work on economic development remains premised on neoclassical concepts of utility maximization and the idea of ever increasing individual desires for goods and services.[192,193] These discussions largely neglect how development (e.g., greater livelihood opportunities for the poor; expansion of peoples' abilities to participate in community life) may directly contribute to the mechanisms driving climate change and thereby constrain longer-term poverty alleviation efforts. While recent work within ecological economics has argued for alternative theories of development centered on notions of sustainability, efficiency, non-wastefulness, and social justice,[194–197] many of these insights have yet to be incorporated into theorizations of the connections between poverty and climate change.

While additional research within the areas covered in this review is certainly a priority, examination of the literature on climate change and poverty also revealed a number of important gaps where little work has been done to date. Two noteworthy gaps include studies of the effects of climate change on income distribution and studies of the poverty impacts of extreme climate change. The notion that climate change will exacerbate existing inequalities is widely accepted in the research literature,[42,198,199] but there is relatively little empirical work on the effects of climate change and adaptation responses on income distribution and inequality either within or across countries. With regard to extreme climate change, most studies of climate-poverty linkages are premised on gradual climate change, yet recent projections are suggesting the possibility of larger and more dramatic changes, including temperature increases of 4 °C and beyond.[200,201] Such changes, though less likely, are outside the bounds of what societies have experienced to date, and there is good reason to suspect that poor populations will be at grave risk.

REFERENCES

1. Myers S, Kulish N. Growing clamor about inequities of climate crisis. *New York Times* 2013, November 16.
2. de Brum T, Rigg K, Robinson M. 2013. Warsaw climate talks: The world's poorest cannot wait for a 2015 deal. *The Guardian 2013*, November 21.
3. Warner K, van der Geest K. Loss and damage from climate change: local-level evidence from nine vulnerable countries. *Int J Global Warm* 2013, 5:367–386.
4. Kelly P, Adger W. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Clim Chang* 2000, 47:325–352.
5. Rayner S, Malone E. Climate change, poverty, and intragenerational equity: the national level. *Int J Global Environ Issues* 2001, 1:175–202.
6. O'Brien K, Leichenko R. Winners and losers in the context of global change. *Ann Assoc Am Geogr* 2003, 93:89–103.
7. Eriksen S, O'Brien K. Vulnerability, poverty and the need for sustainable adaptation measures. *Clim Pol* 2007, 7:337–352.
8. Schipper E. Climate change adaptation and development: Exploring the linkages. Tyndall Centre for Climate Change Research, Working Paper 107, 2007, 13.
9. Naudé W, Santos-Paulino A, Mcgillivray M. Measuring vulnerability: an overview and introduction. *Oxf Dev Stud* 2009, 37:183–191.
10. Kwak S, Smith S. Multidimensional poverty and interlocking poverty traps: framework and application to Ethiopian household panel data. Institute for International Economic Policy Working Paper Series 2011–04, 2011, 50.
11. Trani J, Cannings T. Child poverty in an emergency and conflict context: a multidimensional profile and an identification of the poorest children in Western Darfur. *World Dev* 2013, 48:48–70.
12. Victor B, Fischer E, Cooil B, Vergara A, Mukolo A, Blevins M. Frustrated freedom: the effects of agency and wealth on wellbeing in rural Mozambique. *World Dev* 2013, 47:30–41.
13. Bohle H, Downing T, Watts M. Climate change and social vulnerability. *Glob Environ Chang* 1994, 4:37–48.
14. Eriksen S, Klein R, Ulsrud K, Næss LO, OBrien K. Climate change adaptation and poverty reduction: Key interactions and critical measures. *Report prepared for the Norwegian Agency for Development Cooperation (Norad)*, 2007, 42.
15. O'Brien K, Barnett J. Global environmental change and human security. *Annu Rev Environ Resour* 2013, 38:373–391.
16. Rowntree BS. *Poverty: A Study of Town Life*. London: Macmillan and Co; 1901, 426.
17. Riis JA. *How the Other Half Lives: Studies among the Tenements of New York*. New York: Charles Scribner's Sons; 1914, 304.
18. Silva JA. Economics, morality, and method. *Geog Compass* 2011, 5:825–837.
19. Sen A. *Development as Freedom*. Oxford: Oxford University Press; 1999, 384.
20. Narayan D, Patel R, Schafft K, Rademacher A, Koch-Shulte S. *Voices of the Poor: Can Anyone Hear Us?* New York: Oxford University Press and World Bank; 2000, 360.
21. Pogge T. *World Poverty and Human Rights*. 2nd ed. Maldan, MA: Polity Press; 2008, 304.
22. Mosse D. A relational approach to durable poverty, inequality and power. *J Dev Stud* 2010, 46:1156–1178.
23. Alkire S, Foster J. Understandings and misunderstandings of multidimensional poverty measurement. *J Econ Inequal* 2011, 9:289–314.
24. Ferreira F, Lugo M. Multidimensional poverty analysis: Looking for a middle ground. World Bank, Development Research Group, Policy Research Paper 5964, 2012, 16.
25. Ravallion M. The two poverty enlightenments: historical insights from digitized books spanning three centuries. *Pov Public Policy* 2011, 3:167–212.

