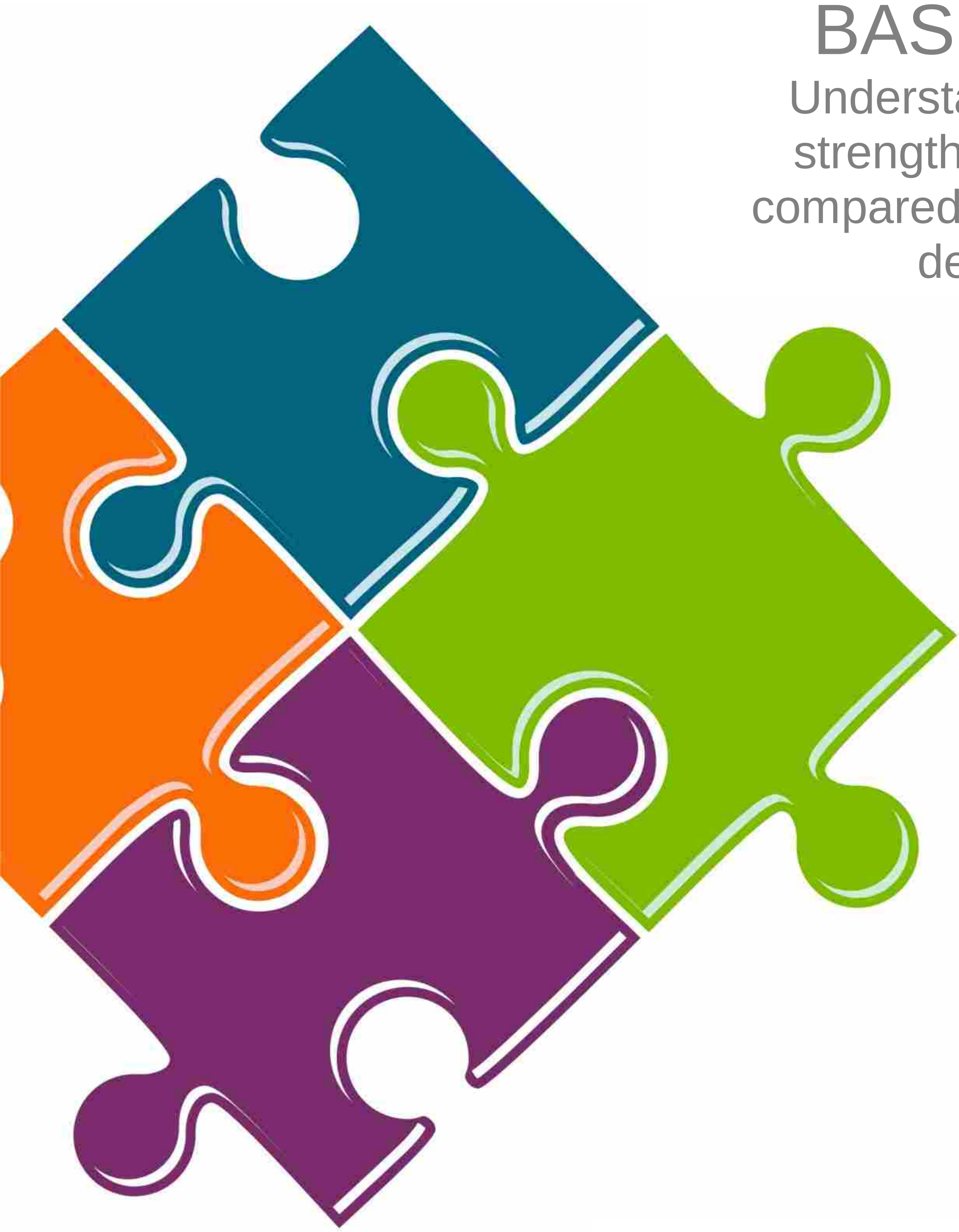
RAPID DESK-BASED STUDY:

Understanding the relative strength of climate signals compared to other expected development results



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Introduction

Evidence on Demand was requested by DFID to undertake a rapid desk-based study to provide evidence for understanding the relative strength of climate signals compared to other expected development results. The work is intended to help decision makers understand some of the trends that are arising and how this is impacting vulnerability to climate change in specific contexts.

The study has been structured in order to briefly review the relative strength of climate signals across four thematic areas:

- Health, with a focus on malaria;
- Agriculture, considering cash crops and food security;
- Urban and transport infrastructure aspects of economic development; and
- Disaster resilience, including an analysis of migration, as this was considered an indication where adaptation strategies were limited.

Other sectors, which might benefit from similar review, are noted at the end of this report.

The research focused on key geographical areas for DFID such as sub-Sahara Africa and South Asia. Latin America was not heavily explored although a few cases studies were found.

Section one of this report sets out and analyses the key findings of the strength of climate signals of development and the strength of the climate signals themselves. This summarises overall findings in as a ‘traffic light’ (Red, Amber, Green) rating and sets out some of the contested nature of findings, drawing on one example from Bangladesh, before considering the strength of the climate signals themselves. **Section two** summarises the evidence to understand the climate signals as drivers of development. Finally, **Section three** presents an annotated bibliography.

Methodology and Limitations

This study took the form of a review of selected literature dealing with linkages between climate signals and its strength on development. The authors primarily reviewed mainstream peer-reviewed academic research published from 2009 onwards, so that those that reference climate data, tend to use scenarios from the IPPC's Fourth Assessment Report (published in 2007). However, a number of studies have been included that are based on climate data from the earlier IPCC Third Assessment Report. As climate change emissions have continued to rise since this date, and climate modelling increased its level of confidence in the draft physical science section of the IPPC's Fifth Assessment Report (published in September 2013), the evidence referenced, and therefore conclusions drawn in this report, are likely to be conservative. Recent research by Anderson (2012) in Section 1.3 confirms the (very high) level of mitigation required for the current adaptation modelled to be realistic, and provides an overview of research that considers to what extent climate signals would be strengthened if current trends towards 4°C+ global warming continue.

An in-depth internet search was carried out of academic literature and a limited amount of other sources focusing on four thematic areas: health (malaria), agriculture (cash crops and food security), disaster resilience and aspects of economic development. However, it should be noted that, given the time available for this study (three days for research and two days for report writing) an exhaustive review of the literature in all of these areas was beyond the scope of this work. References were accessed via the British Library, university academic journal access and via Google Scholar. Those references cited have been included in the bibliography at the end of the report, indicating the climate data used, where appropriate. Where possible additional references and literature reviews were sought to test whether findings in one piece of research were justified.

The impacts of climate signals were categorised as dominant, mixed or marginal in each of these four areas. A mixed signal is considered one that will just slow the rate of development, so that the level of investment might change but the current approach will continue to lead to developmental progress in this area.

SECTION 1

Key Findings

1.1 Summary

This rapid review aims to explore the range of research that exists and attempts to quantify the strength of climate impacts (climate signals) relative to the strength of other developmental signals and interventions. This need is reflected in the Up in Smoke series (Working Group on Climate Change and Development led by IIED, 6 reports 2004-2009) which suggest that national vulnerabilities are mapped out in detail and the 'climate test' is applied. It recommended that, "there is an urgent need to develop detailed maps of the complex impacts of global warming, integrating climate change-related risks with other vulnerabilities.' (IIED et al, 2006). Early reviews such as this, while setting out *qualitative* climate signals and new development narratives, tended only to quantify the *strength* of impacts at a household and community scale. This report aims to review quantitative research and scenarios produced over the past five years in particular.

Our preliminary findings in each of the four research areas are summarised in the following 'Traffic Light' summary table. This presents the strength of the Climate Signal as an overall RAG (Red, Amber, Green) rating, where Red is where the climate signal dominates, Amber is where there is a mixed signal and Green where the climate signals are overshadowed.

Sector Area	Climate Signal Strength	Overview of Findings
Health	🟡	**Mixed signal overall** for the health sector.
	🔴	**Increasingly dominates in some locations** such as Kenya and African highlands.
Agriculture (and impacts upon wider rural development)	🔴	**Dominates overall** under current business-as-usual climate predictions.
	🟡	**Mixed signal in many locations** in Africa and Asia in terms of local food security and agricultural productivity.
	🔴	**Dominates for some cash crops**, in some locations, and in relation to the overall food security challenge.
Disaster Resilience (including migration)	🔴	**Dominates in vulnerable locations** now. Failure to address climate change in the short-term will result in scaling up of climate impacts from infrequent sub-national mixed signals to increasing scale and severity of climate signals.
	🟡	**Mixed signal in other locations** as the impacts of climate change will still be experienced indirectly.
Economic Development (overall economic growth, urban development,	🔴	**Dominates** economic growth, although this is under-reported in economic climate models and has delayed impact due to the time lag between economic growth impacting upon green house emissions and experiencing climate impacts, both directly and indirectly. Failure to incorporate climate mitigation in the short term (despite clear climate signals due to local

Sector Area	Climate Signal Strength	Overview of Findings
transport infrastructure, poverty)		impacts masked by global economy and time lags) will lead to climate signals increasingly dominating national and global economy to the point at which these are unable to be sustained.
		Increasingly dominates in terms of how climate change impacts the overall pathway of economic development.
		Mixed signal for current urbanisation and transport infrastructure developments, impacting the nature, location, spatial planning and institutional aspects).
Impact of Time Lags		There is a **delay** between observed climate signals due to the time lag between greenhouse gas emissions and impacts, notably surface temperature increases. This means that long-term impacts should not be discounted.
Impact on other sectors		Impact on other sectors, such as natural resources and energy, have not been investigated here.

Table 1 Summary of the Strength of Climate Signals

Our preliminary **findings** in each research areas are summarised in more detail in the following table.

Sector area	Climate Signal: overshadowed, mixed, dominates	Comments
Health (human impact)	Increasingly **Dominates** in sub-Saharan Africa, such as Kenya and African highlands but evidence suggests currently still **Mixed signals** overall for the health sector.	**Research:** extensive research exists on the transmission of malaria as a result of climate change. Most of the papers analysed the model of malaria transmission and the overall economic impacts of this disease. There is a lot of evidence indicating that health is a key goal to sustainable development. High levels of economic development generally lead to better access to health services and health development outcomes, and in the same way improvement of health contributes to better economic development. **Conclusion:** According to the articles reviewed, the climate impact on the health sector is mixed. For example, the World Health Organisation (2010) stated that “Climate is not the only factor affecting the geographic range and incidence of climate-sensitive health outcomes. Non-climatic factors can have a strong or even dominant effect, either independently or by modifying climate effects”. Although climate change has increased the risk of malaria and other weather sensitive diseases in most of the endemic countries such as the African highlands and Kenya, there is not enough evidence that quantifies the likely impact of climate signals. However, evidence does suggest that malaria cases have already risen as a result of climate change alongside increased international and domestic finance to malaria-endemic countries to tackle malaria. This suggests that climate signals increasingly dominate development outcomes.
Agriculture (and rural	**Dominates:** (some cash crops,	**Research:** Extensive research, focused on agricultural productivity although often at low level of granularity making

Sector area	Climate Signal: overshadowed, mixed, dominates	Comments
development in general)	locations, overall food security challenge) **Mixed Signal** (local food security and agricultural production in many locations of Africa and Asia) **Dominates:** overall under current BAU climate predictions.	exact impacts less clear. Not all models included impact of variability of the climate (as opposed to changes in temperature and precipitation), so some policy prescriptions may not be robust. **Conclusion:** Will dominate agricultural policy in some countries and regions in the short/medium term, such as parts of sub-Saharan Africa and South Asia, both with regards to cash crops and food security. Research by Kotir (2011) on the impact of climate change on food security is one example of a general consensus that the Sub Saharan Africa region is likely to be the most vulnerable region to Climate Change, which is correlated to the region's high dependence on agriculture and natural resources, warmer baseline, lower precipitation and predicted lower ability to adapt. However, the focus on mainstream economic development which is proposed in many places to address this, such as green growth and securing access to resources has not generally been considered against climate impacts per se, and sector-specific adaptation has not generally been quantified against the climate signals.
Disaster Resilience (including migration)	**Dominates:** in vulnerable locations. **Mixed Signal** in other locations, climate change will still be experienced indirectly.	**Research:** There is a lot of existing research on resilience, but to date it has focused primarily on the developed world, except for a significant body of literature focused on Bangladesh. For example, there is lot of work on adaptation in cities but they tend to be focused on places like Holland, London and the US (e.g. following the impact of Katrina, considering risks in other areas such as Florida) but the same level of granularity of studies have not been complete in areas that might have higher climate vulnerability but less research budget. Much of the focus of existing research was on capacity building and community resilience, as opposed to quantifying the scale of the climate impacts. Some research highlights the need to move from measuring direct impacts (e.g. flooding) and direct responses, to develop overall resilience solutions based on complex systems. However, the overall challenge of resilience will continue to respond to not just climate change but many other natural and man-made hazards. **Additional Research Focus – Migration:** Migration from rural to urban areas and between countries may be a form of adaptation itself but also an indicator of where climate signals are already dominating, by making livelihood more unsustainable. This section focused on climate displacement in Bangladesh. **Conclusions:** Impacts are already great in some locations, including Bangladesh. Unless the dominant trends in economic development change, the climate signals will dominate worldwide in the medium to longer term. However, in Bangladesh it is possible that insufficient resilience to climate impacts in some areas is already increasing internal displacement, which is helping to facilitate the rapid growth in the garment-trade. This pathway for economic development is unlikely to be sustainable, and will have wider development impacts if it continues in the medium to longer term.
Economic	**Understated and**	**Research:** There has been a lack of overall research relating

Sector area	Climate Signal: overshadowed, mixed, dominates	Comments
Development (urban development and transport infrastructure)	Increasingly **Dominates:** in terms of challenge to overall pathway of economic development. **Mixed Signal** in terms of challenge to current urbanisation and transport infrastructure (nature, location, spatial planning, institutions)	economic development directly to climate change and tendency for economic models to understate the strength of climate signals. This leads to the both the costs of climate damage as well as climate mitigation to both be overstated, although the former still substantially outweigh the latter, as concluded in the Stern Review on the Economics of Climate Change. Therefore, a link has been identified between economic development and increase in physical assets (principally cities and transport infrastructure) and the level of vulnerability of these physical assets to climate impacts has then been reviewed. In quantifying these impacts there may still be a lack of consideration of joint probabilities, such as sea-level rise from climate change combined with storm surge events. **Conclusions:** Current mainstream development strategies; whether focused on economic growth, poverty alleviation or green growth; do not consider the climate signals noted above. This will mean that, at least in the long term, climate signals will dominate as climate adaptation and mitigation then have to respond to a much warmer climate and higher impacts than most of those modelled to date. This is in part because economic measures of development such as GDP do not internalise environmental goals, and in some ways are a measure of the scale of physical development (assets) and level of consumption (throughput) of an economy. The main links between economic development and climate change are considered both in overall terms (whether or not a zero carbon and climate resilient development path is chosen) and physical terms (the location of built environment and physical infrastructure and its vulnerability to climate change and whether that vulnerability is increasing or not). This will have impacts on health and resilience. The overall climate impact is rising as global warming strengthens climate signals, particularly in terms of disaster risk for coastal cities and in cyclone areas. This means that development 'business-as-usual' is likely to exacerbate climate change (through increased greenhouse gas emissions) and through the likelihood that new physical growth is concentrated in climate vulnerable locations. This requires a new pathway for economic development and importance of spatial planning, particularly for long-term decisions.
Other Aspects: Energy, Natural Resources,	Not investigated	Indicative research suggests that climate signals are likely to dominate the **energy** sector (due to its close coupling to climate impact), that **natural resources** impact may be similar to agricultural impact (noted above) and increasingly dominate strategies in the area of internally displaced persons and refugees. That **water** supply should be considered, as well as impact upon the **environment** and **natural resources.**

Table 2 Summary of Key Findings

An example of how contested some of these findings are within the published material referenced in this report is provided in section 1.2 below. Full summaries of the research conducted in each of the four research areas is then provided in section 2 below.

1.2 Climate Signals and Development in Bangladesh – An Example of Contested Findings

Figure 1 Example of impact of Climate Change. Source: Author (2004)

One aspect the authors have focused on is to determine whether there is any research to determine whether there is the ability to generate sufficient capacity fast enough, both institutional and otherwise - to cope with the rate of increase of climate related shocks anticipated – or whether the volume, intensity and complexity of climate impacts is likely to outpace household, community and national capacities to respond.

Using Bangladesh as a study, two examples perhaps encapsulate the response. Firstly, while the World Bank (2011) estimates that over 50% of the total adaptation costs against cyclonic storms in Bangladesh until 2050 ($1.2b) will be to construct cyclone shelters, Displacement Solutions (2012) note that of the 60,000 persons displaced by Cyclone Alia in 2009, 25,000 of these displaced persons, unable to return to their houses and lands and with little access to new land, were forced to live on a 25km long, 2m high and 3-4m wide embankment. For these people, a cyclone shelter is not sufficient: they need somewhere to safely build a house and to secure a livelihood.

The second example focuses on the question: is the success of Bangladesh's burgeoning garment trade a driver or the product of rural-urban migration to Dhaka, and if so, to what extent is this climate induced? Mahmud, Sadiq Ahmed, and Sandeep Mahajan (2010) suggest that "Bangladesh's Development Surprise" is led by the success of a ready-made garments industry, which has expanded at 15% a year since 1990[1], driven by rural-urban migration as a means of delivering upward mobility for the migrants (citing Khundker et al., 1994).

In contrast, Shadsuddoha et al (2012) challenges this conclusion, suggesting Bangladesh's two highest export earners; foreign remittances and ready-made garments; both rely significantly on migrant workers from areas badly affected by or prone to disasters. Around 70% of the four million garment workers are described as migrant women. However, there

1 Brady and Spence, 2010: Page 233, Table 8.2.

has been little discussion of migration as a tool for development policy as a strategy for economic growth (Mukand, 2012), let alone climate adaptation (as discussed in the section on resilience below).

It is clear that this migration drives urbanisation, for which Bangladesh's economy is noted as a beneficiary. However, does this shift from precarious rural subsidence to an urban slum household (perhaps among those who described their coping strategies against increased 'climate variability' to UCL researchers (Jabeen et al, 2010) in Dhaka, ranked perhaps the most vulnerable city to the onset of climate change[2]) constitute an improvement in terms of resilience?

There is some irony that while delivering strong-term export growth through an expansion of Dhaka's low-wage urban economy, that this may be fuelled by a surplus of climate migrants due to climate signals, which are a consequence of similar urban industrialisation in developed countries. While this could be viewed as economically beneficial at a national level in the short-term, it is not a sustainable development strategy for the long-term. This risk of attempting to separate out short-term impact from long-term outcome risks is described by Smith (2011, as cited by New, 2011):

"Responses that might be most appropriate for a 2℃ world may be maladaptive in a +4℃ world; this is, particularly, an issue for decisions with a long lifetime, [for example] coastal protection designed for 2℃ may be overcome [instead requiring] a complete transformation in many aspects of society, rather than adaptation of existing activities, for example, sea-level rise may require the relocation of cities. [Therefore] a range of psychological, social and institutional barriers to adaptation is exacerbated by uncertainty and long time frames, with the danger of immobilizing decision-makers, and suggest ways in which some of these barriers might be overcome."