26. Mitra S, Posarac A, Vick B. Disability and poverty in developing countries: a multidimensional study. *World Dev* 2013, 41:1–18.
27. Hulme D, Shepherd A. Conceptualizing chronic poverty. *World Dev* 2003, 31:403–423.
28. Laderchi CR, Saith R, Stewart F. Does it matter that we don't agree on the definition of poverty? A comparison of four approaches. QEH Working Paper Series – QEHWPS107, 2003, 41.
29. Sen A. *Commodities and Capabilities*. Oxford: Oxford University Press; 1985, 104.
30. Foster J. Absolute versus relative poverty. *Am Econ Rev* 1998, 88:335–341.
31. Duclos J, Gregoire P. Absolute and relative deprivation and the measurement of poverty. *Rev Income Wealth* 2002, 2002:471–492.
32. Population Reference Bureau. *2008 World Population Data Sheet*. Available at: http://www.prb.org/Publications/Datasheets/2008/2008wpds.aspx.
33. World Bank. *Global monitoring report 2013: Rural–urban dynamics and the Millennium Development Goals*. World Bank, New York, 2013, 178.
34. Sumner A. Global poverty and the new bottom billion: what if three-quarters of the world's poor live in middle-income countries? IDS Working Paper 349, 2010, 43.
35. Notten G, De Neubourg C. Monitoring absolute and relative poverty: 'Not enough' is not the same as 'much less'. *Rev Income Wealth* 2011, 57:247–269.
36. Milbourne P. The geographies of poverty and welfare. *Geog Comp* 2010, 4:158–171.
37. Sen A. Poor, relatively speaking. *Oxf Econ Pap* 1983, 35:153–169.
38. Chronic Poverty Research Center (CRPC). *The Chronic Poverty Report 2004–05*, 2005, 152.
39. Carter M, Barrett C. The economics of poverty traps and persistent poverty: an asset-based approach. *J Dev Stud* 2006, 42:178–199.
40. Jo YN. Psycho-social dimensions of poverty: when poverty becomes shameful. *Crit Soc Policy* 2013, 33:514–531.
41. Adger W, Huq S, Brown K, Conway D, Hulme M. Adaptation to climate change in the developing world. *Prog Dev Stud* 2003, 3:179–195.
42. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Cambridge: Cambridge University Press; 2007, 976.
43. Ribot J. Vulnerability does not fall from the sky: toward multiscale, pro-poor climate policy. In: Mearns R, Norton A, eds. *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*. Washington, DC: World Bank; 2010, 47–74.
44. Füssel H-M. Vulnerability to climate change and poverty. In: Edenhofer O, Wallacher J, Lotze-Campen H, Reder M, Knopf B, Müller J, eds. *Climate Change Justice and Sustainability, Linking Climate and Development Policy*. Dordrecht, Netherlands: Springer Science; 2012, 9–17.
45. Intergovernmental Panel on Climate Change (IPCC). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. New York: Cambridge University Press; 2012, 594.
46. Jones A, LaFleur V, Purvis N. Double jeopardy: what the climate crisis means for the poor. In: Brainard L, Jones A, Purvis N, eds. *Climate Change and Global Poverty: A Billion Lives in the Balance*. Washington, DC: The Brookings Institution; 2009, 10–42.
47. Skoufias E, Rabassa M, Olivieri S. The forecast for poverty: a review of the evidence. In: Skoufias E, ed. *The Poverty and Welfare Impacts of Climate Change: Quantifying the Effects, Identifying the Adaptation Strategies*. Washington DC: The World Bank; 2012, 17–54.
48. Barua A, Katyaini S, Mili B, Gooch P. Climate change and poverty: building resilience of rural mountain communities in South Sikkim, Eastern Himalaya, India. *Reg Environ Chang* 2013:1–14.
49. Sen A. *Poverty and Famines: An Essay on Entitlement and Deprivation*. Oxford: Clarendon Press; 1981, 259.
50. Appadurai A. The capacity to aspire: culture and the terms of recognition. In: Rao F, Walton M, eds. *Culture and Public Action*. Stanford, CA: Stanford University Press; 2004, 59–84.
51. Mani A, Mullainathan S, Shafir E, Zhao J. Poverty impedes cognitive function. *Science* 2013, 341:976–980.
52. Barnett J, Lambert S, Fry I. The hazards of indicators: insights from the environmental vulnerability index. *Ann Assoc Am Geogr* 2008, 98:102–119.
53. Preston B, Yuen E, Westaway R. Putting vulnerability to climate change on the map: a review of approaches, benefits, and risks. *Sustain Sci* 2011, 6:177–202.
54. Romero-Lankao P, Qin H, Dickinson K. Urban vulnerability to temperature-related hazards: A meta-analysis and meta-knowledge approach. *Glob Environ Chang* 2012, 22:670–683.
55. de Sherbinin A. Climate change hotspots mapping: what have we learned? *Clim Chang* 2014, 123:23–37.
56. Wisner B, Blaikie P, Cannon T, Davis I. *At Risk: Natural Hazards, People's Vulnerability and Disasters*. 2nd ed. New York: Routledge; 1994, 471.
57. Adger W. Vulnerability. *Glob Environ Chang* 2006, 16:268–281.
58. Casale M, Drimie S, Quinlan T, Ziervogel G. Understanding vulnerability in southern Africa: comparative findings using a multiple-stressor approach in South Africa and Malawi. *Reg Environ Chang* 2010, 10:157–168.

59. Eakin H, Benessaiah K, Barrera JF, Cruz-Bello GM, Morales H. Livelihoods and landscapes at the threshold of change: disaster and resilience in a Chiapas coffee community. *Reg Environ Change* 2012, 12:475–488.
60. Gentle P, Maraseni TN. Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environ Sci Policy* 2012, 21:24–34.
61. McSweeney K, Coomes OT. Climate-related disaster opens a window of opportunity for rural poor in northeastern Honduras. *PNAS* 2011, 108:5203–5208.
62. Pelling M. *Adaptation to Climate Change: From Resilience to Transformation*. New York: Routledge; 2011, 203.
63. Adger W, Eakin H, Winkels A. Nested and teleconnected vulnerabilities to environmental change. *Front Ecol Environ* 2009, 7:150–157.
64. Eriksen S, Silva JA. The vulnerability context of a savanna area in Mozambique: household drought coping strategies and responses to economic change. *Environ Sci Pol* 2009, 12:33–52.
65. Silva JA, Eriksen S, Ombe Z. Double exposure in Mozambique's Limpopo river basin. *Geogr J* 2010, 176:6–24.
66. Howe C, Suich H, van Gardingen P, Rahman A, Mace G. Elucidating the pathways between climate change, ecosystem services and poverty alleviation. *Curr Opin Environ Sustain* 2013, 5:102–107.
67. Pelling M. *The Vulnerability of Cities: Natural Disasters and Social Resilience*. London: Earthscan; 2003, 212.
68. Satterthwaite D, Huq S, Reid H, Pelling M, Lankao P. Adapting to climate change in urban areas: the possibilities and constraints in low-and middle-income nations. International Institute for Environment and Development IIED, 2007, 112.
69. Douglas I, Alam K, Maghenda M, Mcdonnell Y, Mclean L, Campbell J. Unjust waters: Climate change, flooding and the urban poor in Africa. *Environ Urban* 2008, 20:187–205.
70. Tanner T, Mitchell T, Polack E, Guenther B. Urban governance for adaptation: assessing climate change resilience in ten Asian cities. *IDS Working Papers* 2009, 47.
71. Hardoy J, Pandiella G. Urban poverty and vulnerability to climate change in Latin America. *Environ Urban* 2009, 21:203–224.
72. Chatterjee M. Slum dwellers response to flooding events in the megacities of India. *Mitig Adapt Strateg Glob Chang* 2010, 15:337–353.
73. Adelekan I. Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. *Environ Urban* 2010, 22:433–450.
74. Nagel J. Intersecting identities and global climate change. *Identities* 2012, 19:467–476.