Figure 2 Contrasting Climate Impact and Climate Response Source: IMC

"A damaged home at low-tide in Galia Khali; at high-tide water completely surrounds the home. Along with hundreds of thousands of others, the owners of this home lost all of their land and have no means of livelihood." (Displacement Solutions, 2012)

Completed School-cum-Cyclone Shelter, Bangladesh Source: IMC

1.3 Strength of Climate Signals and their Time Lag

This study has involved a review of selected literature dealing with linkages between climate signals and its strength on development. The authors primarily reviewed mainstream peer-

2 Dhaka, ranked as the most vulnerable city to the onset of climate change according to Maplecroft's 5th annual Climate Change & Environmental Risk Atlas: maplecroft.com/about/news/ccvi_2013.html

reviewed academic research published from 2009 onwards, so that most of those that reference climate data, use scenarios from the IPPC's Fourth Assessment Report (published in 2007). However, a number of studies have been included that are based on the earlier IPCC Third Assessment Report. As climate change emissions have continued to rise since this date, and climate modelling increased its level of confidence in the draft physical science section of the IPPC's Fifth Assessment Report (published in September 2013), it is likely that the evidence referenced, and therefore conclusions drawn, are likely to be conservative. Recent research by Anderson (2012) in the next section confirms the (very high) level of mitigation required for the current adaptation modelled to be realistic. The extent of this could be significant. Below the authors summarise why climate signals lag greenhouse gas emissions and consider to what extent climate signals would be strengthened by current trends towards 4°C+ global warming.

The impact of the time lag between greenhouse gas emissions and climate signals

Stern (2007) concluded that "recent estimates suggest that, even if emissions peak in the next decade or two and then fall sharply, the impact on global temperatures will still be very large" This is noted by Stern as being due to "many greenhouse gases, including carbon dioxide, stay in the atmosphere for more than a century and the effects of climate change come through with a lag, temperature and sea level will continue to rise during the twenty-second century, even if we stabilise emissions soon."

This is reflected in the latest IPCC scientific assessment. The IPCC AR5 scientific assessment noted that the initial climate signal is smaller than the long-term (equilibrium) climate response due to how ocean heat uptake delays surface warming (IPCC 2013a, p1220) with 'a large fraction of the total of the surface temperature response realised within years to a few decades' (IPPR 2013a, p1659). This means that from an emissions perspective, to limit climate change requires us to "limit warming caused by CO2 emissions to a given temperature target, cumulative CO2 emissions from all anthropogenic sources therefore need to be limited to a certain budget." (IPPR, 2013a, p1686).

Therefore, if the principal driver of long term warming is the total cumulative emission of CO2 over time, the climate signals cannot be viewed as either immediate, or in terms of a simple time lag.

However, it is not simply a question of considering future impacts and limiting our overall greenhouse gas emission 'expenditure' below a notional climate 'budget'. This is because of the positive feedback effects within the climate system and the increased energy and unpredictability in a warming climate that leads to greater damage and climate shocks for increased amounts of global warming. Indeed, the IPCC propose "a number of components or phenomena within the Earth system have been proposed as potentially possessing critical thresholds (sometimes referred to as tipping points, beyond which abrupt or non-linear transitions to a different state [i.e. much higher temperatures, and therefore with far greater climate signals, than any of the modelling considered in this report) ensues" (IPCC, 2013a, p1688). Therefore, the aim should not be to stay within budget but limit our exposure to climate risk by reducing cumulative emissions to as far as possible below this emissions budget.

Because it is *cumulative*[3] as opposed to per annum carbon emissions that are important, it is not just the scale of carbon emissions at some future date, but the emission reduction

3 This is also reflected in earlier research. For example, Stern (2006, p6) refers to the existing 'stock' of green house gases in the atmosphere, as opposed to the existing rate of emissions. Similarly (Stern, 2007, p197) sets out how the challenge of climate mitigation is not simply to reduce the rate of carbon emissions (which is still accelerating globally) but to reduce the

pathways that achieve this which are important. In other words it is more unsustainable to increase carbon emissions now and then reduce later than to plan a sustainable-growth pathway for developing and developed countries alike. A global approach that has reduced total emissions, particularly in the short term will reduce the risk of catastrophic climate-induced events in the medium-to-longer term. Stern (2006, p3-4) expresses the challenge to least developed countries as follows: “emissions from developing countries are likely to rise rapidly ... and the involvement of developing countries is necessary if emissions are to be substantially reduced.”

Scale of Climate Mitigation needed for current adaptation predictions to be correct.

This summarises the recent report by Kevin Anderson (2012), Deputy Director of the Tyndall Centre for Climate Change Research. This research developed scenarios which showed the rate of decline in greenhouse gas emissions required globally for a global peak in greenhouse gas emissions in 2015, 2020 and 2025 if we are to retain a 50:50 chance of not exceeding the 2°C threshold – that is, to avoid what arguably constitutes *extremely dangerous* climate change.

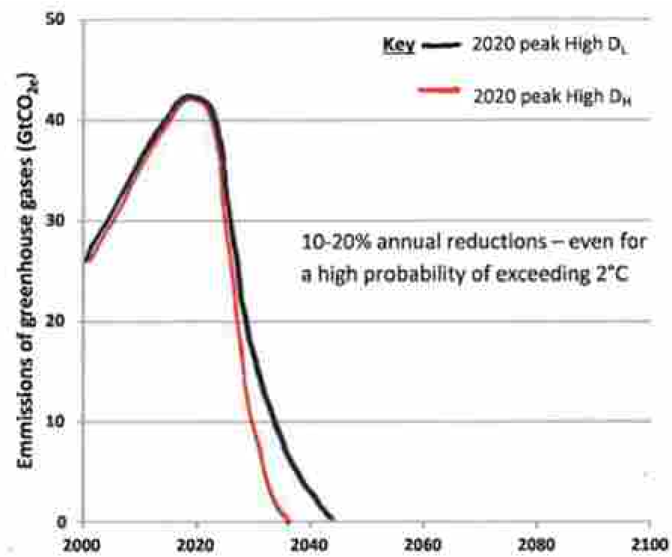
The scientific uncertainty about the exact correlation between emissions levels and resulting temperature increase is represented by the different coloured curves. Curves of the same colour correspond to the same cumulative emissions budget (Anderson & Bows, 2008).

Anderson notes that it is important to note that the emissions in all of the scenarios above continue to increase before they reach a global peak between 2015 and 2025, and if this is not met (which suggests a radical change to our approach to economic development, urbanisation and transport infrastructure development as set out below) all of the estimates in this report are likely to be underestimates and maybe completely unrepresentative of the impact of climate signals in the medium to long-term.

Adapting these scenarios to assume continued emission, from deforestation and food production, results in the trend illustrated in Figure 3 below. This scenario suggests that global energy-related CO_2 emissions have to decrease by 10-20% per year, hitting zero between 2035 and 2045. All activities would need to be zero carbon.

volume of greenhouse gases in the atmosphere, bearing in mind that some of these gases such as CO2 persist for a long-time.

Figure 3 Global Energy Related Carbon Emissions Targets.



When taking unavoidable emissions from food production and deforestation emissions into consideration, global energy-related CO_2 emissions have to decrease by 10-20% per year from a peak in 2020, hitting zero between 2035 and 2045. (Adapted from presentation to DFID by Anderson, 2012)

The climate adaptation scenarios set out here assume all of this takes place[4].

This differs from most current climate analyses, in that it assumes that emissions will grow by only 1-2% per year before peaking. In reality, emissions are growing nearer to 3-5%[5] per year and are set to continue, with nothing in train to curtail this level of growth. Also, there is a challenge that western climate models, such as the UK's Committee on Climate Change are based on emissions peaking in China and India in 2017, whereas climate experts in these countries do not expect peak emissions before 2030, at a much higher level.

In summary, following previous analysis (Anderson and Bows, 2008), science tells us that for an outside chance of 2°C warming, Annex 1 countries need to reach emission reductions of the order of about 40 per cent by 2015, 70% by 2020, and over 90% by 2030, with similar reductions globally with a lag of a decade or two – a short time frame. Anderson notes that these numbers are strikingly different from the sort of numbers we traditionally see. The typical response is: 'That is impossible[6]'. In response, we need to ask: Is living with a 4°C global temperature rise [whether as a whole, or in sub-Saharan Africa or Bangladesh in particular] by 2050 or 2070 less impossible?

How much would 4ºC Warming Increase Climate Signals?

The above analysis aims to summarise research based on the latest IPPC projections, which are based upon limiting climate change to 2-4ºC warming. Most scenarios chosen for

4 Similarly, Up in Smoke (2005 et al) present three overarching challenges if development is to address the climate signals: firstly, to both stop and reverse global warming, while secondly enabling living within the degree of global warming that cannot be stopped, by thirdly, designing a new model of human progress and development that is climate proof and climate friendly...'. While this report focused on the second of these challenges if it does not address the first, then it will only be able to ameliorate short to medium term impacts.

5 Anderson and Bows (2012) note that globally, emissions rose an average of 5.9% per annum from 2009-2010, and 3.5% per annum in the recession year of 2010-2011, the last 2 years for which data is available.

6 Note this is the response chosen by Dobbs et al (2010) in the economic development section below, choosing to ignore climate impacts and focus on resource productivity challenges instead.

analysis assume that climate change is limited to 2ºC warming, which is the current political commitment, under the Copenhagen Accord and Cancun Agreements.

Also, "there is often a disconnect between the scale of the risks and what many of the scientific models (climate and particularly impact models) are telling us about the impacts of a shift to a 4ºC or warmer world, in part because impact models tend to extend broad statements to more regional or local effects such as desertification, rainfall patterns, potential agricultural outputs etc" (Stern, 2013). This means that not only the specific climate signals set out in this report, together within the IPCC's latest reports (2013b, 2014[7]) are likely to be of a conservative nature, but also the overall relationship of climate signals to economic costs as set out below. A summary of how climate modelling relates to economic development is developed further in section 1.4 which follows, while the rest of this section gives the best available snap-shot of what these future impacts might entail.

This section summarises the work of Anderson and Bows, (2011) which reviews a small selection of the (much smaller) studies that consider this future climate scenario against developmental impacts. Rogelj et al. (2009, cited in New, 2011) argued that achieving a 50% chance of constraining warming to 2ºC requires developed countries to cut emissions by up to 80% below 1990 levels by 2050, but even the best case commitments prior to Copenhagen only resulted in a 4 per cent cut by 2020 and a 63 per cent cut by 2050. They concluded that there was 'virtually no chance of limiting warming to 2ºC above preindustrial temperatures'.

Anderson (2012) notes that a 4°C future globally will lead to much higher warming in many developing countries as this equates to around 5-6°C warming of global mean *land* surface temperature, and even greater increases inland. For example, this will result in an average 6-8°C increase on the hottest days experienced in recent heat waves in China and at low latitudes and reductions of around 30-40% in the yields of important staple crops such as maize and rice.

Failure to reduce climate impacts in developed countries to date, as well as continued carbon emissions growth in most other countries too, mean that many of the predictions in this report understate the likely climate impact. As expected, the climate signals experienced across many sectors—coastal cities, agriculture, water stress, ecosystems, migration—the impacts and adaptation challenges at 4ºC will be larger than at 2ºC. In some cases, such as farming in sub-Saharan Africa, a 4ºC+ warming could result in the collapse of systems or require transformational adaptation out of systems, as we understand them today. Thornton et al (2011, cited in New, 2013) model decreased yields across Africa including an increase in rain-fed crop failures in much of southern Africa to a likely occurrence of every two years.

Betts et al. (2011, cited in New, 2011) predicts that 2ºC of warming will occur between 2045 and 2060 (for all climate models) and, considering a high-end business as usual scenario, 4ºC of warming by 2100, which Nicholls et al (2011, cited in New, 2011) estimate will result in between 0.5m and 2m of sea-level rise by that date[8]. For example, Sriver et al (2012) suggest the IPPC fourth assessment report likely upper bound sea-level rise for 2100 is increased from 0.6m to approximately 2m. Betts considers two scenarios of no protection (abandonment) and aggressive protection. This shows that protection cost is very sensitive

[7] These reports have not been used as references here, as they were published after the main body of this report was drafted, in January 2014.

[8] This would lead to further, much larger, sea level increases post-2100, should irreversible melting of the Greenland ice sheet be triggered and break-up of part of the West Antarctic ice sheet occur.

to sea-level rise, with the predicted annual global cost increasing at least tenfold from $25billion to $270 billion for 2m and 0.5m sea-level rise respectively[9].

Warren (2011, cited in New, 2011) notes the interplay between mitigation, adaption, and other sectors, also need to be considered. For example, shifts to bio-fuel production as an alternative fuel and programmes to prevent forest conversion to agriculture may place an additional stress on food and water security.

Smith (2011) anticipates a trend in adaption options, from minor adjustments to 'business as usual' (such as the impact of the 'resource revolution' or 'green growth' on current prescriptions for economic development) towards more transformative options. While this applies for current adaptive processes Smith notes that this can be seen much more starkly while considering a +4ºC world. For example, coastal protection designed for 2ºC may be overcome at 4ºC. Finally, as is the subject of this report, where climate signals dominate (in the long-term, even if not evident in the short-to-medium term) a complete transformation of society, rather than adaptation of existing activities, may be required. The choice to migrate rather than adapt to a more precarious livelihood on a polder in south-west Bangladesh highlights how this might look today at the household scale. Whereas in the future high crop failure frequency in sub-Saharan Africa may require new approach to farming, or sea-level-rise require the relocation of large port cities.

One of the greatest challenges for economic development in a climate constrained world will be how to deliver such simultaneous climate adaptation and mitigation, with peak carbon emissions occurring far sooner than either peak world population (expected to peak at about nine billion in the 2050s), urbanisation (mostly in developing countries) increasing from 3.5 billion in 2010 to an estimated 6.3 billion by 2050, and demand for food and water rising in parallel. New et al (2011) conclude noting that a faster rise in temperature might be reached by the 2050s or 2060s, precisely at the time when vulnerability as a result of population demands for food and water is highest – while a slower rise in temperature, would mean that associated climate signals occur after demand for food and water begins to decline in line with a shrinking population.

1.4 The Strength of Climate Signals in Economic Models

Introduction

This section reviews how the modelling of the future strength of climate signals is modelled, in terms of the economic cost of climate signals associated with different amounts of global warming. The time lag associated with this is considered separately, in section 1.3 above. The cost of mitigating these climate signals associated with alternative (green) growth strategies, is calculated to be less than this impact (Stern, 2007 and extensive subsequent analysis) but is not addressed further in this report.

Stern (2007) highlights both the scale of economic investment in both mitigation *and* adaptation required to address the long-term consequences in the case of climate change. The main conclusion of this report is that the cost of stabilising greenhouse gases are considerably less than the costs of delayed action: based on sound economic principles,

[9] As infrastructure such as this is likely to have a long design life, it would be appropriate to plan for one or the other of these future scenarios. Smith (2011) stresses the need for sufficient targets for adaptive planning with long lifetimes, of which sea level protection is a strong candidate due to the high risk of abandonment, migration and higher long-term overall costs with inadequate (mitigation and) adaptation.

reflects detailed disaggregation of business-as-usual risks and likely to cost around 1%-2% of world GDP[10].

Economic Models underestimate climate signal strength, risk and associated costs.

Stern (2013) contends that it is not just the assessment of climate impacts that tends to be conservative (as set out above), but the way in which economic models further limit risks by "assuming exogenous drivers of growth, only modest damages from climate change and narrow distributions of risk" and therefore for an accurate view of economic impact new models are required[11], particularly in the area of economics.

The first major study of the impact of climate change upon economic growth was the Stern Review (Stern, 2007) which comprehensively considered the cost to both mitigate and adapt to climate change, and therefore its interrelationship with economic growth. Since this time, research has tended to strengthen this relationship, but as Stern sets out above, still underestimate the economic costs and therefore the strength of the climate signal on economic growth.

A more recent review of the way that the economic impacts of climate change are modelled (Dietz and Stern, 2014), concludes that the most commonly used modelling for the economic impact of climate change (as developed by Nordhaus in 1991 and adapted since) underestimates the economic impacts. Dietz and Stern set out how this relationship is more complex than earlier models which tend to have unrealistic assumptions and should instead consider the probability to which climate change is likely to directly impacting the drivers of economic growth. For example, Dietz and Stern highlighted that the main alternative climate-change economic model (Nordhaus's models of climate cost-benefit [DICE] predicts that a 18ºC of warming is required to reduce global output by 50%), which is a large underestimation of explicit and large risks associated with climate change previously considered.

This new analysis includes a reduction of the capital assets and productivity as a result of climate impacts (reflecting likely climate signals, as set out earlier in this report). Even so, it does not completely model the DRR and subsequent 'rebuild' costs associated with climate signals. This report concludes that to limit the climate response and damages as a result of global warming to avoid passing critical climate thresholds, the carbon price used today should be increased from $44/tonneCO2 to up to 271$/tonneCO2 to limit mean global temperature increase over pre-industrial levels to less than 2ºC. However, the computed economic impact is average (i.e. taking no account of changing income distribution) and still 'omitted important risks in relation to the distribution of damages', which could have significant developmental and poverty impacts.

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10 See Dietz (2007) and ODI (2014). However, these costs of inaction, together with the estimate of climate mitigation and adaptation costs, are likely to be underestimated, as set out below.

11 Stern proposes these in three areas: "scientists "better describing the risks in a 4ºC+ warmer world"; "better impact modelling ... of how this affects livelihoods"; and economic models that "consider lasting damage" and "embrace the real possibility of creating an environment so hostile that physical, social and organisational capital are destroyed, production processes are radically disrupted, future generations will be much poorer and hundreds of millions will have to move."

SECTION 2

Summary

This section summarises the key findings of the literature review.

2.1 The Impact of Climate Signals on Health

Introduction

Health is recognised as a key goal of sustainable development. Health contributes to social, economic and environmental development through different pathways. However, overall efforts to achieve sustainable development and improved health have not been sufficient. Significant changes are necessary if MDG targets to reduce poverty, avoid environmental degradation, and achieve provision of effective health services are to be met together. This is a virtuous circle; resultant improvements in health can enhance sustainable development, and sustainable development can improve health outcomes. For example, good health improves development via pathways such as survival of trained labour, higher productivity among healthier workers, higher rates of savings and investment, greater enterprise and agrarian productivity and increased direct foreign investment and tourism. Thus, negative macro-economic impacts on sustainable development and on health will need to be addressed in unison (WHO, 2002).

Climate change should not only be considered as an environmental or a development issue; it also affects the health and wellbeing of a whole population. If we better understand the implications of climate change on health and related development choices, we could therefore improve policies and more active public engagement. Health and human wellbeing should be the centre of environment and development decisions and the ultimate goal of climate change mitigation and adaptation (World Health Organisation, 2008).

Currently, the reserve is often true. Poverty impacts health and ultimately poor health has negative impacts on development. For example, it has been estimated that malaria has slowed economic growth in Africa by up to 1.3% each year. When the lack of effective care is added, the result is estimated as hundreds of billions of dollars (WHO, 2002). More recently, WHO (2010) stress the importance of understanding the strengths and weaknesses of current programmes under current conditions of climate variability and recent climate change in order to increase the capacity to address the additional health risks due to climate change in the future. This must address vulnerabilities both within and outside the formal health sector, such as improved resilience of health care facilities and services, reducing socio-economic disparities, targeting these towards vulnerable populations.

Increases in extreme weather events in different regions are a result of global climate change. This causes floods, surface-water pooling, anomalous rise in temperatures and displacing animal host species. Within this overall context, climate change is likely to increase the global burden of disease (McMichael, 2004 cited in Hunt and Watkiss, 2011).

Therefore, WHO (2008) stress the importance in strengthening public health systems in general, which will reduce exposure to climate health risks. This need is identified as being greatest in Africa and South America. These have been identified as geographies with particularly high numbers of climate sensitive disease vectors, requiring particularly intensive effort and resources to obtain the expected change in reduction of vector-borne disease cases (Githeko A.K, 2000).

The WHO (2010) suggested that the climate change impact on the health sector is significant, however the signal is mixed:

> *"Climate is not the only factor affecting the geographic range and incidence of climate-sensitive health outcomes. Non-climatic factors can have a strong or even dominant effect, either independently or by modifying climate effects".*

The WHO (2010) notes that there may be a limited developmental response to climate signals in some areas as the marginal cost of avoiding some impacts are higher than households or governments are willing to pay. Opportunities include data collected from surveillance programmes can be the basis of climate early warning systems for some climate sensitive health outcomes (WHO, 2005). If appropriately designed, such early warning systems could reduce the magnitude or extent of a disease outbreak and help prevent other adverse health outcomes (WHO, 2010).

Relationship between Climate Change Signals and Malaria

This rapid desk based research focused upon the impact of climate change on malaria, as it is one of the diseases with greatest impact on development. This vector-borne disease is already responsible for the death of about 1 million people each year, mainly poor children in Africa. In addition, there is lot of evidence that the increased transmission of this vector borne disease is due to climate change. However, there is no evidence that there has been any increase in investment on health or sufficient improvement in health services in the key areas where malaria is prevalent.

Malaria is one of the most devastating vector-borne diseases and has burdened many deaths all over the world, especially in tropical and subtropical regions. Climate change is impacting the transmission of malaria and affecting all phases of the development of the disease (Goklany, 2012).

Figures 4 and 5 below (WHO, 2010) contrast the countries currently where malaria does occur, with the much wider areas where it could potentially occur. This indicates that there is a real risk of the expansion of malaria, if development and control is outstripped by other impacts, such as those due to climate change.

Figure 4 Countries at Risk of MalariaTransmission. Source: World Health Organization (2010)[12]

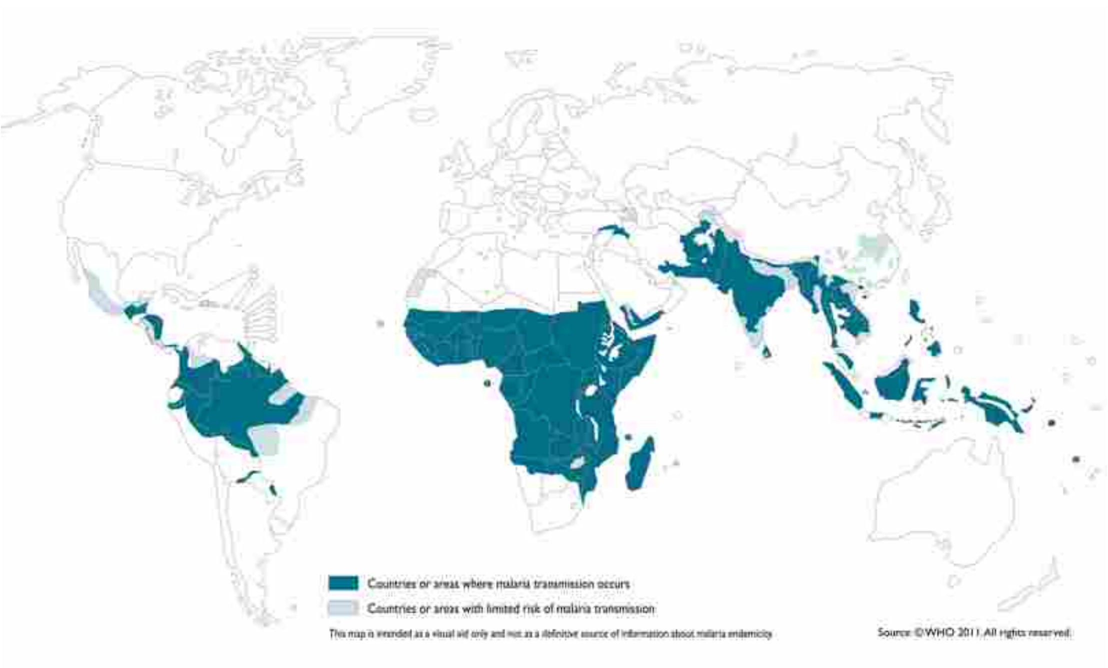
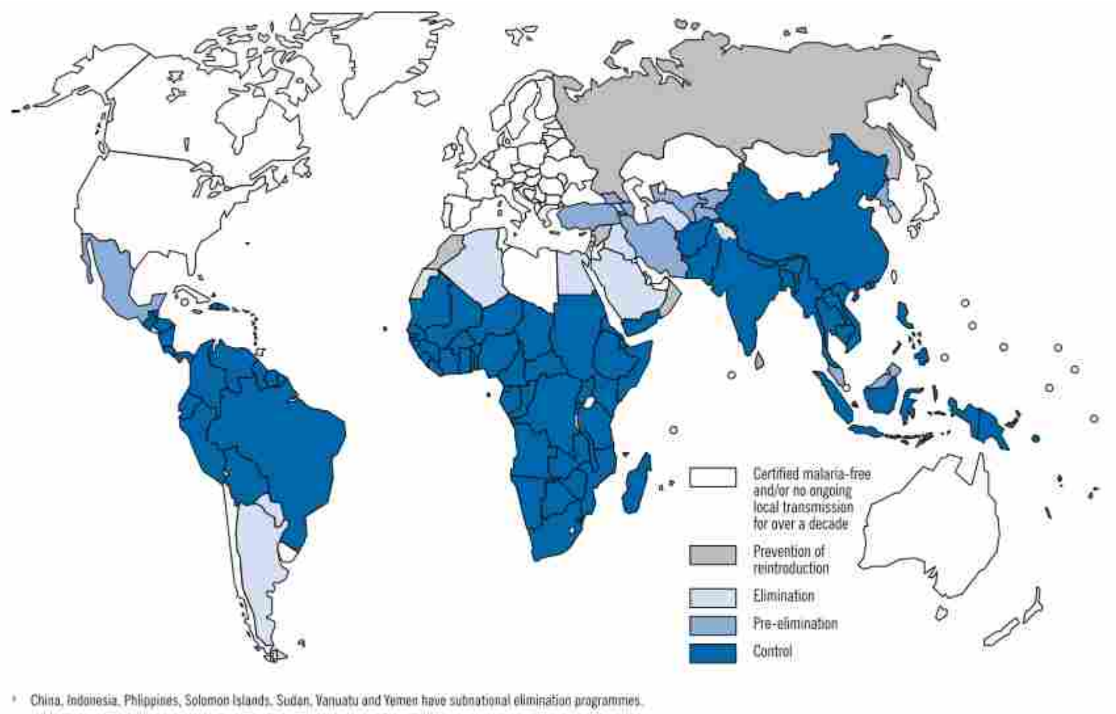


Figure 5 Countries Categorised by Stage of Control/Elimination of Malaria. Source: WHP (2008)



The distribution of malaria is strongly affected by climate. Vector-borne diseases such as malaria are directly influenced by seasonal weather variation, socio-economic status, vector

12 Available at http://gamapserver.who.int/mapLibrary/Files/Maps/Global_Malaria_ITHRiskMap.JPG

control programmes, environmental changes and drug resistance, climate change and variability (Githeko A.K, 2000). Warmer temperatures, high humidity and places where water can be collected favours malaria transmission. There is evidence that in the highlands of East Africa, warmer conditions have increased the probability of malaria transmission (Afrane, Y.A, 2012). This research details how warmer weather has facilitated larval development, enhanced vector survival rates and reproductive fitness and increased the blood feeding frequency and parasite development rate across the previously cooler highlands. Deforestation in the Western Kenyan highlands has also enhanced the development and survival of mosquito larvae in this area.

Malaria is the disease that has the greatest impacts on growth and development. This vector borne disease has cost Africa more than US$12 billion per year and it may have slowed down economic growth by maximum 1.3% per year. This is due to costs of health care, working days lost due to sickness, days lost in education, decreased productivity, and loss of investment and tourism. This recognition of malaria as major development issue in most endemic countries makes the illness a focus of one of the United Nations' Millennium Development Goals (Asenso-Okyere, 2011).

Economic impact of the burden of malaria has been estimated by measuring the impacts on households, health systems and national economies. Direct cost comprises time lost from work and medical treatment costs including transportation and medical care. Indirect costs are related to loss of work efficiency and time and work reallocation within the household and in the case of children nutritional deficiencies, cognitive and educational disabilities, and physical retardation in the case of children (Asenso-Okyere, 2011).

Anomalies in climate variability in Kenya account for up to 26% of the anomalies in hospital-based highland malaria cases. However, a multivariable analysis of all the factors affecting disease transmission and clinical outcomes needs to be taken into account. The science of climate and health is not well developed and thus the proportion of variations in vector-borne diseases attributable to climate change is still unknown. This is a barrier to evidence-based health policy change. Although the impacts of climate variability on vector-borne diseases are relatively easy to detect, this cannot be said of climate change because of the slow rate of change (Githeko A.K, 2000).

Conclusions and Wider Impacts

Research by Goklany (2012) concluded that global warming would increase total mortality by 7–13% through a combination of malaria, hunger, and extreme weather events, by 2085. Meanwhile (Jhajharia, 2013) demonstrates the link between poor health infrastructure and the increase of life threatening illness or even death as a result of failure to properly treat malaria. Jhajharia proposes that addressing this, as part of integrated malaria control approaches, will also help fight against other diseases, and therefore reduce the overall disease burden of poor countries. Global donor support to improve public health infrastructure is critically needed and it has been estimated around US$ 10–20 billion per annum (Utzinger, 2002). However, an even greater increase in expenditure on improved health services, and wider education and health will be needed due to the impact of climate change.

This is also likely to increase not just the malaria prevalence (discussed below) but lead to a general expansion of climate sensitive infectious diseases and weather related effects, such as Cholera and other infectious diseases (Lipp, Huq and Colwell, 2002). Malnutrition, injuries and deaths could also be attributed, indirectly, to the effects of extreme weather events, as noted above. In urban environments, especially those located in tropical cities as well as those with inadequate drainage systems, precarious housing, insufficient coverage of clean water and poor disposal services of waste make the population highly vulnerable to climate-sensitive infectious diseases (WHO, 2008). Further research to identify the extent to which climate signals impact the incidence of flooding and reduce access to clean water, and how this relates to the prevalence of Cholera/Diarrhoea could be considered, such as in Bangladesh.

Health impacts can also be indirect. For example, the agricultural section below highlights the relationship between climate change and crop yields, which in turn impact upon the strength of local economies, the level of food availability and global food prices which impact upon livelihood security and an individual's immunity and susceptibility to infection. Underdevelopment and under-nutrition are inextricably linked with many infectious and non-infectious diseases (WHO, 2013).

2.2 The Impact of Climate Signals on Agriculture

Here the authors have investigated the relative strength of climate signals with respect to cash crops and food security after an overview of research that maps global climate models onto agricultural productivity. However, impacts on fishing nor aquaculture have been considered.

Global Impacts

The ODI summary of the impact of climate change on agriculture (Slater et al, 2007) draws heavily on analysis by Slater (2004) which concluded that climate change would impact cereal yields globally, with an overall 18% reduction in productivity by 2050 and 30% by 2080, focused upon Africa and parts of Asia (based on IPCC A1F1 and A2 scenarios). This suggests that by 2080 11% of the agricultural crop area could be lost. Increased production in Northern America, Europe, Russia and East Asia could mean greater reliance on trade for food security with some of the poorest countries seeing an increase in risk from hunger, with an increase from 600 million (1999) to 1300 million possible under the most extreme scenarios. While asking questions on how best to respond to this (should development focus on small or large farms, cash or food crops, investment in high or low potential areas) few conclusions are given as to whether development can overcome these climate signals.

Lines (2012) agrees that a response focusing on support for farmers and promotion of traditional crops with lower inputs (oil, agro-chemicals and fertilisers) would also be beneficial, as his analysis shows that many developing country farmers will suffer as their inputs are likely to increase in price faster than their produce; this is based on analysis of the last 30 years of input versus global food prices - although whether this would be sufficient to overcome climate impacts is not clear.

IFPRI analysis on the impact of climate change and agriculture for East Africa (edited by Waithaka et al, 2013) modelled up to 3°C increase in temperature and showed reductions in areas with reduced rainfall, although its methodology appeared not to model the increased unpredictability of drought[13]. In contrast, the need for agricultural systems to be planned to be resilient, not just to long-term climatic changes but to increasing frequency and rising damage caused by natural disasters is highlighted by de Haen and Hemrich (2007). This is not quantified, but a series of practical entry points and policy responses are set out.

Slater et al (2007) conclude by noting that even in 15 years time climate models are unable to predict impacts at scales less than 50km, so more 'flexible approaches' to deal with increased future uncertainty is required. This same conclusion is also reached by van Wart,

[13] Therefore, it is not clear how robust its findings are, which support increased production of maize and rice (in higher rainfall areas), rather than developing improved yielding varieties of more drought resistant crops such as millet and sorghum.

Grassini and Cassman (2013) who have reviewed three global crop simulation models for rice, maize and wheat production. This concludes that there is a poor performance of Gridded Weather Databases (GWDs) on estimating crop yields and there is a need to complement global analyses using GWD with studies based on up-scaling from point-based weather station data for the major centres of current crop production.

Examples of new approaches that address these climate signals at the local level cited by IIED et al (2009) tend to focus on agricultural production and education, improved water resource management and protection of other natural resources. While setting out the potential to adapt, this does not attempt to quantify the scale of adaptation that is required. Slater et al (2007) also argue for increased disaster preparedness and flexibility (such as in trade policies) and diversification at the country level. This overall concern about the scale of climate change impact on food security and hunger is reflected by others (Wheeler and Braun, 2013), although others, notable for China (see Ye, 2013 below) confirm that not all areas will be affected.

Later research by Calzadilla et al (2013), which model climate impacts on agricultural productivity, show a reduction in global food production, welfare and GDP on both a relatively optimistic and a relative pessimistic climate change scenario, for both 2020 and 2050. This separately considers the impacts of rain-fed and irrigated agriculture, as the former is more climate vulnerable, while the second requires increased water input with increased temperature. This theoretical modelling may be optimistic as crop yields are noted as increasing, although no allowance for increase in pests are considered. Even so the research suggests 0.5% reduction in global agricultural production by 2020 and 2.3% by 2050, with cereals declining by 3-5%, resulting in a 39-43% increase in cereal prices by 2050. The authors note that other studies have shown an increase in food production. The worst affected regions are noted as being former Soviet Union, South Asia and the Middle East. For this reason the following research focuses on the impact of climate change on cash crops in Africa (which is noted as having a positive gain) and food security in Asia.

Cash Crops

Coffee quality is noted as highly sensitive to ambient temperature (Laderach et al, 2010 cited in Laderach, 2013), so will be impacted by climate change. Davis et al (2012) model the impact of climate change and determine a 65% to 100% reduction in current Arabica coffee plantations in East Africa, with a 38-90% reduction in suitable locations overall by 2080.

Climate change will influence agriculture both directly, and through the emergence of new patterns of pests and diseases[14]. Jaramillo et al (2011) reviewed the impact of climate change on coffee production, both directly, and as a result of increased pests, such as the coffee berry borer. Jaramillo et al (2011) note that 'even a small increase in temperature would have serious consequences for coffee production, including in plantations in Brazil, Mexico and Uganda, especially where Coffea Arabica is produced. Their modelling predicts a reduction in coffee growing in most of Kenya, Uganda, Rwanda and Burundi with some increase in Tanzania and Ethiopia. Some of these impacts are already noted to be occurring[15], in part as the reproduction cycles of this insect increases from 1-4.5 to up to 16-20 each year, which will require relocation of coffee plantations to 167m higher altitude for every 1C increase in temperature to maintain quality and productivity.

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14 This reflects recent experiences. For example in Columbia, flooding led to an increase in coffee rust, which affected coffee production: *www.bbc.co.uk/news/world-latin-america-12216419*.

15 Reflected in 160% price increases for C. Arabica from 2009 to 2011.

The IPCC and International Coffee Organisation estimates a 10-20% decrease in production by 2050 but this does not consider the additional impact of pest prevalence researched here. This will have major impacts with the majority of production by small-scale farmers, for which 120 million depend on coffee for their subsistence worldwide.

Laderach et al (2013) investigated the impact of climate change on cocoa production in Ghana and Cote D'Ivoire, which are responsible for 53% of global production. This suggests that some sites will become unsuitable (climate signal dominant) while others will need site-specific adaptation strategies (mixed signal) such as drought resistant varieties, crop diversification and increased plant spacing and shading. Overall, research concludes that there will be a decrease in overall range but there is 'no need for farmers and governments ... to panic', as adaptation measures are possible, in part as the main impacts are likely to be on the next rather than current generation of cocoa farmers. So, while this might not dominate agriculture in the short-term it does highlight the need to start adapting and planning now.

Food Security

In some countries food security is perhaps more critical than cash crops. For example around 85% of Ethiopians live in rural areas and rely heavily on subsistence farming for survival as noted by Evangelista, Young and Burnett (2013). Their modelling of the impact of climate change on cultivated land area under the four key cereal crops of Ethiopia (2013) shows that all are affected, suggesting a major risk to future food security. This reduction is found globally in tropical regions by Berg et al (2013) whose modelling defines a global reduction of 6% in productivity of millet, but suggest that this scale of impact is able to be managed generally through adaptive measures and improved agricultural practices[16].

Another review of the impact of climate change on food security in sub-Saharan Africa by Kotir (2011) concludes that although uncertainties exist with regard to the magnitude of impacts, climate will negatively affect agricultural productivity across the region. This is also noted by Meade and Rosen (2013), who predict food insecurity increasing globally by 23%, slightly faster than population growth. Kotir noted that the area suited for agricultural and yield potential is expected to decrease, impacting food availability, accessibility, utilisation and food stability – and hence the risk of hunger in the region. Kotir suggests that this confirms that general consensus that the sub-Saharan Africa region is likely to be the most vulnerable region to Climate Change, which Kotir suggests is due to the region's high dependence on agriculture and natural resources, warmer baseline, lower precipitation and predicted lower ability to adapt.

Calzadilla et al (2013b) note that in sub-Saharan Africa agriculture supports around three quarters of all employment, 30% GDP and 40% of exports, (citing the Commission for Africa, 2005). They note that currently this focuses 97% on rain-fed agriculture, and relatively low yields compared to elsewhere, notably for sorghum, millet and maize. There are already adverse impacts, particularly on rural areas in LDCs dependant on rain-fed agriculture. By 2050 crop harvested area and food production are expected to decrease by 0.3% and 2.66% respectively, with most of the decline in production due to irrigated wheat, which is unlikely to be produced by 2050. Without adaptation there are predicted to be major losses (e.g. sugarcane -10%, wheat -24%). Two adaptation strategies were modelled against this

16 It is not clear to what extent increased focus on production of maize for food security in Africa (such as noted at www.cgiar.org/our-research/cgiar-research-programs/cgiar-research-program-on-maize/) will be as adaptable, due to maize yields falling away much more sharply when there is insufficient rain or if it falls at the wrong time. The extent to which new crop varieties or a shift to different crops or agriculture techniques will cope with climate impacts is unclear.

(SRES B2) baseline: increased irrigation and increased productivity. These were considered to be technically feasible and produced sufficient increase in productivity to offset climate impacts. However, the modelling was based on no cost or investment associated with the improvement and assumes sufficient water use as required. Further work is therefore required to prove whether this is true in practice. One study for Zimbabwe (Manyeruke et al, 2013) suggests that it could be achieved through new schemes to assist farmers in attaining the maximum crop yields.

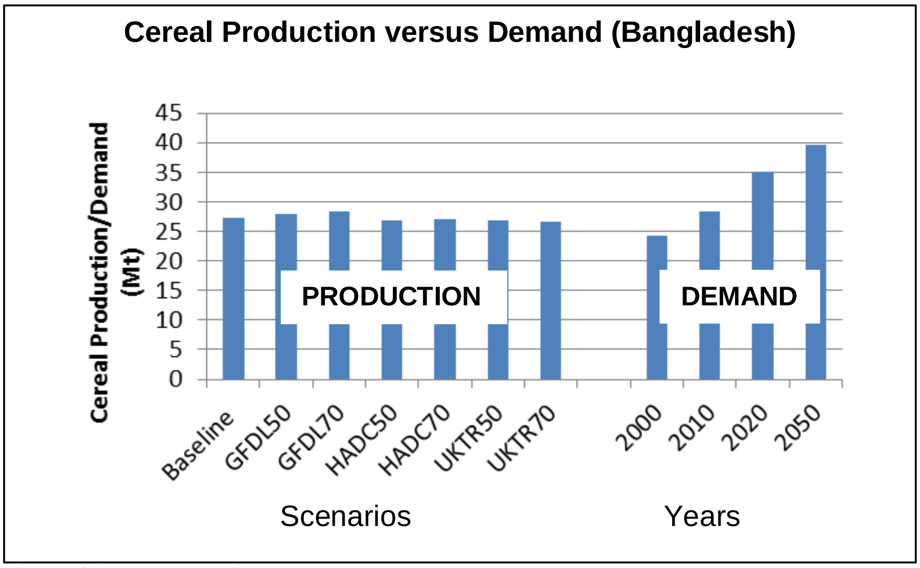
Ye et al (2012) include the impact of increased productivity due to higher CO_2 concentrations, and as a result their study suggests that climate change will increase food security in China. Tao (2008) modelled China's food security and also concluded that this will be met in China in the future.