75. Burnham M, Radel C, Ma Z, Laudati A. Extending a geographic lens towards climate justice, Part 1: climate change characterization and impacts. *Geog Comp* 2013, 7:239–248.
76. Ajibade I, McBean G, Bezner-Kerr R. Urban flooding in Lagos, Nigeria: patterns of vulnerability and resilience among women. *Glob Environ Chang* 2013, 23:1714–1725. doi: 10.1016/j.gloenvcha.2013.08.009.
77. Cutter S, Boroff B, Shirley W. Social vulnerability to environmental hazards. *Soc Sci Q* 2003, 84:242–261.
78. Lal P, Alavalapati J, Mercer E. Socio-economic impacts of climate change on rural United States. *Mitig Adapt Strateg Glob Chang* 2011, 16:819–844.
79. Leichenko R, Klein Y, Panero M, Major D, Vancura P. Equity and economics. *Ann N Y Acad Sci* 2011, 1244:62–78.
80. Paolisso M, Douglas E, Enrici A, Kirshen P, Watson C, Ruth M. Climate change, justice, and adaptation among African American communities in the Chesapeake Bay Region. *Weather Clim Soc* 2012, 4:34–47.
81. Martinich J, Neumann J, Ludwig L, Jantarasami L. Risks of sea level rise to disadvantaged communities in the United States. *Mitig Adapt Strateg Glob Change* 2013, 18:169–185.
82. Maldonado J, Shearer C, Bronen R, Peterson K, Lazrus H. The impact of climate change on tribal communities in the US: displacement, relocation, and human rights. *Clim Chang* 2013, 120:601–614.
83. Cutter S. The geography of social vulnerability: race, class, and catastrophe. Social Science Research Council, *Understanding Katrina: Perspectives from the Social Sciences*, Social Science Research Council, 2006. Available at: http://forums.ssrc.org/understandingkatrina/author/scutter/.
84. Halpin S. *The Impact of Superstorm Sandy on New Jersey Towns and Households*. Rutgers-Newark: School of Public Affairs; 2013, 111.
85. Leichenko R, Solecki W. Climate change in suburbs: an exploration of key impacts and vulnerabilities. *Urban Clim* 2013, 2013:82–97.
86. Barnes M. The management and adaptation of a legacy transit system for weather extremes in the Philadelphia metropolitan region, PhD Dissertation, Rutgers University, 2014, 175.
87. Preston B. Local path dependence of U.S. socioeconomic exposure to climate extremes and the vulnerability commitment. *Glob Environ Chang* 2013, 23:712–732. doi: 10.1016/j.gloenvcha.2013.02.009.
88. Kim N. How much more exposed are the poor to natural disasters? Global and regional measurement. *Disasters* 2011, 36:195–211.
89. Macours K. Volatility, agricultural risk, and household poverty: micro-evidence from randomized control trials. *Agric Econ* 2013, 44:79–84.

90. Müller C, Cramer W, Hare W, Lotze-Campen H. Climate change risks for African agriculture. *PNAS* 2011, 108:4313–4315.
91. Hertel T, Rosch S. Climate change, agriculture, and poverty. *Appl Econ Perspect Policy* 2010, 32:355–385.
92. Oberlack C, Eisenack K. Alleviating barriers to urban climate change adaptation through international cooperation. *Glob Environ Chang* 2014, 24:349–362. doi: 10.1016/j.gloenvcha.2013.08.016.
93. Füssel HM. How inequitable is the global distribution of responsibility, capability, and vulnerability to climate change: a comprehensive indicator-based assessment. *Glob Environ Chang* 2010, 20:597–611.
94. Balk D, Montgomery M, McGranahan G, Kim D, Mara V, Todd M, Buettner T, Dorelien A. Mapping urban settlements and the risks of climate change in Africa, Asia and South America. In: Guzman J, Martine G, McGranahan G, Schensul D, Tacoli C, eds. *Population Dynamics and Climate Change*. London: IIED; 2009, 80–103.
95. Ayers J, Huq S. Supporting adaptation to climate change: What role for official development assistance? *Dev Policy Rev* 2009, 27:675–692.
96. McGranahan G, Balk D, Anderson B. The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environ Urban* 2007, 19:17–37.
97. FAO, WFP and IFAD. *The State of Food Insecurity in the World 2012*. Rome: Food and Agriculture Organization of the United Nations; 2012, 63.
98. UN Habitat. *State of the World's Cities 2012/2013: Prosperity of Cities*. New York: Routledge; 2013, 184.
99. United Nations Development Programme (UNDP). Human development report 2013. The rise of the South: Human progress in a divided world. United Nations Development Programme, New York, 2013, 203.
100. Patt AG, Tadross M, Nussbaumer P, Asante K, Metzger M, Rafael J, Goujon A, Brundrit G. Estimating least-developed countries' vulnerability to climate-related extreme events over the next 50 years. *PNAS* 2010, 107:1333–1337.
101. Leichenko R, O'Brien K. *Environmental Change and Globalization: Double Exposures*. New York: Oxford University Press; 2008, 167.
102. Wheeler T, von Braun J. Climate change impacts on global food security. *Science* 2013, 341:508–513.
103. Council NR. *Climate and Social Stress: Implications for Security Analysis*. Washington, DC: The National Academies Press; 2013, 237.
104. Hertel T, Burke M, Lobell D. The poverty implications of climate-induced crop yield changes by 2030. *Glob Environ Chang* 2010, 20:577–585.
105. Ahmed S, Diffenbaugh N, Hertel T. Climate volatility deepens poverty vulnerability in developing countries. *Environ Res Lett* 2009, 4:034004.
106. Ahmed S, Diffenbaugh N, Hertel T, Lobell D, Ramankutty N, Rios A, Rowhani P. Climate volatility and poverty vulnerability in Tanzania. *Glob Environ Chang* 2011, 21:46–55.
107. Ivanic M, Martin W, Zaman H. Estimating the short-run poverty impacts of the 2010–11 surge in food prices. *World Dev* 2012, 40:2302–2317.
108. Ruel M, Garrett J, Hawkes C, Cohen M. The food, fuel, and financial crises affect the urban and rural poor disproportionately: a review of the evidence. *J Nutr* 2010, 140:170S–176S.
109. Skejolke S. Measuring household vulnerability to climate change—Why markets matter. *Glob Environ Chang* 2013, 2013:1694–1701.
110. Paavola J. Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environ Sci Pol* 2008, 11:642–654.
111. Kuruppu N, Liverman D. Mental preparation for climate adaptation: The role of cognition and culture in enhancing adaptive capacity of water management in Kiribati. *Glob Environ Chang* 2011, 21:657–669.
112. Rodima-Taylor D. Social innovation and climate adaptation: local collective action in diversifying Tanzania. *Appl Geogr* 2012, 33:128–134.
113. Becken S, Lama AK, Espiner S. The cultural context of climate change impacts: perceptions among community members in the Annapurna Conservation Area, Nepal. *Environmental Development* 2013, 8:22–37.
114. Leonard S, Parsons M, Olawsky K, Kofod F. The role of culture and traditional knowledge in climate change adaptation: insights from East Kimberley, Australia. *Glob Environ Chang* 2013, 23:623–632.
115. Wolf J, Allice I, Bell T. Values, climate change, and implications for adaptation: evidence from two communities in Labrador, Canada. *Glob Environ Chang* 2013, 23:548–562.
116. Niamir-Fuller M. The Resilience of Pastoral Herding in Sahelian Africa. In: Berkes F, Folke C, eds. *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge University Press: Cambridge; 2000, 250–284.
117. McKune S, Silva JA. Pastoralists under pressure: double exposure to economic and environmental change in Niger. *J Dev Stud* 2013, 49:1711–1727. doi: 10.1080/00220388.2013.822067.
118. Martin R, Müller B, Linstädter A, Frank K. How much climate change can pastoral livelihoods tolerate? Modeling rangeland use and evaluating risk. *Glob Environ Chang* 2014, 24:183–192. doi: 10.1016/j.gloenvcha.2013.09.009.
119. Wang J, Brown B, Agrawal A. Climate adaptation, local institutions, and rural livelihoods: a comparative study of herder communities in Mongolia and Inner Mongolia, China. *Glob Environ Chang* 2013, 23:1673–1683.