An independent evaluation for the ADB (Working Paper, 2013) suggests that generally the challenge of food security can be addressed through improved productivity, support for resource-poor farmers, interventions to eliminate malnutrition and food security – to avoid food price hikes. This demonstrated that food price hikes tracked oil prices, but again, overall it was considered that climate change impacts in Asia could be mitigated.

In contrast, Waithaka et al (2013), in reviewing adaptation measures for climate change in Africa questioned whether adaptation would occur. Their review highlighted that actual adaptation might be constrained by finance, concluding "*options* for response to climate change that are noted in the National Adaptation Programmes for Action *are costly and yet to be implemented*."

In Asia there is significant research into the relation of climate change to overall agricultural productivity and food security. The impact of climate change on cereal production, and hence national food security in Bangladesh is studied by IWM (2008) and Hussain (2011). The scenarios suggest Bangladesh will not be able to meet its cereal demand beyond 2025, due to the combined impacts of climate change and increased demand (through expected 50% population increase) would require a doubling of yield/hectare by 2020, as shown in Figure 6 below. The actual changes depend on the global climate models used as a base, but most of the models show similar or reduced yields that are insufficient to meet demand either in 2030 or 2050.

Figure 6 Climate Impact on Food Security in Bangladesh until 2050.



Source: Adapted from Hussain, 2010.

The links between food security, climate change mitigation and adaptation, and the demand for bio-fuels and biomass production could also be significant in the future. For example, Edame (2011) notes:

Bryant et al (2000) in stating the risks climate change poses on food security are particularly pressing at a time of high oil prices, at levels surpassing $130 a barrel in May 2008 (citing IFAD, 2008). High fuel prices make agricultural production more expensive by raising the cost of fertilizers, irrigation, and transportation. With high oil prices, calls for increased energy efficiency, and government biofuel subsidies, agriculture-based energy production has surged. Farmers have switched massively to production of crops for ethanol and biodiesel. The increased level and volatility of agricultural prices is negatively impacting the purchasing power and the food security of the poor (von Braun, 2007). However, the relation of this to climate change adaptation has not been studied in this case.

This is just a snap-shot of an extensive literature that investigates the impact of climate change and food security in particular. Other impacts could include migration due to a lack of food security (see section below) or reduction in food security in urban areas.

2.3 The Impact of Climate Signals on Disaster Resilience

Impact of Increased Incidence of Disasters

Hanson (2011) conclude that around 1 in 10 people globally are currently exposed to a 1:100 year flood event, with around US$3,000 billion of assets exposed, corresponding to around 5% of global GDP in 2005, particularly in developed countries such as USA, Japan and the Netherlands.

However, by 2070s the affected population could triple and asset exposure increase ten-fold to 9% of global GDP, with the top five cities in terms of population exposure all in Asia (Kolkata and Mumbai in India, Dhaka in Bangladesh, Guangzhou in China and Ho Chi Minh City in Vietnam) (ibid). By the 2070s the asset exposure is noted as having shifted from developed to include current developing cities: with 9 of the top 20 cities in terms of financial asset value impacted in China, India, Vietnam, Thailand and Egypt. In terms of preparedness, Hanson noted that with 136 cities affected, there is a 99.9% chance of at least one being affected by a 1:100 return period event every five years, which is likely to translate into recurring city-scale disasters at the global scale. As removal of this risk, or relocation seems unlikely, developing the community resilience and capacity to withstand disasters is noted by many as critical in limiting impacts. This also points to the need to integrate the consideration of climate change into long-term coastal flood risk management and disaster planning.

Modelling of the impact of increased hurricane storm surges, due to a warming atmosphere and sea level has been undertaken for the developed countries following the $81billion damage and 1500 deaths of hurricane Katrina (e.g. USA: Condon and Sheng, 2012) but less evidence is present for developing countries. One study for Kolkata (Dasgupta et al, 2012) investigated vulnerability to an increased incidence of flooding. It found that some mitigation measures such as de-silting of the main sewers could reduce flooding by 4% and the population affected by 5%. But in the context of 41% of the city and 47% of the population likely to be impacted by a future 1:100 return period flood this is only a minor benefit. This study concluded that ‘current development plans for Kolkata are only up to 2025 and do not account for the possible long-term effects of climate change or any adaptation that may be needed to cope with the problems arising due to climate change over time. It also noted that ‘the use of cost-benefit analysis using NPV approach that takes into account climate change effects will increase the viability of many projects not found viable earlier with only current weather data.

Hunt and Watkiss (2011) conclude that future city-scale assessments should not exclude inter-dependencies with surrounding regions, which suggests that to respond to climate signals development should focus beyond the project or city to the programme and at least sub-regional scale.

Also, qualitative evidence suggests that improving disaster preparedness can effectively reduce the impact of climate signals. For example IIED et al (2006) note that while six major hurricanes ran over Cuba between 1996 and 2002 only 16 lives were lost. In contrast to around 1,500 due to Hurricane Katrina in the US, only one life was lost when Hurricane Wilma struck Cuba in October 2005, as 640,000 people were evacuated before the sea went one kilometre inland and flooded the capital.

Disaster Resilience

Various papers describe the development of local capacity to disaster resilience, but do not quantify how this relates to the climate signals currently experienced, or in the future: such as in Zimbabwe (Manyena, 2006), Ethiopia (Tadele and Manyena, 2009) and Nepal (Jones, Aryal and Collins, 2006), highlighting that the close links to livelihoods and institutionalisation of DRR, such as in local government structures might be key. Rubin and Rossing (2012) note that while the 2010 World Development Report explicitly acknowledged that local communities typically precede national government in climate action (citing World Bank, 2009: 20), only 20% of the National Adaptation Programs of Action documents prepared by environmental ministries incorporate local institutions as the focus of adaptation projects (citing Agrawal, 2008).They conclude, that, “on a local level, vulnerability is closely related with community assets, most notably social memory and the capacity for self-organisation, which are not easily captured by national indicators.” Therefore, Latin American experience suggests that climate change adaptation could be enhanced through encouraging social asset-based formation at the local level. Adaptive Social Protection is also noted by Davies et al (2013) as helping to shift the time horizon for social protection towards that needed for climate adaptation and disaster resilience.

There is also a perceived gap in practical methodologies for measuring resilience (as set out by Sudmeier, Jaboyedoff and Jaquet, 2013, with reference to communities in Nepal, although climate change was not considered. Parvin and Shaw (2011) have measured the resilience of a city, which suggests a poor to medium resilience in Dhaka, Bangladesh.

Meanwhile, Linnenlueke, Griffiths and Winn (2011) conclude that while recent studies have improved projections of future climate impacts, there is still limited research at a suitably fine-grained scale to enable decision makers to plan for improved institutional resilience.

Therefore, in the many academic studies reviewed which focused on resilience, there is little attempt to quantify the scale of the climate threat, and therefore while detailed qualitative examples are given, the extent to which resilient infrastructure or institutions can mitigate against climate impacts has not been determined.

O’Brien et al (2006) conclude in their review of climate change and disaster management that disaster policy response to climate change (which could be viewed as both a complex and protracted hazard, so does not sit well with traditional response regimes) needs to better enhance capacity-building and resilience as a prerequisite for managing climate change risks in ways which reduce vulnerability.

Impact of scale on relative strength of climate signals and resilience

One of the constraints in determining whether climate signals are a governing factor are the starting points of different pieces of research. Those that start by exploring climate scenarios determine whether or not there is an impact – but adaptation and institutional capacities are often not considered. In contrast, much research focused on institutional capacities appears to start from a premise that adaptation *is* possible, focusing instead on identifying best practice, such as set out by Satterthwaite (2011) with regard to the potential for low-carbon city development. Also there is a challenge to focus on climate change signals and impacts at the same scale. As noted elsewhere global climate models are often not sufficiently finely granulated to enable local impacts to be determined. However, as noted by Satterthwaite (2013) resilience is not just secured at the city or government scale common in climate modelling but also at the community and household scale. Without more detailed modelling it is likely that adaptation measures will focus on national and regional-scale infrastructure provision (such as proposed by World Bank, 2010), which is likely to reinforce rather than challenge current development investment portfolios. Whether improved climate change adaptation is possible, would be aided by discussion of city-scale, sub-regional and community sustainability rather than a focus on national and economically significant assets.

This might require a greater focusing on local institutional capacity, which currently has virtually negligible investment in many developing countries as set out by Satterthwaite and Dodman (2013).

Therefore, in terms of disasters overall, this could be considered a **mixed** signal. However, considering whether or not sustainable livelihoods are still possible in specific regions and countries would benefit from further research, considering more localised and longer-term impacts, as noted in terms of food security (see agriculture above) or overall livelihood security (as noted under migration below). In this case the climate signal is likely to be **dominant**.

Migration

The impact of climate change on migration, both through the notion of 'climate refugees' as well as the potential for internally displaced persons, is widely reported, with Up In Smoke (IIED et al, 2008) citing 150 million environmental refugees by 2050. Other estimates include 'as many as 200 million people displaced by 2050 by the disruptions of monsoon systems and other rainfall regimes, by droughts of unprecedented severity and duration, and by sea level rise and coastal flooding' (Norman Myers, Oxford University cited in EquityBD, 2009) and estimates of 200 million people by climate change related phenomena by the Stern Review on the Economics of Climate Change in 2006 and 250 million a Christian Aid report in 2007. Myers (2002, cited in McMichael et al ,2012) claims that climate change will cause up to an additional 200 million "environmental refugees" by 2050 has become a widely accepted figure—but notes that the evidence for this figure has been questioned. Brown et al (2007) considers that climate change is now one of many (i.e. mixed) signals with regard to the security threat it poses in Africa.

An example of impacted livelihoods is provided within DFID's Chars Livelihood Programme, which supported some of the 3 million people in Bangladesh on the temporary islands, or chars of the Jamuna River in North West Bangladesh. Conroy, Goodman and Kenward (2010) reviewed the Chars Livelihood programme which aimed to halve poverty on these communities prone to livelihood loss due to climate change, in part through cash-for-work programmes for households in extreme poverty.

Significance of Climate Signal on Migration

In some cases this could be viewed as a signal as to whether and in what circumstances climate signals dominate as the livelihood choices made are to move rather than to adapt.

Evidence and Impacts

Walsham (2010) calls for more localised mapping to determine the impact of climate change on migration. Walsham notes that while anecdotal and media reports suggest that many migrants from environmentally vulnerable regions of Bangladesh end up in the country's urban slums, particularly those of Dhaka, while existing data suggests that many urban migrants do come from districts prone to natural disasters, it is not detailed enough to identify the role played by environmental factors in driving migration from these areas.

Kniveton et al (2013) review the causality of climate change and migration in Bangladesh. They cite IOM (2009) that people who lose their homes in disasters often move on to slums in cities like Rajshahi, Khulna, Chittagong and Dhaka. They also cite Gray and Mueller (2012), who confirm that it is not immediate flooding but crop failure that drives the long-term mobility trend in Bangladesh. Crop failure is not necessarily due to the flooding alone, but a combined effect of late or untimely rains and an extreme rain event that follows. They note that disaster-related migration is often short-term and involves short distances. For example, 88 per cent of migrant agricultural communities in Bangladesh were found to remain within two miles of their previous residence following the erosion of land and loss of homes due to flooding (citing Zaman, 1989).

Rashid (2013)'s analysis of migrants concludes that many are enforced to move in response to changes in conditions (or in their perception of conditions) at the places of origin, which are recognised as climate signals. Rashid also suggests it is complicated to draw a line between voluntary and forced migration, and thereby consider whether migration is an adaptation strategy or just a failure of adaptation due to the lack of shelter, unemployment, lack of adaptive cropping patterns, lack of capital, insufficient level of awareness and knowledge of climate change scenarios as a result of climate impacts within affected villages. In some cases, forced resettlement is imposed in the name of climate resilience, but this approach may worsen rather improve livelihoods, as illustrated in the lower Zambezi valley with resettlement chosen over an alternative to improve resilience to 'live with floods' in this part of Mozambique (Arnall, 2013).

EquityBD (2009) cite general research that show that with just a 1 to 2 degree increase in temperature this force physical dislocation of more than 35 million people in Bangladesh alone.

Bangladesh is widely recognised as one of the most climate impacted nations, with two-thirds of the country less than 5m above sea-level and "on average a severe tropical cyclone hits Bangladesh every 3 years..." (Displacement Solutions, 2012). EquityBD (2009) and Displacement Solutions (2012) illustrate household and community-scale qualitative evidence of climate impact. For example, Displacement Solutions (2012) highlight the example of 60,000 displaced by permanent coastal flooding in the Khulna district of South West Bangladesh as a result of sea level rise where 25,000 of these displaced persons, unable to return to their houses and lands and with little access to new land, were forced to live on a 25km long, 2 metre high and 3-4 metre wide embankment.

Lack of Institutional Frameworks, Policies and Laws

Displacement Solutions (2012) reviewed Bangladesh's National Adaptation Programme of Action (NAPA, produced in 2005) and later 2009 Climate Change Strategy and Action Plan (BCCSAP, produced in 2009). The NAPA did not quantify the links between climate change and migration, or prescribe any actions or specific policies related to the issue of climate displacement. In contrast, the BCCSAP states that if sea level rise is higher than currently expected and coastal polders are not strengthened and/or new ones built, "six to eight million people could be displaced by 2050 and would have to be resettled". However, this still underestimates the full extent of climate displacement in Bangladesh, both in terms of severity but most importantly it still presents this as a future event, and as a result, is noted as failing to set out any policies or strategies for displaced people, let alone any rights-based housing, land and property solutions for these affected communities. There is no indication of where or how the "institutional support" noted in the BCCSAP will be provided.

The need for national strategy, is also important as much of the climate migration in Bangladesh is to Dhaka (Akter, 2009 cites the International Organization for Migration (IOM), which estimates that about 70% of slum dwellers in Dhaka experienced some kind of environmental shocks) which itself is one of the most climate vulnerable worldwide, sitting just 2-13 metres above sea level (see for example, UN Habitat, "Case Study: Dhaka's Vulnerability to Climate Change", in UN Habitat, State of the World's Cities 2008/2009). There is also a general need to improve assessment and institutional arrangements to improve disaster resilience within informal settlements (noted by Miles, Green and Svekla, 2011) based upon analysis of housing in Guatemala, although it is not clear to what extent this will mitigate against the climate risks.

Displacement Solutions (2012) comment that under current international law, the Refugee Convention would not apply to the circumstances of the vast majority of climate displaced people of Bangladesh, possibly as the Refugee Convention was drafted many decades before the existence of climate displaced people and that it was never intended to offer protection to such category of person. Similarly, EquityBD (2009) note that the UNFCCC agreement, while detailing the need for climate change mitigation and adaptation, does not mention 'climate change induced forced migrants'. While 'climate adaptation' includes relocating population from the flood prone or at risk areas it has not clearly defined how to address the multi-causality of forced displacement largely caused by climate change. This lack of clear policies and legal frameworks, either nationally or internationally, to cope with this 'new' group of forced climate migrants is reflected in the declaration of the Climate Vulnerable Forum, adopted in 2011[17].

The World Bank (Human Development Report, 2009: Box 7.6) suggests that climate change calls for a different urban form, not slower urbanisation. However, with regard to climate migration the proposals in Displacement Solutions (2012) of rural relocation to less climate vulnerable locations might be an alternative, to the current rural to urban migration[18].

Summary

Analysis above suggests that Climate Signals will **dominate** in this area in the future, but there is still little evidence of policy measures taken so far. This might be, at least in part due to a lack of evidence and analysis at noted by Walsham (2010). The institutional capacity to respond to this challenge is noted as often not present, and alternative strategies such as voluntary rural resettlement not studied in detail. There is also a need for adaptation and

17 See http://daraint.org/2011/11/14/2748/climate-vulnerable-forum-declaration-adopted/

18 See Adarsha Gram II Project at www.eudelbangladesh.org/en/projects/projectdetails/13.htm and Ashrayan-2 Project at www.ashrayanpmo.gov.bd/.

coping mechanisms to include migration, both in policies and legal frameworks, as suggested in Box 1 below.

Box 1 Adaptation with Dignity – the need for inclusion of migration within adaptation strategies

Already adaptation measures are helping to prevent displacement in Bangladesh, such as those who have developed indigenous knowledge to raise their houses on plinths, protected their houses or land with flood defences, or adjusted their farming techniques (including by using flood-resistant strains of rice or by developing floating gardens' to deal with water-logging). Efforts are also being made to raise embankments and to protect them with forest cover, and to establish coastal green belts... But, as one Bangladeshi official notes, however, Bangladesh cannot adapt indefinitely'.

There is a risk that the focus on adaptation may come at the expense of a human rights-based approach to climate change-related displacement. As the head of one prominent Bangladeshi NGO explained, currently nobody talks about human rights in the adaptation process'.

There is a difference between adaptation and adaptation with dignity: "if this is your house, and because of the saline water inundation or submerging of land areas, you are today surrounded by water and [therefore] don't have any other place you go, you start doing floating gardens in the flood water. That is adaptation, but that denies the right to a dignified life, because I have a right to live in normal situation. I don't accept living surrounded by, you know, this stagnant, dirty, filthy water that gives me diseases". Migration should be regarded as a normal form of adaptation – as a path to a more dignified life – rather than as a sign that adaptation has failed.

Bangladesh's approach to climate change policy (including adaptation) needs to shift to a rights-based framework focused on human dignity with policies and laws (national and international) that focus on preventing displacement (adaptation, education and support for livelihoods); assisting those displaced and viewing migration itself as an acceptable form of adaptation (including through planned, rights-respecting resettlement schemes involving the participation of affected communities).

In addition, Bangladesh, its neighbours and the international community should establish more bilateral and regional economic migration opportunities for Bangladeshis – without expending unnecessary energy pursing a global protection-oriented treaty that would be ill-suited to the complexity of the movements involved. Such policies would also go far in addressing the genuine human security problems arising from climate change-related displacement in Bangladesh, particularly social tensions over scarce resources, problems of urbanization, cross-border sensitivities about irregular migration, and the (albeit limited) potential for radicalization.

Summarised from McAdam and Saul, 2010

2.4 The Impact of Climate Signals on Economic Development

Introduction

It is widely cited that current economic development is increasing rather than reducing climate signals. For example, in Up in Smoke (IIED et al, 2009), R K Pachauri, Chairman, Intergovernmental Panel on Climate Change notes, "The Fourth Assessment Report of the

Intergovernmental Panel on Climate Change (AR4) states, ‘There is a high agreement and much evidence that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades. ... Therefore the current pattern of development pursued worldwide will continue to endanger the well-being not only of citizens in developing countries but also those in the developed world’.