120. Suckall N, Tompkins E, Stringer L. Identifying trade-offs between adaptation, mitigation and development in community responses to climate and socio-economic stresses: evidence from Zanzibar, Tanzania. *Appl Geogr* 2014, 46:111–121.

121. Vongvisouk T, Mertz O, Thongmanivong S, Heinimann A, Phanvilay K. Shifting cultivation stability and change: contrasting pathways of land use and livelihood change in Laos. *Appl Geogr* 2014, 46:1–10.

122. Fisher J, Patenaude G, Meir P, Nightingale A, Rounsevell M, Williams M, Woodhouse I. Strengthening conceptual foundations: analysing frameworks for ecosystem services and poverty alleviation research. *Glob Environ Chang* 2013, 23:1098–1111. doi: 10.1016/j.gloenvcha.2013.04.002.

123. Ebi K, Lindgren E, Suk J, Semenza J. Adaptation to the infectious disease impacts of climate change. *Clim Chang* 2013, 118:355–365.

124. Huynen M, Martens P, Akin S. Climate change: an amplifier of existing health risks in developing countries. *Environ Dev Sustain* 2013, 15:1425–1442.

125. Tol R. The economic impact of climate change in the 20th and 21st centuries. *Clim Chang* 2013, 117:795–808.

126. Doherty T, Clayton S. The psychological impacts of global climate change. *Am Psychol* 2011, 66:265–276.

127. Paranjothy S, Gallacher J, Amlot R, Rubin G, Page L, Baxter T, Wight J, Kirrage D, McNaught R, Palmer S. Psychological impacts of the summer 2007 floods in England. *BMC Public Health* 2011, 11:1–8.

128. Hanigan I, Butler C, Kokic P, Hutchinson M. Suicide and drought in New South Wales, Australia, 1970–2007. *PNAS* 2012, 109:13950–13955.

129. Crate S. Gone the bull of winter? Grappling with the cultural implications of and antropology's role(s) in global climate change. *Curr Anthropol* 2008, 49:569–595.

130. Strauss S. Are cultures endangered by climate change? Yes, but…. *WIRES Clim Change* 2012, 3:371–377. doi: 10.1002/wcc.181.

131. Adger W, Barnett J, Brown K, Marshall N, O'Brien K. Cultural dimensions of climate change impacts and adaptation. *Nat Clim Chang* 2013, 3:112–117.

132. Barnett J, Adger W. Climate change, human security and violent conflict. *Polit Geog* 2007, 26:639–655.

133. Koubi V, Bernauer T, Kalbhenn A, Spilker G. Climate variability, economic growth, and civil conflict. *J Peace Res* 2012, 49:113–127.

134. Scheffran J, Battaglini A. Climate and conflicts: the security risks of global warming. *Reg Environ Change* 2011, 11:27–39.

135. Stern P, Ebi K, Leichenko R, Olson R, Steinbruner J, Lempert R. Managing risks with climate vulnerability science. *Nat Clim Chang* 2013, 3:607–609.

136. Warner K, Hamza M, Oliver-Smith A, Renaud F, Julca A. Climate change, environmental degradation and migration. *Nat Hazards* 2010, 55:689–715.

137. Afifi T. Economic or environmental migration? The push factors in Niger. *Int Migr* 2011, 49:e95–e124.

138. Lilleør H, Van den Broeck K. Economic drivers of migration and climate change in LDCs. *Glob Environ Chang* 2011, 21S:S70–S81.

139. Black R, Adger W, Arnell N, Dercon S, Geddes A, Thomas D. The effect of environmental change on human migration. *Glob Environ Chang* 2011, 21S:S3–S11.

140. Foresight. Migration and global environmental change: Future challenges and opportunities. Final project report. Government Office for Science, London, 2011, 237.

141. Skoufias E, Rabassa M, Olivieri S. The poverty impacts of climate change: a review of the evidence. World Bank, Policy Research Working Paper 5622, 2011, 37.

142. Thurlow J, Zhu T, Diao X. Current climate variability and future climate change: estimated growth and poverty impacts for Zambia. *Rev Dev Econ* 2012, 16:394–411.

143. Arndt C, Strzepeck K, Tarp F, Thurlow J, Fant C, Wright L. Adapting to climate change: an integrated biophysical and economic assessment for Mozambique. *Sustain Sci* 2011, 6:7–20.

144. Eboli F, Parrado R, Roson R. Climate-change feedback on economic growth: explorations with a dynamic general equilibrium model. *Envir Dev Econ* 2010, 15:515–533.

145. Brown C, Meeks R, Hunu K, Yu W. Hydroclimate risk to economic growth in sub-Saharan Africa. *Clim Chang* 2011, 106:621–647.

146. Rodriguez-Oreggia E, De La Fuente A, De La Torre R, Moreno HA. Natural disasters, human development and poverty at the municipal level in Mexico. *J Dev Stud* 2013, 49:442–455.

147. Skoufias E, Vinha K. The impacts of climate variability on household welfare in rural Mexico. *Popul Environ* 2013, 34:370–399.

148. Dell M, Jones BF, Olken BA. Temperature shocks and economic growth: evidence from the last half century. *Am Econ J* 2012, 4:66–95.