Up In Smoke (IIED et al, 2009) notes the continued connection between economic development and increased use of already-overused resources, yet development is still generally considered dependant on global economic growth. To address the growing climate signal James Hansen (cited in IIED, 2009) states, “If humanity wishes to preserve a planet similar to that on which civilisation developed and to which life on Earth is adapted ... CO_2 will need to be reduced from its current 385 ppm to at most 350 ppm [parts per million] CO_2 but likely much less than that ... if the present overshoot of the target CO_2 is not brief there is a possibility of seeding irreversible catastrophic effects. IIED cite Simms et al (Consumption Explosion, 2009) which sets out how both the overall ecological footprint and the average footprint per person for high, middle *and* low income countries has continued to increase from 1965 to 2005. They also quote Woodward and Simms (2006) who conclude that in the 1990s for every $1 of poverty reduction, $166 of additional global production and consumption was created, ‘generating enormous environmental impacts which counter-productively hurt the poorest most. So, rather than ameliorating climate signals, the current model of economic growth amplifies them.

Economic Growth and Agricultural Resilience: Separate Agendas?

In the section above, Kotir (2011) proposes that shifting away from an agriculturally-based economy, through increasing economic growth, would improve the ability to adapt. This would be true with regard to finance if the costs of climate adaptation (as noted by Waithaka et al, 2013) are to be met in-country. However, it is not clear whether effective agricultural adaptation is linked to economic development, or otherwise. Rather, the dominant strategy to transition from agriculture, such as in Rwanda, appears not so much to improve resilience but to facilitate development, which as noted by the World Bank’s Leadership and Growth report (Davy and Spence, 2010) tends only to be interested in developing a strong *investment* climate[19]. Although, Rwanda is planning ‘green growth’ it is not clear if this affects the nature of agricultural transition, as the strategy focuses on the nature of its urbanisation and expansion of its transport network and nature of its expanded energy supply.

19 This report of the World Bank’s Commission on Growth and Development makes no reference to climate change, although the importance of a strong investment climate is mentioned a number of times.

Sub-sector	2010 GDP[1] in Billion RWF	2010 (% share of total GDP)	(Change in share since 2000) %
Agriculture [2]	814.5	37%	-10%
Real estate	161.2	7%	-1%
Mining, Manufacturing and Utilities	154.9	7%	0%
Finance, insurance, personal services	93.3	4%	0%
Public sector, education and health	282.1	13%	1%
Construction	171.1	8%	**2%**
Transport, storage, communication	197	9%	**4%**
Wholesale, retail, hospitality	341.9	15%	4%

Notes: 1. GDP is before adjustment for taxes and bank service charges.
2. Cash crops accounted for 2.7% of Rwanda's agriculture GDP in 2010.

Table 3 Contrast of GDP Growth, by subsector for Rwanda, 2004-2008

Source: Adapted from World Bank, 2011, Annex 2.

Economic Development – current focus on resource constraints not climate impacts

Mainstream analysis tends to consider the impact upon economic growth of resource constraints (as opposed to climate impact). For example, McKinsey's report on the impact of China's city growth to 1 billion urban residents (Woetzel et al, 2009) makes no mention or consideration of either climate adaptation or even climate change in its consideration of resource and economic growth impacts. Similarly, McKinsey's review of growing energy, materials, food and water demands globally (Dobbs et al, 2011) asks whether, "*as the resource landscape shifts, an era of sustained high resource prices and increased economic, social, and environmental risk is likely to emerge". McKinsey conclude that, "If investment in supply remained at historical levels and productivity growth improved only in line with our base case, there would be a notional gap between supply and demand in 2030 of 15-80% across the four key resources [so] the annual pace for supply additions over the next 20 years would have to be almost triple the rate at which it expanded over the past two decades*."

Heatley (2012) comments that this is expected to be met by productivity opportunities and an overall 2% per annum productivity improvement, based on an additional US $3 trillion of investment, 75% of which is in developing countries.

However, when considering this challenge alongside action to mitigate climate change, Dobbs et al conclude that this is 'almost impossible', suggesting that governments choose a combination of the 'expanding supply' and 'boosting resource productivity' rather than response to the climate challenge[20] as illustrated in table 4 below. Their ultimate modified optimism is based on not dealing with climate change, but to continue on the current development path and then build long-term resilience to *resource constraints rather than climate change,* whose sufficiency is not quantified (p136).

But, as Heatley (2012) notes, the McKinsey analysis only covers the next twenty years, discounts climate change, pollution, reduction in bio-diversity or degradation of eco-system services and double counts input productivity improvements and does not take proper account of rebound effects from resource or energy efficiency gains. This approach is

[20] This is summarised in exhibit 32, page 119 and notes that the climate response will require an additional $260 billion to $370 billion capital expenditure a year, largely for the generation of power using renewables.

reflected further in McKinsey's work underpinning Ellen MacArthur Foundation's championing of the circular economy, not to create a economy that is sustainable in climate mitigation or increases overall resilience, but one that retains long-term access to resources to the industrial sector (McKinsey, 2012).

	Supply expansion	Productivity response	Climate response
Return on investment (£, not energy)		30% opportunities < 10%	Requires public subsidy
Agency issues in decision-making		Some issues	
Information for investment	Reserves remaining unclear	Low awareness of opportunities	
Supply-chain needed for implementation	Risk	New skills needed	Lacks full value chain
Capital available (perception of financial institutions)	Familiar	Less familiar	Higher risk
Technology required	Some new technologies	Existing technologies	Some unproven technologies
Culture change needed	No change	Requires change in behaviour/ mind-set	

Table 4 Analysis on Economic Strategies to address Resource Scarcity proposes no response to climate signals. Source: adapted from Dodds et al (2011)

This approach does not promise to solve climate change, or sit within a scenario that does so but, sets out that 'circular economy offers a valuable contribution to climate change mitigation' through reducing carbon emissions per tonne of resource processed, but does not reduce (or even stem the continued increase in) the overall scale of resource use, as predicted by McKinsey (Woetzel et al, 2009 and Dobbs et al, 2011). Therefore, the only adaptation proposed is for businesses, to continue to grow their profit and market share.

Such an analysis is reflected in a general disconnect between mainstream economics and consideration of climate change impacts, which at best reduces concern to climate adaptation, independent of climate change mitigation; an approach that will be catastrophic in the shorter-term for climate vulnerable economies such as Bangladesh and unsustainable globally in the medium to long-term. For example, the World Bank's Commission on Growth and Development (Brady and Spence, 2010) chooses not to consider climate change at all.

In the concluding chapter on Bangladesh, in reviewing the country's development over the past 30 years, Mahmud, Ahmed and Mahajan (2010) claim Bangladesh has now made 'famines a phenomenon of the past'[21] and notes the fastest economic growth has been in ready-made garments, expanding at 15.2% a year since 1990[22], increasing concentration from 50 to 75% of exports, rather than developing a more resilient (diverse) economy. This job creation, the authors' suggest, has driven rural-urban migration, as a means of delivering upward mobility for the migrants (citing Khundker et al., 1994).

21 This contrasts with Hussain (2010) whose study on food security and climate change in Bangladesh is referenced in the agriculture section above.

22 Brady and Spence, 2010: Page 233, Table 8.2.

In contrast, analysis using more recent data by Shadsuddoha et al (2012) summarise analysis by the Bangladesh Bank (2012), which shows that foreign remittances and ready-made garments, the two highest earning foreign currency sectors and the biggest contributors to Bangladesh's annual budget, rely significantly on migrant workers from areas badly affected by or prone to disasters. In 2010-11 the contribution from remittances was about US$12.8 billion[23] while the ready-made garment industry, about 70% of whose four million workers are migrant women, earned a total of US$17.9 billion, which was over 78% of the total export revenue for Bangladesh for that period. However, there has been little discussion of migration as a tool for development policy as a strategy for economic growth (Mukand, 2012), let alone climate adaptation (as discussed in the section on resilience). While this drives urbanisation, and therefore a shift from subsidence to monetised work for which Bangladesh's economy is noted as a beneficiary, there may be a reluctance to consider the role of climate migration, at least in the short term. The irony is the strong export growth is as a result of low-wage economy fuelled by a surplus of climate migrants to the urban area, as noted below: economically beneficial at a national level in the short-term, not a long-term sustainable development strategy going forward.

For climate change to limit the need for adaptation in other areas such as agriculture, health and resilience discussed here, a different direction for economic development is required. For example, Anderson and Bows (2012) show this would require a complete change in proposed economic development planned for shipping, which is increased to expand emissions by 100-200%, compared to 2010 levels by 2050, while emissions must reduce by 85% to 2050 to reduce chances of exceeding 2C by to 50%.

In considering whether the response so far has been sufficient to address these climate signals this report focuses on transport and urbanisation. Further work to evaluate to what extent the notion of 'green growth' (Evidence on Demand: Scott, A., McFarland, W, and Seth P; 2013) is sufficient in adapting to and mitigating the impact of climate change could be a subject for further research[24].

Smith et al (2011) suggests that planning adaptation to climate change should map decisions with respect to their lifetime. So, adaptation might be stronger in arable agriculture than coffee growing (as the lead-time is shorter), and shorter for specification sea-level rise for the design of sea-defences (50 years) than for bridges or locating urban development (nearer 100 years). It also means that climate change mitigation and adaptation for investment with longer life times (such as urban development and transport infrastructure) should be carried out in parallel: therefore zero carbon *and* sufficiently climate resilient.

The remainder of this section considers the direct impact of climate signals on economic growth, through focusing on climate impacts in the transport sector and cities. The rationale for focusing on these two areas is set out below.

Economic Development, Expansion in the Transport Sector and Urbanisation

Turok and McGranahan (2013) highlight the importance of urbanisation and the chosen development path (and its climate resilience) as a key area of concern. The benefits of

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23 See BGMEA 2012, see www.bgmea.com.bd/home/pages/TradeInformation.

24 Anderson and Bows (leading UK climate scientists, writing in the journal Nature Climate in 2012) write that the science demonstrates that the threshold of 2 °C is no longer viable, at least within orthodox political and economic constraints. Against this backdrop, unsubstantiated hope leaves such constraints unquestioned, while at the same time legitimizing a focus on increasingly improbable low-carbon futures and underplaying high-emission scenarios. ... work on adapting to climate change suggests that economic growth cannot be reconciled with the breadth and rate of impacts as the temperature rises towards 4 °C and beyond — a serious possibility if global apathy over stringent mitigation persists.

economic concentration in terms of labour supply and economies of scale are set out, citing examples from the global north that suggest urbanisation increase productivity (as defined in GDP – which is reflected in built environmental capital spend), research from Asia is mixed and whereas Africa was noted as an exception with research suggesting less evidence or even a negative correlation between aggregate poverty and urbanisation in sub-Saharan Africa. Although research was provided to counter this, none were noted as having considered the impact of climate change upon development. While this paper concluded that the relationship between urbanisation and social development was variable the reasons for this variability, such as climate change were not examined.

This is not unusual for research focused on economic development. For example, Brady and Spence (2010) studied strategies for leadership in economic development globally, but made no reference to either climate change mitigation or adaptation as part of their best practice examples. As an example of economic development in a LDC, the example of Rwanda (see table 2 above) shows that while that the cumulative GDP growth is focused on construction and expansion of physical assets as opposed to agriculture, mining and manufacturing. This again considers a focus on transport and urbanisation to consider the link between economic development and climate impact.

Extent of Impact of Climate Signals on Transport Systems

The World Bank's assessment of the costs of adapting to extreme weather events in Bangladesh appears to focus predominantly on road transport impacts, although it's scope is not identified as such (2011). This contrasts strongly to the EU's strategy for adapting *infrastructure*, which takes a broader view. While the World Bank analysis of rural climate change impacts in Bangladesh by 2050 requires $5.7 billion, mainly to raise road infrastructure and strengthen polders, the EU's working paper on infrastructure strategy also considers energy generation, transmission, rail, aviation, shipping, construction and urban transport, as well as anticipating increased maintenance costs[25].

In contrast to the conclusions of the World Bank in Bangladesh (2011), COWI (2010), conclude in, their study in Mozambique, that maintenance is key to ensuring climate resilience. They estimate that for Mozambique's road network climate induced costs will be around 0.5 billion USD to 2050, with increased maintenance costs dominating.

Also the Bangladesh study is based on a 0.27m sea level rise to 2050 while the EU study considers longer term impacts of 0.18m – 0.58m by 2100, and expects an increase of 0.9 – 1.6m for coastal cities, as well as other impacts such as a strengthened heat island effect in cities. In contrast, the Bangladesh study did not consider urban impacts by stating, "current government policies will determine where this urban population will settle", which conflicts with the recent empirical study cited above, from Haque, Grafakos and Huijsman, 2012 which suggests this is not the case, especially as many of the new urban population in Bangladesh are climate displaced people. The World Bank's conclusion that "coping with climate change over the longer term will also require strengthened cooperation among neighbouring countries [to] prevent the need for more expensive, disruptive solutions in the future". In contrast, Warpo, 2005 cited in IWM, 2008 considers the impact of sea level rises of 32cm and 88cm, for 2050 and 2100 respectively, which would be more useful in planning infrastructure development for the long-term. This suggests that the scale of the climate impacts for some of the most vulnerable countries is not yet fully integrated into development approaches, such as those followed by the World Bank.

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25 The EU (2013) notes that for road transport infrastructure, which was the focus of the World Bank's Bangladesh study, around 30-40% of current road maintenance costs are due to 'weather stresses' and 10% of these due to extreme weather events alone. No increased maintenance costs or disaster rehabilitation were considered for Bangladesh.

Transport and the need for systemic analysis rather than a risk analysis approach

As noted above, much of the research relating climate impacts to infrastructure concerns the risk of an impact, based on a business-as-usual development scenario. To consider the relative strength of climate versus other developmental signals a scenario analysis approach would be useful. For example, transport infrastructure functions as a complex adaptive system with numerous interdependencies and there is a huge amount of uncertainty around the probability of a hazard occurring and its impact on infrastructure.

This suggests that at the level of project design, where it is important to capture interdependencies, traditional risk assessment techniques are inappropriate for understanding the behaviour of transport infrastructure (Giannopoulos, Filippini and Schimmer, 2012). The concept of resilience is used instead, most frequently in climate change, where the risks are too difficult to accurately predict and unavoidable.

There is a need for infrastructure adaptation to be matched by institutional changes, as noted by Park et al (2013) in distinguishing between risk of failure and resilience (requiring continuous management) of infrastructure. Mallick et al (2005) note that in Bangladesh such disaster preparedness and integration of institutional and coping strategies into infrastructure designs was already being mainstreamed around 10 years ago.

There is a growing body of research on applying complex systems modelling techniques to critical infrastructure, including transport, and seeing risk assessment as a subset of an overall resilience framework. For example, Halcrow have developed a complex system modelling tool to help project managers include sustainability objectives in the design of infrastructure projects, and both Birmingham University on the FUTURENET project and the Infrastructure Transitions Research Consortium led by Oxford University have adopted a similar complex system modelling technique (see http://www.itrc.org.uk/).

Extent of Impact of Current Signals on Cities and Urbanisation

Key indicators of harm to economic development are considered by Hanson (2011) to be the population affected and asset (financial) value. The timescale considered by Hanson is not the 15-25 year time horizon considered for many agricultural/rural impacts (for example see studies above tending to a 2040-2050 impact time horizon) but 2070s, as this is the timescale relevant for planning adaptation measures: 'the length of time over which current policy choices and debates can influence both exposure and risk'.

One crucial aspect of an export-led economy, with development tied to globalisation, is the need to develop key transport infrastructure: principally national road and rail networks, airports and ports. 13 of the 20 largest cities worldwide are port cities, but Hanson (2011) references UPFPA, 2007 that there has been little preparation for such events and their economic implications in the long term. Similarly, Hunt and Watkiss (2011)'s review of research at the city-scale concludes that while spatial analysis has been conducted for vulnerable first-world cities (as opposed to elsewhere) these have tended to focus on the qualitative impact of flooding, health and water resources, with the climate impacts upon energy, transport and built infrastructure less studied. This could reflect the relatively advanced level of analysis possible for sea-level rise and flooding but also potentially limited institutional capacity to consider other aspects. Therefore, while the studies highlight the scale of the climate signal, there is a research-gap in determining how this impacts the physical development process, and therefore the extent to which it should reframe donor investment priorities. This applies both to ports, primarily from a climate adaptation perspective, and increasingly airports, from a climate mitigation perspective as urban development is increasingly airport-led (Freestone, 2009).

So, for example while there is wide ranging studies on the impacts and economic costs of flooding, which identify the trade-offs between protection costs against reduced flood risks, the same is not true for built environment impact, although some work in progress was identified (e.g. ADB-World Bank-JBIC Initiative on climate Impact and Adaptation in Asian Coastal Cities). The tendency has been for studies to compare city vulnerabilities (e.g. as conducted by Sherbinin et al, 2006) rather than compare climate signals to development scenarios. The scale of climate signal vulnerability of infrastructure has been estimated such as studied by ABI (2005, referenced in Hunt and Watkiss) estimating a 75% increase in insured damage of US hurricanes by the 2080s. Anderson and Holcombe (2013) note that if this is normalised with respect to inflation and wealth at a national level, and changing population and housing in climate vulnerable locations there is no change in damage. This suggests that what matters more is what is built, where and how – than climate change alone: so whether development in Bangladesh leads to expansion of populations in climate vulnerable locations, such as coastal cities, will be significantly affected by the type and location of new construction[26]. For example, expansion of the built environment in Dhaka into its lowest lying area, which was previously set aside as flood plain for temporary storage of water (Haque, Grafakos and Huijsman, 2012) will increase future disaster risk (see Figure 7 below). However, this would be to neglect recent evidence that suggest the scale of natural disasters is also increasing worldwide. For example, Yeb Sabo, Philippines lead negotiator at the COP19 climate talks in Warsaw, December 2013 commented that:

> "*According to satellite estimates, the US National Oceanic and Atmospheric Administration also estimated that Haiyan achieved a minimum pressure between around 860 mbar (hPa; 25.34 in Hg) and the Joint Typhoon Warning Center estimated Haiyan to have attained one-minute sustained winds of 315 km/h (195 mph) and gusts up to 378 km/h (235 mph) making it the strongest typhoon in modern recorded history.* [27]"

Also, Mendelsohn (2012) found that climate change is expected to cause global tropical cyclone damage by US$53b/year by 2100 (almost double the 2100 baseline), which is consistent with most research findings.

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26 The scale of urbanisation until 2050 implies new construction will equal all existing urban built environment worldwide, based on predictions of population growth and anticipated urbanisation worldwide. The location and nature of this new construction will have an impact, and could increase vulnerability through expansion of coastal cities, unless a different development path is chosen.

27 Speech: www.rtcc.org/2013/11/11/its-time-to-stop-this-madness-philippines-plea-at-un-climate-talks

Figure 7 Dredging to facilitate real estate development, East Dhaka. Source: Author photo, 2004.

In Bangladesh, Alam and Rabbani (2007, referenced in Hunt and Watkiss) note that pro-active adaptation could reduce climate costs by up to 80%: which suggests that the climate signal is likely to dominate over development in vulnerable locations such as Bangladesh.

Jabeen et al (2010) highlight the increased climate ‘variability’[28] experienced by the urban poor in Dhaka, Bangladesh. Interviews of households in the 90 acre, 100,000 person Korail slum identified that the urban poor [already] have a certain level of built-in-resilience based on their existing coping capacities, but few links to formal planning/institutions and built-in resilience of the communities to work for a comprehensive disaster risk management. It also highlighted that people are responding to multiple perceived risks (e.g. flooding, possible job loss, future health problems) at the same time. Therefore, the authors conclude it would be useful to view their livelihood not in terms of disaster risk alone but multiple dimensions of risk. The climate signal is experienced as ‘climate variability’ (real, regular events) while ‘climate change’ is still viewed as a future issue, and not well understood.

Another example is the city of Dar es Salaam, which could be significantly impacted by sea-level rise and extreme weather events, but has no climate change adaptation plan (Kiunsi, 2013). Kiunsi reflects that the city is noted as having a high-level of climate vulnerability due to the scale of informal settlements, and while significant development interventions are ongoing these have not been compared to the climate signals.

In other areas, such as the city of Rosario in Argentina, research has considered the qualitative impacts of responses to the climate signals (Hardoy and Ruete, 2013), but clear quantification of whether the measures are sufficient to address future climate signals is not evident. This highlighted the high vulnerability due to climate change in part due to uneven provision and poor maintenance of critical infrastructure services. The focus on climate change was noted to focus on mitigation (low carbon development) as opposed to having a clear understanding of adaptation, in part due to a lack of data and modelling beyond

28 For example, the author’s highlight that on July 28, 2009 Dhaka experienced 333ml rainfall in 24 hours and 290ml in 6 hours, highest record in 53 years.

assessing the vulnerability of the city to flood risk. Bhat et al (2013) also refer to climate impact purely in terms of predicting flood risk and providing flood control measures and restriction of building in the flood plain, rather than considering whether the pattern of development should change.

In comparison in China, Li (2013) notes that there has been limited consideration of the implications of adaptation actions on reducing the climate change impacts. For example, a 1C rise in temperature in Shanghai is estimated to have led to a 3.67 GWh increase in daily electricity consumption. The main focus in China has been on economic growth, and only policies that are built into the growth framework have traction at a city/developmental level.

Thus, as the growth framework is driven by government, scientists, as well as local residents and small businesses who could be affected by climate change, are excluded from the decision making process, so limiting the opportunity for adaptive measures to be included and the impact of existing policies to be evaluated. So, while China has developed approaches to adapt its economic framework to address climate impacts there is a lack of evidence-based policy to determine whether the changes made so far (such is in terms of green growth) are sufficient to address the strength of the climate signals forecast.

Therefore, the overall ability of such developmental capacity to overcome the strength of climate signals is unknown.

How does the strength of economic development's climate impact affect poverty reduction targets?

This final section considers how the interrelation between economic development and climate change might impact poverty reduction in general terms. This is then explored in more detail in four sectors in the rest of this report. Gutierrez, McFarland and Fonua (2014) confirm that poverty reduction is exacerbated by climate change, alongside growth. This suggests that while the 2ºC of global warming already could put between 30 and 200 million people at risk of hunger (Stern, 2007), whether even greater impacts happen towards the second half of this century depends on the emissions path taken in the next few years and decades (for the reasons set out above). Therefore, even if the international community eradicates poverty, it also needs to tackle the effects of climate change in order to make these poverty reductions sustainable in the long term.

Woodward and Sims (2006) conclude that the current economic growth-led development pathway could make climate change irreversible (Woodward and Sims, 2006) with only limited poverty reduction, whether at a global, country or local level. Woodward and Sims cite the World Bank (2000) saying that focusing on growth first and environmental impacts later is dangerous because "many developing countries cannot reach the turnaround income level for decades", while further depleting natural resources, which reduces the possibility of a sustainable development pathway and the natural capital available to underpin disaster resilience. Therefore, not only is it not possible to reduce poverty without economic growth, economic growth as a goal (as opposed to allying poverty reduction to environmentally sustainable living[29] through improving distribution of incomes and benefits in an economy) tends to increase inequality[30], which will increase as opposed to reduce the capacity for climate adaptation.

29 Such as that set out in the 2010 WWF Living Planet Report: WWF, 2010, Figure 30.
30 Woodward and Sims (2006, Table 1) calculated an average of 0.6% of increase in economic growth leading to poverty reduction.

2.5 Other Areas Impacted by Climate Signals

The Up in Smoke reports (2004-2009), in addition to the areas above, considered the strength of climate signals against impacts in the areas of energy supply, water systems, livelihoods, migration and environment (including extinctions and biodiversity). Although these are not within the scope of this study, a synopsis of the relative strength of climate signals in these additional areas is discussed briefly below.

Energy

Energy is tied directly to climate change: in that choices made in these areas need to reduce the climate's impact (through mitigation) as well as enabling adaptation. IIED et al (2008) highlight many qualitative examples of adaptation and change. IIED et al (2009) cite the IEA's 2008 Energy Economic Outlook which predicts coal increasing from 25% to 28% of energy consumed by 2030, contributing to a 57% rise in CO_2 emissions from 2005 levels. A number of city-wide studies (e.g. Giannakopoulos and Psiloglou, 2006 cited in Hunt and Watkiss, 2011) note the likely increased energy demand, due to climate change. This is reflected by research in China highlighting the scale of summer peak electricity use that is used to satisfy air-conditioning in cities (Baoxing, 2007). Kirshen et al (2008, cited in Hunt and Watkiss, 2011) predict a 25% rise in energy use by 2030 alone, with a corresponding significant need to expand energy supply infrastructure – thus climate change could be significant in driving future patterns of investment in the energy sector. And this does not consider also the need to transition away from fossil fuel investment, and divestment in the sector, including by the donor and IFIs as noted by McKibben (2012).

Also, links between increased energy use and current development pathways for urbanisation could be investigated. For example, Baoxing (2007) notes that over 50% of Shanghai's carbon emissions in early 2000s was due to the construction industry alone: the urbanisation process is both creating a lot of carbon emissions directly and its scale and blueprints are locking-in the propensity for significant further increased carbon emissions in the future.

Tourism

With respect to Tourism, Hunt and Watkiss (2011) note that this is likely to largely be unaffected by climate change in areas where cultural heritage (e.g. Venice) are affected, while wider impacts such as on beaches and coastal environments are not cited although impacts could be significant.

Water

Most of the research identified considered the impact of water demand with respect to agriculture, and flooding in terms of impact. However, wider impacts include the links between flooding and health (through mixture of foul/waste water with drinking water sources). For example, IWM (2008) considers the impact of various sea level rises to salinity intrusion in Bangladesh, concluding that salinity in Khulna will be increased by 0.5 to 2 ppt for the 32 cm and 88 cm sea level rise. These wider impacts are studied less, in part as modelling is more complex and conclusions are less clear cut. One example though is Fung *et al* (2011) which investigates the interactions between climate change and population-driven demand for water in 2◦C and 4◦C worlds.

Hunt and Watkiss note few examples of city-scale studies of water availability although some have studied and note the increased demand for water as a result of climate change, but in relation to the USA, UK and Japan.

Environment (including extinction, habitat and biodiversity loss)

This is well reported elsewhere, such as the impacts including deforestation due to increased prevalence of wildfires (as well as related impact of deforestation), and has not been considered within the scope of this report.

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change: Health	Impacts of Climate Change: Agriculture	Impacts of Climate Change: Economic developmen	Impacts of Climate Change: Disaster resilience
1. Goklany, I. (2012). ‘Is climate change the number one threat to humanity?’ *Wires Climate Change*. 3: 489–508. doi: 10.1002/wcc.194	Secondary research	This article highlights that climate change is one of the most important issues mankind is currently facing, however other factors would have a greater net adverse impact on human and environmental well-being, ie “although climate change would increase the population at risk for malaria by as much as 320 million in 2085, population at risk in the absence of warming would be 8800 million. That is, climate change would contribute less than 4% to the total population at risk for malaria”. By 2085, only 13% of mortality from famine, malaria, and extreme weather events will be from global warming. It has also been estimated that malaria could be functionally eliminated if average GDP per capita exceeds $3100. Climate Data based on IPCC Report 2007.	✓			
2. Bowden, S. et al (2008). ‘Chasing Mosquitoes: an Exploration of the Relationship Between Economic Growth, Poverty and the Elimination of Malaria in Southern Europe in the 20th Century’. *Journal of International Development*, 20, pp. 1080–1106	Secondary research	This article explores how the elimination of malaria might reduce poverty and its implications on labour force and on agricultural sector. The paper concludes that while controlling malaria has positive economic effect, the escape from poverty is encouraged but not totally achieved by malaria elimination. The reduction of poverty is in part because of the escape from mortality and morbidity that malaria caused, but that reduction is mainly due to avoid the costs of ill health in general.	✓			
3. Jhajharia, D. et al. (2013) ‘Influence of climate on incidences of malaria in the Thar Desert, northwest India’. *International Journal of Climatology*, 33, pp. 312–325.	Secondary research	This research analyses the trend in the cases of malaria incidence in Bikaner, located in the Thar Desert of Rajasthan, in northwest India. From 1975 to 2008, malaria incidences increased significantly corresponding to monthly (April and September) and seasonal (monsoon) time-scale, as a result of warmer temperatures during this	✓			

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
		time. This paper corroborates global warming and climate change are likely to increase the incidences of vector-borne diseases such as malaria. Climate data based on IPCC report 2007				
4. Lindblade, K. et al. (2000). 'Land use change alters malaria transmission parameters by modifying temperature in a highland area of Uganda'. *Tropical Medicine and International Health*. 5, April, pp 263–274.	Primary research and entomological surveys	This paper demonstrates although highland regions of Uganda have been historically free of malaria, recent epidemics in these areas have raised concerns that high elevation malaria transmission is increasing. This is mainly due to change of land use, demographic patterns and variation of temperature.	✓			
5. Utzinger, J. (2002). 'The economic payoffs of integrated malaria control in the Zambian copperbelt between 1930 and 1950'. *Tropical Medicine and International Health*. 7, August pp 657–677	Secondary research	This study intends to assess the economic impact of malaria on the industrial and service sectors that will probably become the economic base of developing countries. An estimation of economic effects of integrated malaria control (rapid diagnosis, treatment, bed nets) was carried out on mining communities in Zambia. Analysis of historical data.	✓			
6. Sari Kovats, R. et al (2005). Climate Change and Human Health: Estimating Avoidable Deaths and Disease. *Risk Analysis*. 25, pp 1409-1418.	Secondary research	This paper estimates the future potential health impacts of climate change. Climate change can affect human health by different mechanisms and for a range of diseases and health outcomes such as mosquito-borne diseases, malnutrition. It concludes on the need to improve and develop tools of climate impact assessment. Climate data based on IPCC Report.	✓			
7. Asenso-Okyere, K. et al (2011). A review of the economic impact of malaria in agricultural development. *Agricultural economics*. 42, pp 293-304.	Secondary research	This study reviews the direct and indirect economic impacts of malaria in the agricultural sector. It highlights the importance of malaria as a major development issue and therefore its inclusion as one of the UN Millennium Development Goals. This also examines the economic impacts of malaria at household, health system and national scale.	✓		✓	
8. Packard, R. (2009) "Roll Back Malaria, Roll in Development"? Reassessing the Economic Burden of Malaria. *Population and Development*	Secondary research	This article traces the history of the arguments concerning economic burden of malaria and the economic benefits of malaria control. This historical research concludes that malaria causes a serious toll on health	✓		✓	

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change: Health	Agriculture	Economic development	Disaster resilience
Review. 35, pp 53-87.		and well-being. Thus, malaria results in economic losses, directly through spending on drugs and medical treatment. This highlights that effective control of malaria could significantly improve household incomes, reduce the burden malaria imposes on overused health services, and, in some settings, increase the productivity of labour.				
9. Afrane, Y.A (2012). The Ecology of Anopheles Mosquitoes under Climate Change: Case Studies from the Effects of Deforestation in East African highlands. *Annals of the New York Academy of Sciences*. 1249. Pp 204-210.	Primary research	This study analyses how changes in climate could lead to variations in species composition in areas that may change the dynamics of mosquito-borne disease transmission, due to different anopheles species (vector for malaria and other diseases) being adapted to different climatic conditions. It is important to consider the effect of climate change on rainfall and environmental changes such as deforestation, urbanization and agricultural practices which could increase local temperatures in the highlands.	✓			
10. World Health Organization (2011). Malaria: Global Fund proposal development (Round 11). Available at http://www.who.int/malaria/publications/atoz/malaria_gf_proposal_dev_who_policy_brief_201106.pdf [accessed 18 December 2013]	Secondary research	This WHO report provides an overview of recommended tools that can be incorporated into Global Fund proposals. This also highlights overall objectives of antimalarial treatment including the decrease of malaria transmission by reducing the malaria parasite reservoir.	✓			
11. World Health Organization Pan American Health Organization (2010). Protecting Health from Climate Change Vulnerability and Adaptation Assessment. Available at: http://www.who.int/globalchange/VA_Guidance_Discussion.pdf [Accessed on 18 December]	Secondary research 3	This WHO report provides guidance to conduct assessment on vulnerability to the health risks of climate change, and of policies and programmes that could increase resilience, taking into account the multiple determinants of Climate - sensitive health outcomes. This illustrates various assessments carried out by different countries. The study concludes that risks of climate change provide opportunities and challenges to the health sector to demonstrate leadership on adaptation and mitigation. Nonetheless benefits will be greater if it involves other sectors in designing climate resilient pathways.	✓			

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
		Climate data based on IPCC Report (2007).				
12 World Health Organization. Protecting Health from Climate Change World Healthy Day 2008. Switzerland: WHO. Available at http://www.who.int/world-health-day/toolkit/report_web.pdf [Accessed on 18th December]	Primary research	This report on the World Healthy Day 2008, highlights that climate change is not only an environmental or developmental issue; more importantly, it places at risk the protection and improvement of human health and well-being.	✓			
13. Hulden, L. et al (2013) Average household size and the eradication of malaria. Journal of the Royal Statistical Society. Serie A, pp 1-18.	Secondary research – comparison	This paper demonstrated the probability of eradication of malaria increase when average household size drops below four people. This research proposes and tests that not only warmer temperatures increased malaria prevalence, also household size matters because malaria is transmitted indoors at night.				
14. World Health Organization (2013). Research Priorities for the Environment, Agriculture and Infectious Diseases of Poverty. WHO: Switzerland.	Primary research	This report evaluates information on research and the challenges presented by interfaces between environment, agriculture and infectious diseases of public health importance.	✓			
15. World Health Organisation (2008). World Malaria Report, Switzerland: WHO. Available at: http://whqlibdoc.who.int/publications/2008/9789241563697_eng.pdf [Accessed 17 December 2013]	Primary research and household surveys	This is a global report on malaria with a focus on policies, strategies and targets for malaria control, estimated burden of malaria in 2006, interventions to control malaria, impact of malaria control, and the country profile of high-burden countries.	✓			
16. World Health Organization (2013). World Malaria Report 2013.	Secondary research	This report intends to bring a better understanding of global malaria trends and the burden disease. It estimates malaria mortality rates were reduced by about 45% globally and by 49% in African Region between 2000 and 2012 and malaria incidence rates declined by 29% around the world and by 31% in African Region. These are as a result of major scale-up of vector control interventions, diagnostic testing and heath treatments. This report also recognises the importance of strengthening health infrastructures.	✓			

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change: Health	Agriculture	Economic development	Disaster resilience
17. World Health Organization (2002). Health and Sustainable Development, Meeting the Senior Officials and Ministers of Health. Available at: http://www.who.int/mediacentre/events/HSD_Plaq_02.7_def1.pdf [Accessed 17 December 2013]	Primary research	This report summarises the meeting held in Johannesburg, South Africa in 2002, which aimed to plan the health agenda for the upcoming World Summit on Sustainable Development.	✓			
18. Federal Ministry for Economic Cooperation and Development BMZ (2013). Saved Health Saved Wealth: an approach to quantifying the benefits of climate change adaptation. Germany: GIZ Deutsche Gesellschaft fur Internationale Zusammenarbeit. Available at: http://seachangecop.org/sites/default/files/documents/2013%2009%20GIZ%20-%20Approach%20to%20quantifying%20the%20benefits%20of%20CCA.pdf [Accessed 12 December 2013]	Secondary research	This report proposes a framework of two indicators that estimates the total value of an adaptation project to be assessed. Saved wealth (SW) comprises the value of public infrastructure, private property and income loss. Saved health (SH) evaluates avoided disease, disability and life loss. Also environmental impacts are taken into account qualitatively. The methodology for coastal adaptation projects has been applied to the Vietnamese case study.	✓			
19. Jackson, M. et al (2010). Modelling the effect of climate change on prevalence malaria. Statistica Neerlandica. 64, pp 388-400.	Secondary research	This study intends to analyse the effect of climate change on reported malaria in Western Africa by using various weather-related factors, however there are still many limitations and it would be necessary to refine the regression analysis.	✓			
20. Githeko, A.K, et al (2000). Climate Change and Vector-borne Diseases: a Regional Analysis. Bulletin of the World Health Organization. 78, pp. 1136-1147.	Secondary research	This article analyses climate variability on vector-borne diseases based on a continental assessment with the aim of shedding light on possible future trends, particularly in view of the increased likelihood of climate change.	✓			
21. Lipp, E K, Huq A and Colwell R (2002) Effect of Global Climate on Infectious Disease: the Cholera Model. doi: 10.1128/CMR.15.4.757-770.2002Clin. Microbiol. Rev. October 2002 vol. 15 no. 4 757-770	Secondary research	Review of the interlinkages between climate change and infectious diseases, focusing on cholera.	✓			

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
22. Hussain, G., 2009. 'Assessing the Impacts of Climate Change on Cereal Production and Food Security in Bangladesh.' Presented at the International Conference on Global Climate Change and its Effects, August 25-30, 2008, Dhaka, Bangladesh	Climate change scenario modelling	The study used a baseline and modelled three scenarios for cereal production in Bangladesh for 2050 and three for 2070 based on the IS92a emission scenario (515ppm for 2050) in IPCC Third Assessment Report (2007).		✓		
23. Lines, T (2012) Primary Commodity Prices and Global Food Security: Why farmers struggle when food prices rise. ISBN 978-0-9573738-1-5. http://www.greenhousethinktank.org/files/greenhouse/home/Food_smaller.pdf	Analysis of global crop and agricultural input prices.	Research for UNCTAD, examining the prices of commodities used in the world food economy, against food prices. It compares two recent periods about 30 years apart, and considers how price changes affected poor developing countries and food security within them.		✓		
24. Calzadilla, A. et al. (2013) Climate change impacts on global agriculture. Climatic change. VOL 120; NUMBER 1-2, ; 2013, 357-374	Climate model to predict impact on global agriculture.	This considers the impacts on climate change and CO_2 on global agriculture based on the IPCC SRES A1B and A2 scenarios, not including wider non-physiological impacts.		✓		
25. Calzadilla, A. et al. (2013b) Economy-wide impacts of climate change on agriculture in sub-Saharan Africa. Ecological economics: the journal of the International Society for Ecological Economics. VOL 93, 2013, 150-165.	Analysis of two climate change adaptation scenarios	The authors have analysed two climate change adaptation scenarios that could increase agricultural productivity by 25%, against climate change to determine overall impacts, using IPCC SRES B2 scenario as a baseline.		✓		
26. Laderach, P. et al. (2013). Predicting the future climatic suitability for cocoa farming of the world's leading producer countries, Ghana and Corte d'Ivoire. Published in Climatic change. VOL 119; NUMBER 3-4, 2013, 841-854.	Climate model to predict impact on cocoa production	This study models the impact of climate change (IPCC A2 business as usual scenario, 2007) on the growing of cocoa in the Ivory Coast and Ghana, leading to a 1.2C increase by 2030 and 2.1C increase by 2050, leading to a relative drastic impact on cocoa production.		✓		