149. Barrios S, Bertinelli L, Strobl E. Trends in rainfall and economic growth in Africa: a neglected cause of the African growth tragedy. *Rev Econ Stat* 2010, 92:350–366.

150. Azariadis C, Stachurski J. Poverty traps. In: Aghion P, Durlauf S, eds. *Handbook of Economic Growth*, vol. 1, Part A. Amsterdam: Elsevier; 2005, 295–384.

151. Barrett C, McPeak J. Poverty traps and safety nets. In: Thorbecke E, DeJanvry A, Kanbur S, eds. *Poverty, Inequality and Development*. Springer: New York; 2006, 131–154.

152. Easterly W. Reliving the '50s: the big push, poverty traps, and takeoffs in economic development. *J Econ Growth* 2006, 11:289–318.

153. Barrett C, Barnett B, Carter M, Chantarat S, Hansen J, Mude A, Osgood D, Skees J, Turvey C, Ward M. Poverty traps and climate risk: limitations and opportunities of index-based risk financing. IRI Technical Report 07–02 2008:53.

154. Carter M, Little P, Mogues T, Negatu W. Poverty traps and natural disasters in Ethiopia and Honduras. *World Dev* 2007, 35:835–856.

155. van den Berg M. Household income strategies and natural disasters: Dynamic livelihoods in rural Nicaragua. *Ecol Econ* 2010, 69:592–602.

156. Hallegatte S. A framework to investigate the economic growth impact of sea level rise. *Environ Res Lett* 2012, 7:015604.

157. Matyas CJ, Silva JA. Extreme weather and economic well-being in rural Mozambique. *Nat Hazards* 2013, 66:31–49.

158. Silva JA, Matyas CJ. Relating rainfall patterns to agricultural income: implications for rural development in Mozambique. *Weather Clim Soc* 2013, 6:218–237. doi: 10.1175/WCAS-D-13-00012.1.

159. Hallegatte S, Dumas P. Can natural disasters have positive consequences? Investigating the role of embodied technical change. *Ecol Econ* 2009, 68:777–786.

160. da Silva J, Kernaghan S, Luque A. A systems approach to meeting the challenges of urban climate change. *Int J Urban Sustain Dev* 2012, 4:125–145.

161. O'Brien G, O'Keefe P, Meena H, Rose J, Wilson L. Climate adaptation from a poverty perspective. *Clim Pol* 2008, 8:194–201.

162. Kithiia J. Climate change risk responses in East African cities: needs, barriers and opportunities. *Curr Opin Environ Sustain* 2011, 3:176–180.

163. Hope K. Climate change and poverty in Africa. *Int J Sustain Dev World Ecol* 2009, 16:451–561.

164. Thurlow J, Zhu T, Diao X. *The Impact of Climate Variability and Change on Economic Growth and Poverty in Zambia*. Washington DC: International Food Policy Research Institute (IFPRI); 2009, 72.

165. Anderson S. Climate change and poverty reduction. *CDKN IIED Policy Brief* 2011:3.

166. Ogallo L. The mainstreaming of climate change and variability information into planning and policy development for Africa. *Proc Environ Sci* 2010, 2010:405–410.

167. Boyd E, Grist N, Juhola S, Nelson V. Exploring development futures in a changing climate: frontiers for development policy and practice. *Dev Policy Rev* 2009, 27:659–674.

168. Tanner T. Climate risk screening of development portfolios and programmes. *IDS Bull* 2008, 39:87–95.

169. Silva JA. Relating local experiences to national shifts in rural income inequality in Mozambique. *Rev Reg Stud* 2013, 43:23–50.

170. Arndt C, Chinowsky P, Strzepek K, Thurlow J. Climate change, growth and infrastructure investment: the case of Mozambique. *Rev Dev Econ* 2012, 16:463–475.

171. Block P, Strzepek K. Power ahead: meeting Ethiopia's energy needs under a changing climate. *Rev Dev Econ* 2012, 16:476–488.

172. Spenceley A, Meyer D. Tourism and poverty reduction: theory and practice in less economically developed countries. *J Sustain Tour* 2012, 20:297–317.

173. Mitchell A, Ashley C. *Tourism and Poverty Reduction: Pathways to Prosperity*. London: Earthscan; 2010, 157.

174. Spenceley A. *Responsible Tourism: Critical Issues for Conservation and Development*. London: Earthscan; 2010, 386.

175. Hall C, Scott D, Gössling S. The primacy of climate change for sustainable international tourism. *Sustain Dev* 2013, 21:112–121.

176. Gössling S, Scott D, Hall C, Ceron J, Dubois G. Consumer behaviour and demand response of tourists to climate change. *Ann Tour Res* 2012, 39:36–58.

177. Scott D, Gössling S, Hall C. International tourism and climate change. *WIREs Clim Change* 2012, 3:213–232. doi: 10.1002/wcc.165.

178. Thomas A. An integrated view: multiple stressors and small tourism enterprises in the Bahamas. PhD Dissertation, Rutgers University, 2012, 223.

179. Hamzah J, Habibah A, Buang A, Jusoff K, Toriman M, Mohd Fuad M, Er A, Azima A. Flood disasters, impacts and the tourism providers' responses: the Kota Tinggi experience. *Adv Appl Sci* 2012, 6:26–32.

180. Peskett L, Grist N, Hedger M, Lennartz-Walker T, Scholtz I. Climate change challenges for EU Development Cooperation: Emerging issues. European Development Cooperation 2020 Project, Policy Brief No 3, EADI, Bonn, 2009, 22.

181. Klein R, Eriksen S, Næss L, Hammill A, Tanner T, Robledo C, O'Brien K. Portfolio screening to support the mainstreaming of adaptation to climate change into development assistance. *Clim Chang* 2007, 84:23–44.

182. Tanner T, Mitchell T. Entrenchment or enhancement: could climate change adaptation help reduce poverty? *IDS Bull* 2008, 39:6–15.

183. Ayers J, Dodman D. Climate change adaptation and development I: the state of the debate. *Prog Dev Stud* 2010, 10:161–168.

184. Simon D. Reconciling development with the challenges of climate change: Business as usual or a new paradigm. In: Kjosavik DJ, Vedeld P, eds. *The Political Economy of Environment and Development in a*

Globalized World. Trondheim: Tapir Academic Press; 2011, 196–217.

185. Saito N. Mainstreaming climate change adaptation in least developed countries in South and Southeast Asia. *Mitig Adapt Strateg Glob Change* 2013, 18:825–849.
186. Marino E, Ribot J. Adding insult to injury: climate change and the inequities of climate intervention. *Glob Environ Chang* 2012, 22:323–328.
187. Eriksen S, Brown K. Sustainable adaptation to climate change. *Clim Dev* 2011, 3:3–6.
188. Joseph N. *Matthews K and Myers H*. Conceptualizing health consequences of Hurricane Katrina from the perspective of socioeconomic status decline. *Health Psych* 2014, 33:139–146. doi: 10.1037/a003 1661.
189. Hurricane Sandy Rebuilding Task Force. *Hurricane Sandy Rebuilding Strategy*. Washington, DC: U.S. Department of Housing and Urban Development; 2013, 198.
190. Nussbaum MC. *Women and Human Development: The Capabilities Approach*. Cambridge: Cambridge University Press; 2000, 334.
191. Alkire S. Dimensions of human development. *World Dev* 2002, 30:181–202.
192. Robbins L. *An Essay on the Nature and Significance of Economic Science*. London: Macmillan; 1935, 158.
193. Martins NO. Commentary: the place of the capability approach within sustainability economics. *Ecol Econ* 2013, 95:226–230.
194. Söderbaum P. *Understanding Sustainability Economics: Towards Pluralism in Economics*. London: Earthscan; 2008, 160.
195. Baumgärtner S, Quaas M. What is sustainability economics? *Ecol Econ* 2010, 69:445–450.
196. Ballet J, Bazin D, Dubois J-L, Mahieu F-R. A note on sustainability economics and the capability approach. *Ecol Econ* 2011, 70:1831–1834.
197. Scerri A. Ends in view: the capabilities approach in ecological/sustainability economics. *Ecol Econ* 2012, 77:7–10.
198. O'Brien K, Leichenko R. Climate change, equity and human security. *Die Erde* 2006, 137:223–240.
199. Jerneck A. Searching for a mobilizing narrative on climate change. *J Environ Dev* 2014, 23:15–40. doi: 10.1177/1070496513507259.
200. New M, Liverman D, Schroder H, Anderson K. Four degrees and beyond: the potential for a global temperature increase of four degrees and its implications. *Phil Trans R Soc A* 2011, 369:6–19.
201. Stern N. The structure of economic modeling of the potential impacts of climate change: grafting gross underestimation of risk onto already narrow science models. *J Econ Lit* 2013, 51:838–859.