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
27. Evangelista, P.; Young, N.; Burnett, J. (2013) How will climate change spatially affect agriculture production in Ethiopia? Case studies of important cereal crops. Published at Climatic change. VOL 119; NUMBER 3-4, ; 2013, 855-873.	Country case studies	Case studies reviewing the impact of climate change on production of different cereals (teff, barley, sorghum and maize) with similar decreasing trends in land area across all four crops with barley affected most (-28 to -62%) and sorghum (-21 to +14%) affected the least. This was modelled using A2a and B2a climate scenarios to 2050.		✓		
28. Berg, A. et al. (2013) Projects of climate change impacts on potential C4 crop productivity over tropical regions. Agricultural and forest meteorology. VOL 170, ; 2013, 89-102 -- Elsevier Science B.V., Amsterdam. -- 2013	Primary research – climate model	Model to determine the impact of climate change on food security in the tropics, based on IPPC 2007 scenarios. Use a new Dynamic Global Vegetation Model to analyse climate impacts.		✓		
29. Tao, F. et al. (2009) Climatic change, land use change and China's food security in the mid 21st century: an integrated perspective. Climatic change. VOL 93; NUMBER 3-4, ; 2009, 433-445	Climate model of impact on food supply	Modelling of IPCC scenarios A1, A2, B1 and B2 on food security in China across the 21st century.		✓		
30. Ye, L. et al. (2012) Climate impact on China food security in 2050. Agronomy for sustainable development. VOL 33; NUMBER 2, ; 2013, 363-374 .	Model of food production and climate change for China	Modelling of the impact of climate change (IPCC 2007 A2 and B2 scenarios) on agricultural productivity. This concludes that through the inclusion of the impact of increased CL2 concentrations on plant growth, this will lead to a positive impact.		✓		
31. Davis A, Gole T, Baena S and Moa J (2012) The Impact of Climate Change on Indigenous Arabica Coffee (*Coffea arabica*): Predicting Future Trends and Identifying Priorities. Published: November 07, 2012. DOI: 10.1371/journal.pone.0047981 http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0047981	Modelling impact of climate change on coffee distribution.	Using distribution data we perform bioclimatic modelling and examine future distribution with the HadCM3 climate model for three emission scenarios (A1B, A2A, B2A) over three time intervals (2020, 2050, 2080). The models show a profoundly negative influence on indigenous Arabica.		✓		

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
32. Jaramillo J, Muchugu E, Vega F, Davis A, Borgemeister C and Chabi-Olaye A (2011) Some Like It Hot: The Influence and Implications of Climate Change on Coffee Berry Borer (*Hypothenemus hampei)* and Coffee Production in East Africa. Published: September 14, 2011. DOI: 10.1371/journal.pone.0024528	Modelling to quantify impact of climate on a coffee pest.	Review of research into impact of a pest on coffee production with predicted climate change impacts until 2050, based on IPPC third assessment report, A1 and B2 projections.		✓		
33. Waithaka, M.; Nelson, G.C.; Thomas, T.S.; Kyotalimye, M. (Editors) East African Agriculture and Climate Change. A Comprehensive Analysis. International Food Policy Research Institute (IFPRI), Washington, DC, USA (2013) 434 pp pp. ISBN 978-0-89629-205-5 [DOI: http://dx.doi.org/10.2499/9780896292055]	Climate and agriculture modelling	This models the impact of climate change on agriculture across East Africa, using the A1B model from IPPC FAR (2007). It focuses on productivity affects not livelihood impacts. For rain-fed crops, it is assumed that for all of the four-month growing period the monthly total precipitation is not less than 60 millimetres (i.e. it appears not to model increased incidence of drought). As a result it appears biased in favour of maize.		✓		
34. Meade, B.; Rosen, S. International Food Security Assessment, 2013-2023, GFA-24.U.S. Department of Agriculture, Economic Research Service, Washington, DC, USA (2013) 56 pp. www.ers.usda.gov/media/1138077/gfa-24a.pdf	Economic model	This provides a quantitative assessment to 2023 of the food security status for 76 low/middle-income countries. The modelling, based on food price, consumption and access, this report concluded that the impact of high global food prices as being small.		✓	✓	
35. ADB (2013) Food Security Challenges in Asia: Working Paper. Published by ADB. URL: http://www.adb.org/sites/default/files/food-security.pdf	Review of available literature	Independent Evaluation Board report of the ADB's internal working group report on the impact of climate change and other factors upon food security in Asia.		✓		
36. Slater R, Peskett L, Ludi E and Brown D (2008) Climate Change, agricultural productivity and poverty reduction – how much do we know? Published as ODI Natural Resource Perspective, No. 109.	Literature Review	Overall review of the interconnections between climate change, agricultural policy choices and poverty choices, drawing principally on Parry (2004) modelling of climate impacts without beneficial CO2 effects.		✓		

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
37. Wheeler T and Von Braun J (2013) Climate change impacts on global food security. Science. 341 (6145) pp508-513.	Review	Review of impact of climate change on stability of food systems.		✓		
38. Manyeruke C, Hamauswa S and Mhandara L (2013) The effects of climate change and variability of food security in Zimbabwe: a socio-economic and political analysis. International Journal of Humanities and Social Science; 2013, 3(6): 270-286.	Country socio-economic analysis	Review of the climate change adaptive strategies in Zimbabwe to date and whether these can continue in the future, to enable the increased productivity needed to address climate change impacts.		✓		
39. Van Wart, ; Grassini, P, and Cassman, K (2013). Impact of derived global weather data on simulated crop yields. GLOBAL CHANGE BIOLOGY volume 19 issue 12 page 3822 - 3834 . DOI: 10.1111/gcb.12302. http://onlinelibrary.wiley.com/doi/10.1111/gcb.12302/full	Evaluation of global crop simulation models	Review of 3 global crop simulation models, concluding that results from studies that rely on GWD to simulate agricultural productivity in current and future climates are highly uncertain. An alternative approach would impose a climate scenario on location-specific observed daily weather databases combined with an appropriate upscaling method.		✓		
40. Kotir, J H (2011) Climate Change and Variability in Sub-Saharan Africa: a review of current and future trends and impacts on agriculture and food security. Environment, development and sustainability. Vol 13. No. 3 2011, 587-605 – Springer Science and Business Media, 2011.	Review of food security and climate change research	Review focused on sub-Saharan Africa, concluding that this is the region most vulnerable to the impacts of climate change and associated loss in food security.		✓		
41. de Haen H and Hemrich G .(2007) The economics of natural disasters: implications and challenges for food security. The Agricultural Economist Vol 37	Review	While most agricultural research focused on the long-term climatic impacts on agricultural productivity this considered the impact of increased natural resources on food security.		✓		✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
42. Greg Edame , Bassey Ekpenyong, William Fonta, EJC Duru (2011). Climate Change, Food Security and Agricultural Productivity in Africa: Issues and policy directions. International Journal of Humanities and Social Science Vol. 1 No. 21 [Special Issue - December 2011] 205	Review	*Examines the economic impact of climate change (CC) on food security and agricultural productivity in Sub Saharan Africa (SSA).*		✓		
43. Seto, Karen C., Susan Parnell, and Thomas Elmqvist. (2013) "A Global Outlook on Urbanization." Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. Springer Netherlands, 2013. 1-12.	Book	Analysis of the impact of global urbanisation trends by 2050.			✓	
44. Kevin Anderson and Alice Bows (2012). Executing a Scharnow turn: reconciling shipping emissions with international commitments on climate change. Carbon Management (2012) 3(6), 615–628	Climate modelling of shipping.	Modelling of current industry projections against climate models to develop safe emission reduction pathways.			✓	
45. Mark New, Diana Liverman, Heike Schroder and Kevin Anderson (2011) 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. doi: 10.1098/rsta.2010.0303.	Climate modelling of economic growth business as usual.	Consideration of the increased implications of 4C rise this century, as contrast to most climate scenarios which consider 2-4C warming.	✓	✓	✓	✓
46. Brady D and Spence M (Ed) (2010) Leadership and Growth: Report of the World Bank Commission on Growth and Development. Published at https://openknowledge.worldbank.org/bitstream/handle/10986/2404/527080PUB0lead101Official0Use0Only1.pdf?sequence=1 DOI: http://dx.doi.org/10.1596/978-0-8213-8100-7	Report of study of economic development	This study analysing the link between growth and development includes no consideration of climate impacts although case studies include sub-Saharan African economies and Bangladesh.			✓	

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
47. Wahiduddin Mahmud, Sadiq Ahmed, and Sandeep Mahajan (2010) Economic Reforms, Growth, and Governance:The Political Economy Aspects of Bangladesh's Development Surprise, published in Leadership and Growth: Report of the World Bank Commission on Growth and Development. Published at https://openknowledge.worldbank.org/bitstream/handle/10986/2404/527080PUB0lead101Official0Use0Only1.pdf?sequence=1	Economic review of last 30 years of development in Bangladesh	Highlights success of garment-industry, driving urbanisation which has led to Bangladesh's "development surprise."			✓	
48. World Bank (2011) Rwanda Economic Update: Spring Edition, April 2011. http://siteresources.worldbank.org/INTRWANDA/Resources/Rwanda_Economic_Rwanda_Update_Spring_Edition_April_2011.pdf	Economic Review	Latest analysis of economic development of Rwanda, analysed to highlight trend in expanding sectors in an LDC.			✓	
49. Park J., Seager T., Rao P., Convertino M., and Linkov I. (2013) Integrating Risk and Resilience Approaches to Catastrophe Management in Engineering Systems. Risk Analysis, Vol. 33, No. 3, 2013 DOI: 10.1111/j.1539-6924.2012.01885.x	Secondary research	Review of risk and resilience approaches to developing resilience of infrastructure and physical development.			✓	✓
50. Mallick D.L., Rahman A., Alam M., Juel A., Ahmad A. and Alam S., (2005) Case Study 3: Bangladesh Floods in Bangladesh: A Shift from Disaster Management Towards Disaster Preparedness. IDS Bulletin Vol 36 No 4 October 2005.	Secondary research	Contrasts the use of the terms risk and resilience in description of infrastructure and construction, arguing that current approaches tend to 'improperly conflates resilience and risk perspectives by expressing resilience exclusively in risk terms. In contrast, we describe resilience as an *emergent property* of what an engineering system *does*, rather than a static property the system *has*. Therefore, this includes not just the technical design of the infrastructure but the institutional capacities and requirement for 'continuous management' thereafter.			✓	✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
51. Freestone, R (2009) Planning, Sustainability and Airport-Led Development. International planning studies. VOL 14; NUMBER 2, ; 2009, 161-176	Review of aviation development	Literature review considering interplay between airport and urban development.			✓	
52. Hunt, A.; Watkiss, P. (2011) Climate change impacts and adaptation in cities: a review of the literature. Published in Climatic change. VOL 104; NUMBER 1, ; 2011, 13-49	Literature review	Review as to the assessment and quantification of climate risks at a city scale, finds that this is mainly focused on developed country cities (e.g. London, New York) and limited focus on energy, transport and built infrastructure. This draws on range of reports both before and after IPPC 4th Assessment Report in 2007.			✓	✓
53. Hanson, S. et al. (2011) A global ranking of port cities with high exposure to climate extremes. Published in Climatic change. VOL 104; NUMBER 1, ; 2011, 89-111 -- Springer Science + Business Media – 2011	Six scenarios using GIS to provide first estimate of vulnerability.	Estimate of the exposure of port cities with over 1 million inhabitants to coastal flooding due to sea-level rise and storm surge until the 2070s.			✓	✓
54. Dasgupta, S., Gosain, A.K., Rap, S., Roy S., Sarraf, M., (2013) A megacity in a changing climate: the case of Kolkata. Published in Climate Change (2013)	Primary research	Modelling of the impacts of increased precipitation and sea-level rise on vulnerability of Kolkata (India) to flooding, based on IPPC AR4 2007 data.			✓	✓
55. Condon, J.A.,, Sheng, P.Y., (2012) Evaluation of coastal inundation hazard for present and future climates. Published in Nat. Hazards (2012) 62: 345-373 DOI 10.1007/s11069-011-9996-0.	Primary research	Simulation and calculation of coastal inundation as a result of sea level rise combined with storm surge.			✓	✓
56. Sherbinin A, Schiller A, Pulsiphe A (2006) The vulnerability of global cities to climate hazards. Environ Urban 12:93-102.	Comparative review	A review of the relative climate vulnerabilities of Mumbai, Rio de Janeiro and Shanghai – referenced by Hunt and Watkiss (2011) based on IPC TAR climate data.			✓	✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
57. Anika Nasra Haque, Stelios Grafakos and Marijk Huijsman (2012) Participatory integrated assessment of flood protection measures for climate adaptation in Dhaka. *Environment and Urbanization* 2012 24: 197 DOI: 10.1177/0956247811433538. URL: http://eau.sagepub.com/content/24/1/197	Study into impact of building on Dhaka's floodplain	Evaluation of the nature and impact of development onto areas set aside as flood plain around the eastern perimeter of the city of Dhaka, in Bangladesh.			✓	✓
58. Baoxing, Qiu (2007) Harmony and Innovation: Problems, Dangers and Solutions in Dealing with Rapid Urbanisation in China. Printed in Italy by l'Arcaedizioni.	Not applicable.	Explanation of the climate impact of development in China by the then Minister of Construction.			✓	
59. McKibben, B (2012) Global Warming's Terrifying New Math. Published in http://www.rollingstone.com/politics/news/global-warmings-terrifying-new-math-20120719	Not applicable	Comparison of the scale of stock-listed fossil fuel assets by the major fossil fuel corporations with the maximum amount of climate change emissions that scientists estimate can safely be emitted to stay within 2C global warming.			✓	
60. Giannopoulos G., Filippini, R., Schimmer, M., Risk Assessment Methodologies for Critical Infrastructure Protection. Part I: A State of Art, JRC Technical Notes, EUR 25286 EN – 2012	Methodology Review for Risk Assessment	Review of various risk assessment methodologies for reviewing the resilience of critical infrastructure, both in the EU and world-wide.			✓	
61. Kiunsi, R (2013) The constraints on climate change adaptation in a city with a large development deficit: the case of Dar es Salaam. Published in Environment and Urbanisation, Vol 25(2) 321-337 DOI: 10.1177/0956247813489617.	Case Study	Review of the level of capacity for development of Dar Es Salaam, Tanzania to overcome climate change impacts.			✓	✓
62. Li, B, (2013) Governing urban climate change adaptation in China. Environment and urbanisation, 2013 25: 413 DOI: 10.1177/095624781390907	Case Study	Review of the level of developmental response against climate change impact in urban areas of China.			✓	✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
63. Hardoy, J and Ruete, R (2013) Incorporating climate change adaptation into planning for a liveable city in Rosario, Argentina. Environment and Urbanisation, Vol 25(2) 339-360, DOI: 10.1177/0956247813493232	Case Study	Review of the extent to which climate signals have been addressed in urban planning in Rosario, Argentina.			✓	✓
64. Bhat G K, Karanth A, Dashora L and Rajasekar U (2013) Addressing flooding in the city of Surat beyond its boundaries. Published in Environment and Urbanisation, Vol 25(2): 429-441. DOI: 10.1177/ 0956247813495002.	Case Study	Consideration of the impact of flooding on Surat in India, and the measures needed to address climate impacts in the short, medium and long term, based on latest climate impact estimates.			✓	✓
65. Turok I, McGranahan G (2013) Urbanisation and economic growth: the arguments and evidence for Africa and Asia (2013) Vol 25(2): 465-482 DOI: 10.1177/0956247813490908	Literature Review	Extensive literature review of the connection between urbanisation and poverty reduction/social development in cities worldwide. No consideration of climate change.			✓	
66. Woetzel, Jonathan, et al. "Preparing for China's urban billion." *McKinsey Global Institute, March* (2009).	Economic-focused review	McKinsey Global Institute research which determines the impacts of the scale of expansion of urbanised areas in China, from resource impact to energy demands.			✓	
67. Richard Dobbs, Jeremy Oppenheim, Fraser Thompson, Marcel Brinkman, Marc Zornes (2011) Resource revolution: meeting the world's energy, materials, food and water needs. Published by McKinsey Global Institute. http://www.mckinsey.com/insights/energy_resources_materials/resource_revolution	Economic scenario planning for resource scarcity	McKinsey Global Institute research setting out three scenarios (increase supply, improve productivity, respond to climate change) as alternative strategies for responding to resource constraints in the future, globally.			✓	
68. McKinsey (2012) Towards the Circular Economy: Economic and business rationale for an accelerated transition. Published at http://www.ellenmacarthurfoundation.org/business/reports/ce2012	Business Case	Research underpinning the notion of a circular economy, produced for the Ellen Mac Arthur Foundation. Sets out strategy for linking resource use and economic development.			✓	

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
69. Heatley, B (2012) Joined up economics: the Political Economy of Sustainability, Financial Crises, Wages, Equality and Welfare. Published at http://www.greenhousethinktank.org/page.php?pageid=publications ISBN 978-0-9569545-9-6	Economic model for UK economy	Review of economic impact of resource scarcity and climate change in the future, based on an economic-based model developed for the UK.			✓	
70. Satterthwaite D (2011) How urban societies can adapt to resource shortage and climate change? Phil. Trans. R. Soc. A (2011) 369. 1762-1783 doi: 10.1098/rsta.2010.0350.	Literature review	Consideration of how cities might development in a low carbon manner in the future.			✓	
71. EC (2013) Adapting infrastructure to climate change (Accompanying "An EU Strategy on adaptation to climate change") Brussels, 16.4.2013, SWD(2013) 137 final.	Infrastructure adaptation strategy for the EU	Strategy for climate adaptation for infrastructure in the EU up to 2100: working paper produced to accompany the EU Strategy on adaptation to climate change.			✓	
72. World Bank (2011) The Cost of Adapting to Extreme Weather Events in a Changing Climate. Bangladesh Development Series, Paper No. 28.	Cost estimate	Cost estimate based on 0.27m sea-level to 2050.			✓	
73. COWI (2010) Making Transport Climate Resilient. Country Report: Mozambique, August 2010. Published by the World Bank.	Country Strategy	Strategy developed for response to climate change within the transport sector of Mozambique. One of three similar country studies produced. Concludes that for resilience a focus on future maintenance of infrastructure is required.			✓	✓
74. Satterthwaite D (2013) The political underpinnings of cities' accumulated resilience to climate change. Environment and urbanisation 2013 25:381, published 2 September 2013. DOI: 10.1177/0956247813500902.	Discussion	Reviews the political response to the challenge of resilience for urban areas, and how this impacts at different levels of institutions.				✓
75. Satterthwaite D and Dodman D (2013) Towards resilience and transformation for cities within a finite planet. Environment and urbanisation. 2013 25 (2) 291-298 DOI:	Secondary research	Review of the challenge of resilience for cities within resource and climate constraints.				✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
10.1177/0956247813501421.						
76. Parvin, G and Shaw, R (2011) Climate Disaster Resilience of Dhaka City Corporation: An Empirical Assessment at Zone Level. Risks, Hazards and Crisis in Public Policy: Volume 2, Issue 2 • 2011 • Article 6. www.psocommons.org/rhcpp/.	Case Study	Consideration of the response to climate change and disasters within the city of Dhaka, Bangladesh.				✓
77. Tadele F and Manyena SB., (2009) Building disaster resilience through capacity building in Ethiopia. Disaster Prevention and Management, Vol. 18 No. 3, 2009, pp. 317-326	Case Study	Review of capacity for adaptation to increased prevalence of disasters in Ethiopia.				✓
78. Sudmeier K., Jaboyedoff M., and Jaquet S., (2013) Operationalizing “resilience” for disaster risk reduction in mountainous Nepal Disaster Prevention and Management, Vol. 22 No. 4, 2013, pp. 366-377	Case Study	Review of the potential to adapt to disasters and reduce corresponding risks in the mountain areas of Nepal.				✓
79. S. Bernard Manyena (2006) Rural local authorities and disaster resilience in Zimbabwe. Published by the Disaster and Development Centre, Northumbria University, Newcastle upon Tyne, UK. DPM 2006:15,5, pp810-820. www.emeraldinsight.com/0965-3562.htm	Case Study	Consideration of the capacity to ameliorate disaster impact through institutional strengthening of local institutions in Zimbabwe.				✓
80. Huraera Jabeen, Adriana Allen and Cassidy Johnson (2010) "Built-In-Resilience: Learning from Grassroots Coping Strategies to Climate Change Variability" 1st EPICentre-JDCR International Risk Perception Symposium "Cities at Risk: Living with Perils in the 21st Century" in London in December 2009 organized by University College of London.	Stakeholder interviews in urban slum.	This research seeks, firstly, to understand how the impacts of climate change in **Bangladesh** are going to affect the urban poor in **Dhaka** and secondly, to address plans for adaptation at the local (neighbourhood level) that will address vulnerability.			✓	✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change: Health	Impacts of Climate Change: Agriculture	Impacts of Climate Change: Economic development	Impacts of Climate Change: Disaster resilience
www.bartlett.ucl.ac.uk/dpu/adaptation_to_climate_change_in_cities/dissemination/UCL_Pereception_Symposium.pdf						
81. Linnenluecke M., Andrew Griffiths A., and Winn M., (2012) Extreme Weather Events and the Critical Importance of Anticipatory Adaptation and Organizational Resilience in Responding to Impacts. Bus. Strat. Env. 21, 17–32 (2012) Published online 16 February 2011 in Wiley Online Library DOI: 10.1002/bse.708	Secondary research	Review of institutional capacity to achieve resilience and adaptation to extreme weather events.				✓
82. Jones S., Aryal K., and Collins A., (2006) Local-level governance of risk and resilience in Nepal. doi:10.1111/disa.12006	Case Study	Review of capacity to build resilience at a local level in Nepal.				✓
83. Davies M., Béné C., Arnall A., Tanner T., Newsham A., and Coirolo C., (2013) Promoting Resilient Livelihoods through Adaptive Social Protection: Lessons from 124 programmes in South Asia. Development Policy Review, 2013, 31 (1): 27-58	Secondary research	Review of the extent to which adaptive social protection is an effective strategy for building resilience in different case studies across South Asia.				✓
84. Rubin O., Rossing T., (2012) National and Local Vulnerability to Climate-Related Disasters in Latin America: The Role of Social Asset-Based Adaptation. Bulletin of Latin American Research, Vol. 31, No. 1, pp. 19–35, 2012.	Secondary research	Reviewing the extent that social assets can provide effective resilience to climate related disasters in Latin America.				✓
85. Geoff O'Brien, Phil O'Keefe, Joanne Rose and Ben Wisner (2006) Climate change and disaster management. Disasters, 2006, 30(1): 64−80. Published by Blackwell Publishing, 9600 Garsington Road, Oxford, OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA.	Secondary research	Review of climate change and disaster management, considering disaster policy response to climate change as both a complex and protracted hazard. Reviews extent to which this fits with traditional response regimes and how capacity-building and resilience can be enhanced as a prerequisite for managing climate change risks in ways which reduce vulnerability.				✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
86. Institute of Water Modelling (2008) Impact Assessment of Climate Change and Sea Level Rise on Monsoon Flooding. Published by Climate Change Cell, Department of Environment (DoE), Bangladesh http://www.bdresearch.org.bd/home/climate_knowledge/cd1/pdf/Bangladesh%20and%20climate%20change/Flood/MonssonFlooding_Jan'09.pdf	Modelling, including review of recent studies in Bangladesh.	Climate modelling of impact of sea-level rise on monsoon flooding in Bangladesh, including a review of flooding over the past fifty years and assessment of future impacts.			✓	✓
87. Anderson M., and Holcombe E. (2013) Managing Disasters in Small Steps. Published by the World Bank. DOI: 10.1596/978-0-8213-9456-4.	Practical manual	Handbook setting out technical and institutional process to improve disaster resilience against landslides in informal settlements.			✓	✓
88. Mendelsohn, Robert, et al. "The impact of climate change on global tropical cyclone damage." *Nature Climate Change* 2.3 (2012): 205-209.	Model of cyclone damage.	Modelling of cyclone damage globally until 2100 against a no-climate-change baseline, and comparison of results against other research.			✓	✓
89. Brown O. , Hammill, A., Mcleman R., (2007) Climate change as the 'new' security threat: implications for Africa International Affairs. Volume 83, Issue 6, pages 1141–1154, November 2007. Article first published online: 22 OCT 2007. DOI: 10.1111/j.1468-2346.2007.00678.x.	Secondary research	Review of climate change impact on security in Africa.				✓
90. Celia McMichael, Jon Barnett, and Anthony J. McMichael (2012) An Ill Wind? Climate Change, Migration, and Health. Environ. Health Perspect 2012 May, 120 (5): 646-654. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3346786/	Secondary research	Review of the inter-relations between climate change, health and the propensity for migration.				✓
91. Kniveton D, Martin M, and Rowhani P, (2013)	Secondary	This study reviews recent research into climate change and mobility in				✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
Sensitivity testing current migration patterns to climate change and variability in Bangladesh. Working paper 5. http://migratingoutofpoverty.dfid.gov.uk/files/file.php?name=wp5-ccrm-b-sensitivity.pdf&site=354	research	Bangladesh. It notes that most climate models indicate an increasing trend of monsoon rainfall and greater inflows into Bangladesh. The general circulation models (GCMs) forecast Bangladesh to be 1.5°C warmer and 4 percent wetter by the 2050s, so the extent of flooding is likely to increase as a recent study by the World Bank (2010) noted.				
92. Walsham, M (2010) Assessing the Evidence: Environment, Climate Change and Migration in Bangladesh. Published by International Organisation for Migration, Regional Office for South Asia. http://publications.iom.int/bookstore/free/environment_climate_change_bangladesh.pdf.	Secondary research	Review of the links between climate change and migration in the context of Bangladesh. While the report concludes that climate change is a critical issue, it concludes that, "predicting the scale of impacts of climate change on migration remains an extremely difficult task as existing estimates are based on long-term projections with a wide geographical scale and little recognition of the ability of individuals, communities and nations to adapt to reduce their vulnerability. There is a need for more localized, fine-grained projections, which take realistic account of the potential for adaptation and provide the data needed for planning over the short- and medium-term, as well as over longer term timeframes."				✓
93. Akter, T (2009) Migration and living conditions in urban slums: implications for food security. http://www.unnayan.org/reports/Migration.and.living.conditions.in.urban.slums.pdf	Primary research	Qualitative impacts of climate change on urban poverty is discussed, but not quantified. By analysing population displacement in major natural events like flood and cyclone over 40 years (1970-2009), it has been found that on an average 25% (39 million) and 2% (3 million) populations in each major flood and cyclone are displaced.				✓
94. Mohammed Mamun Rashid (2013) Migration to Big Cities from Coastal Villages of Bangladesh: An Empirical Analysis. Vol 13, No 5-B (2013): Global Journal of Human Social Science Research. http://socialscienceresearch.org/index.php/GJHSS/article/view/680	Primary research	Review of rural-urban migration in Bangladesh.				✓
95. Shadsuddoha M., Khan S., Raihan S and Hossain T., (2012) Displacement and Migration from Climate Hot-Spots in Bangladesh: causes	Secondary research	Review of the links between climate change, migration and economic development. Analysis of the economic growth of Bangladesh and how this links to climate change and migration.			✓	✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
and consequences. Published by Center for Participatory Research and Development and Action Aid, Dhaka, Bangladesh. http://www.actionaidusa.org/sites/files/actionaid/displacement_and_migration....pdf						
96. Displacement Solutions (2012) Climate Displacement in Bangladesh: The Need for Urgent Housing, Land and Property Rights Solutions, May 2012 http://displacementsolutions.org/ds-initiatives/climate-change-and-displacement-initiative/bangladesh-climate-displacement/	Secondary research	Review of the rights of climate migrants in Bangladesh, and proposal of policies and regulations to ensure that their rights are built into climate-resilient strategies for development.				✓
97. Equity and Justice Working Group Bangladesh (EquityBD) (2009) Climate Change Induced Forced Migrants: in need of dignified recognition under a new Protocol.www.equitybd.org/noticefboard_contain/cop16/Climate%20Migrant%20Printed%20Position.pdf	Secondary research	Review of the impact of current climate change on migration in Bangladesh, and the need for new approaches to migration and rights for migrants to ensure a climate resilience for these communities in the future.				✓
98. Miles S., Green R., Svekla W., (2011) Disaster risk reduction capacity assessment for precarious settlements in Guatemala City. Published at doi:10.1111/j.1467-7717.2011.01267.x	Case Study	Review of the impact of disasters (such as landslides) on vulnerable urban communities, focusing on hillside settlements in Guatemala City.				✓
99. Arnall A., (2013) A climate of control: flooding, displacement and planned resettlement in the Lower Zambezi River valley, Mozambique. The Geographical Journal, 2013, doi: 10.1111/geoj.12036	Case Study	Assessment of migration from the Lower Zambezi river valley in Mozambique and the extent to which the subsequent relocation has been beneficial for those displaced.				✓

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Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
100. Mukand, S (2012) International migration, politics and culture: the case for greater labour mobility. Published by Chatham House. www.chathamhouse.org and www.warwick.ac.uk/cage	Secondary research	Review and study of the potential political and economic impacts of migration as a tool for development.				✓
101. Conroy, K., Goodman, A., Kenward, S., (2010) Lessons from the Chars Livelihoods Programme, Bangladesh (2004-10). www.chronicpoverty.org/uploads/publication_files/conroy_goodman_kenward_chars.pdf	Primary research	Review of the Chars Livelihood Programme in Northern Bangladesh.				✓
102. Forsyth T., and Schomerus M., (2013) Climate Change and Conflict: a systematic evidence review. JSRP Paper 8. ISSN 2051-0926. (Not cited)	Literature review	Review of papers linking climate change and conflicts in developing countries. It concludes that many studies are based on assumptions or causal models that are unexplored, unproven or too simple – and stronger causality is needed to unpick assumptions made.				✓
103. Jürgen Scheffran, Michael Brzoska, Jasmin Kominek, P. Michael Link, Janpeter Schilling (2012). Climate Change and Violent Conflict. www.sciencemag.org Science Vol 336 18 May 2012.	Secondary research	Critical review of whether there is real causality between climate change and conflict, and the extent to which this is proven within existing studies.				✓
104. Nils Petter Gleditsch (2012) Whither the weather? Climate change and conflict. Journal of Peace Research 2012 49: 3. DOI: 10.1177/0022343311431288.	Secondary research	Review of the links between climate change and conflict. It concludes that direct links are limited, but some indirect links may occur, but research in this area is still limited.				✓
105. Adger, W. Neil. "Social capital, collective action, and adaptation to climate change." *Der Klimawandel*. VS Verlag für Sozialwissenschaften, 2010. 327-345.	Secondary research	Consideration of the links between social capital and collective action to climate adaptation. The research concludes that these provide effective responses that increase resilience, but this is not quantified with respect to the climate challenge.				✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
106. Jane McAdam and Ben Saul, "Displacement with Dignity: International Law and Policy Responses to Climate Change Migration and Security in Bangladesh" (December 2010). University of New South Wales Faculty of Law Research Series 2010. Working Paper 63. http://law.bepress.com/unswwps-flrps10/art63	Secondary research	Extensive review of the nature and links between climate change and migration, considering the extent to which migration is an effective adaptation strategy for many and therefore should be mainstreamed into considerations for climate change adaptation. The research focused on Bangladesh.				✓
107. Anderson (2012) Climate change going beyond dangerous - Brutal numbers and tenuous hope. Development Dialogue September 2012 | What Next Volume III | Climate, Development and Equity	Published transcript of presentation to DFID.	This article is based on a transcript of a public presentation at the UK's Department for International Development (DFID) in July 2011, available at http://www.slideshare.net/DFID/professor-kevin-anderson-climate-change-going-beyond-dangerous.	✓	✓	✓	✓
108. Kevin Anderson & Alice Bows. Nature Climate Change 2, 639–640 (2012) A new paradigm for climate change. doi:10.1038/nclimate1646, 28 August 2012. http://www.nature.com/nclimate/journal/v2/n9/full/nclimate1646.html	Review of policy/practice gap of climate action.	Climate science demonstrates the 2 °C threshold is no longer viable within orthodox political and economic constraints. It is unsubstantiated hope in the scientific community that leaves such constraints unquestioned, while legitimizing a focus on increasingly improbable low-carbon futures and underplaying high-emission scenarios.	✓	✓	✓	✓
109. Mark New, Diana Liverman, Heike Schroder and Kevin Anderson (2011) 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. doi: 10.1098/rsta.2010.0303	Review of climate models considering 4^{0}C global rise.	Introductory article to Royal Society journal bringing together papers modelling the likely consequences of 4^{0}C temperature rise globally as a result of climate change.	✓	✓	✓	✓
110. Betts, R. A., Collins, M., Hemming, D. L., Jones, C. D., Lowe, J. A. & Sanderson, M. G. (2011) When could global warming reach 4◦C? Phil. Trans. R. Soc. A 369, 67–84. (doi:10.1098/rsta.2010.0292)	Climate model	Modelling to determine when we will reach 4^{0}C temperature change globally based on current emission projections.	✓	✓	✓	✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
111. Sriver R., Urban N., Olson R., and Keller K., (2012) Toward a physically plausible upper bound of sea-level rise projections. Climate Change Letters (2012). Published at link.springer.com/article/10.1007%2Fs10584-012-0610-6	Climate model of sea level rise	Summary of climate modelling carried out to estimate what an upper-bound sea level rise by 2100 is likely to be.	✓	✓	✓	✓
112. Rogelj, J., Hare, B., Nabel, J., Macey, K., Schaeffer, M., Markmann, K. & Meinshausen, M. (2009) Halfway to Copenhagen, no way to 2◦C. Nat. Rep. Clim. Change 3, 81–83. (doi:10.1038/climate.2009.57)	Climate model	Estimation of emission reductions in developed countries to stay within a 2^0C global warming limit.	✓	✓	✓	✓
113. Nicholls, R. J., Marinova, N., Lowe, J. A., Brown, S., Vellinga, P., de Gusmão, D., Hinkel, J. & Tol, R. S. J. 2011 Sea-level rise and its possible impacts given a 'beyond 4◦C world' in the twenty-first century. Phil. Trans. R. Soc. A 369, 161–181. (doi:10.1098/rsta.2010.0291)	Sea Level Rise Model	Modelling of Sea Level Rise for 4^0C global warming.			✓	✓
114. Thornton, P. K., Jones, P. G., Ericksen, P. J. & Challinor, A. J. 2011 Agriculture and food systems in sub-Saharan Africa in a 4◦C+ world. Phil. Trans. R. Soc. A 369, 117–136. (doi:10.1098/rsta.2010.0246)	Climate and agriculture model	Modelling of a 4^0C+ increase in global warming on agriculture in Africa.		✓		
115. Warren, R. 2011 The role of interactions in a world implementing adaptation and mitigation solutions to climate change. Phil. Trans. R. Soc. A 369, 217–241. (doi:10.1098/rsta.2010.0271)	Review of 4^0C impacts	Interactions between climate impacts in a 4^0C warming world.	✓	✓	✓	✓
116. Smith, Mark Stafford, et al. "Rethinking adaptation for a 4 C world."Philosophical Transactions of the Royal Society A:	Review of decision making models	Review of approaches for adaptive planning that would be need to plan adaptation for a 4^0C+ global warming	✓	✓	✓	✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic development	Disaster resilience
Mathematical, Physical and Engineering Sciences 369.1934 (2011): 196-216.						
117. IPPC (2013). IPPC Working Group 1, Contribution to the IPCC Fifth Assessment Report Climate Change 2013: The Physical Science Basis. 27 September 2013.	Summary for policymakers	Final draft of all peer reviewed physical science basis for climate change, published by the IPCC on 27 September 2013 as the first section of the IPCC's fifth assessment report.	✓	✓	✓	✓
118. IIED and the Working Group on Climate Change and Development (2006) Africa Up in Smoke? 2. Published at http://pubs.iied.org/10018IIED.html	Secondary research	Review of, mainly qualitative links between climate change and development in Africa. This is an update of an earlier report produced.	✓	✓	✓	✓
119. IIED and the Working Group on Climate Change and Development (2006) Up in Smoke? Latin America and the Caribbean. Published at pubs.iied.org/10017IIED.html .	Secondary research	Review of, mainly qualitative links between climate change and development in the Caribbean.	✓	✓	✓	✓
120. IIED and the Working Group on Climate Change and Development (2007) Up in Smoke? Asia and the Pacific. The threat from climate change to human development and the environment. Published at http://pubs.iied.org/10020IIED.html	Secondary research.	Review of, mainly qualitative links between climate change and development in Asia. The high level of climate risk is highlighted for the populations living in Asia to climate change.	✓	✓	✓	✓
121. IIED and the Working Group on Climate Change and Development (2009) Other worlds are possible: human progress in an age of climate change. Published at http://pubs.iied.org/10022IIED.html	Secondary research	Final of six 'Up in Smoke Reports'. Considers the various current mainstream, mitigation and adaptation strategies to respond to the climate challenge in developing countries.	✓	✓	✓	✓
122. Fung, F., Lopez, A. & New, M. 2011 Water availability in +2◦C and +4◦C worlds. Phil. Trans. R. Soc. A 369, 99–116. (doi:10.1098/rsta.2010.0293)	Climate and population model	Review and modelling to identify the level of water stress in 2^{0}C and 4^{0}C global warming projections.				✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
123. Dietz, Simon, et al. (2007) "Right for the right reasons." *World Economics* 8.2 (2007): 229-258.	Economic Review	Review of the discussion of different economists following the publication of the Stern Report. Summary of main findings of the Stern Report and how its methodology compares to other economic climate modelling			✓	
124. Dietz, Simon, and Nicholas Stern. (2014) "Endogenous growth, convexity of damages and climate risk: how Nordhaus' framework supports deep cuts in carbon emissions."	Primary Research: Economic Model	New economic model to address shortcomings of many economic modelling which underestimates the degree of impact of climate change on economic growth			✓	
125. Gutierrez, M, McFarland, W and Fonua, L (2014). "Zero poverty… think again." ODI, London.	Secondary research	Review of the interrelation between climate change, economic growth and poverty reduction in developing countries.			✓	
126. IPCC (2013a) Climate Change 2013: The Physical Science Basis. (Working Group 1 Contribution to the IPCC 5th Assessment Report)	Peer Reviewed Scientific Consensus.	Global consensus on peer reviewed climate research up to 2013.	✓	✓	✓	✓
127. IPCC (2013b) Climate Change 2014: Impacts, Adaptation and Vulnerability (IPCC Working Group II Contribution to AR5).	Peer Reviewed Scientific Consensus.	Global consensus on peer reviewed climate research up to 2013.	✓	✓	✓	✓
128. IPPC (2014) Climate Change 2014: Mitigation of Climate Change (IPCC Working Group III Contribution to AR5)	Peer Reviewed Scientific Consensus.	Global consensus on peer reviewed climate research up to 2013.	✓	✓	✓	✓
129. Stern, N (2006) What is the Economics of Climate Change? World Economics. Volume 7, No.2, April-June 2006.	Economic Methodology	Review of the overall methodology to economically model the impacts of climate change, as set out in the Stern Report.			✓	
130. Stern, N ed. (2007) The Stern Review: The Economics of Climate Change. Cambridge University Press.	Primary and Secondary Research	Comprehensive analysis of how the IPCC report published in 2007 (AR4) relates to economic development, both in terms of economic costs and economic impacts. Concludes that the costs of acting on climate change are far outweighed by the impacts due to the effects of climate change, and these become unacceptable after around 2ºC of global warming.	✓	✓	✓	✓
131. Stern, Nicholas. (2013) "The structure of	Economic	Outline of the mismatch between climate science and the modelling of			✓	✓

Study	Research Design and Methodology	Synopsis, including origin of climate data, where applicable	Impacts of Climate Change			
			Health	Agriculture	Economic developmen	Disaster resilience
economic modelling of the potential impacts of climate change: grafting gross underestimation of risk onto already narrow science models." *Journal of Economic Literature* Volume 51, No. 3 (2013), pp838-859.	Methodology	impacts, particularly in terms of economic development and economic growth.				
132. Woodward, D and Simms, A. (2006) *Growth is failing the poor: the unbalanced distribution of the benefits and costs of global economic growth*. DESA Working Paper No.20. UN, Department of Economic and Social Affairs. Published at http://www.un.org/esa/desa/papers.	Secondary Research	Analysis of the interplay between economic growth, climate change and poverty reduction.			✓	
133. WWF (2010) Living Planet Report 2010: biodiversity, biocapacity and development.	Secondary Research	Quantifying and contrasting the environmental (and social) indicators of different geographical locations and countries, worldwide		✓	✓	