ECONOMICS OF ADAPTATION TO CLIMATE CHANGE
STUDY OVERVIEW

Context

Under the Bali Action Plan adopted at the 2007 United Nations Climate Change Conference, developed countries agreed to allocate "adequate, predictable, and sustainable financial resources and new and additional resources, including official and concessional funding for developing country parties"[1] to help them adapt to climate change. The plan views international cooperation as essential for building capacity to integrate adaptation measures into sectoral and national development plans. Yet studies on the costs of adaptation offer a wide range of estimates, from $4 billion to $109 billion a year.

The Economics of Adaptation to Climate Change (EACC) study is intended to fill this knowledge gap. Soon after the Bali Conference of Parties, a partnership of the governments of Bangladesh, Plurinational State of Bolivia, Ethiopia, Ghana, Mozambique, Samoa, and Vietnam and the World Bank initiated the EACC study to estimate the cost of adapting to climate change. The study, funded by the governments of the Netherlands, Switzerland, and the United Kingdom, also aims to help countries develop plans that incorporate measures to adapt to climate change.

Objectives

The EACC study has two broad objectives: to develop a global estimate of adaptation costs for informing the international community's efforts in the climate negotiations, and to help decisionmakers in developing countries assess the risks posed by climate change and design national strategies for adapting to climate change.

These two objectives complement each other. To some extent, however, they are also at odds with each other, and cannot be fully consistent: supporting developing country efforts to design adaptation strategies requires incorporating country-specific characteristics and socio-cultural and economic conditions into the analyses. Identifying the global costs of adaptation to climate change to support international negotiations requires analysis at a more aggregate level. Reconciling the two involves a tradeoff between the specifics of individual countries and a global picture.

Approaches: the two parallel tracks

To address the two objectives, the EACC was conducted on two parallel tracks: a global track, where national databases were used to generate aggregate estimates at a global scale, and a series of country level studies, where national data were disaggregated to more local and sector levels, helping to understand adaptation from the bottom-up perspective. The top-down and bottom-up approaches were compared and to the extent possible integrated. Some elements had to be analyzed separately, or solely, under each perspective.

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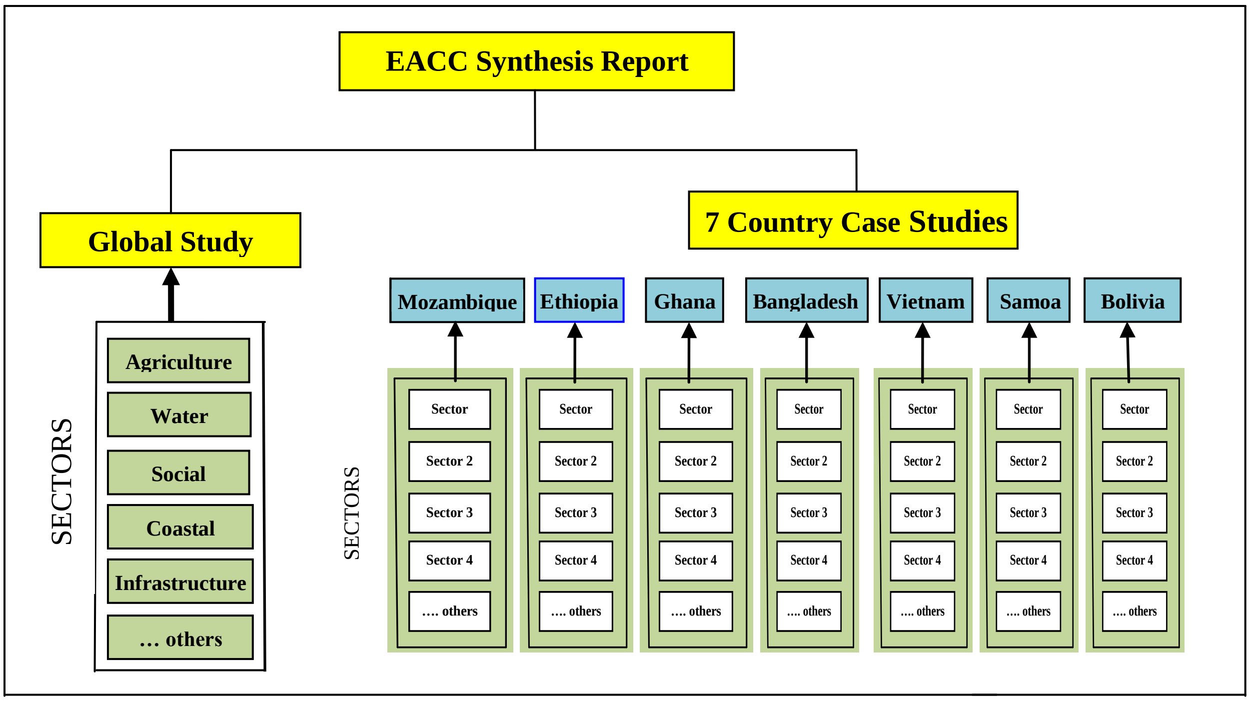
[1] UNFCCC (United Nations Framework Convention on Climate Change), 2007. *Climate Change: Impacts, Vulnerabilities, and Adaptation in Developing Countries*. Bonn, Germany.

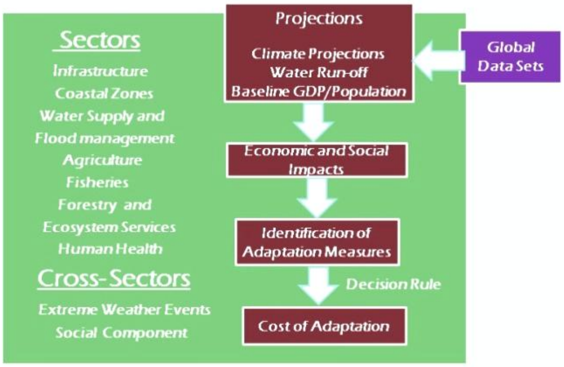
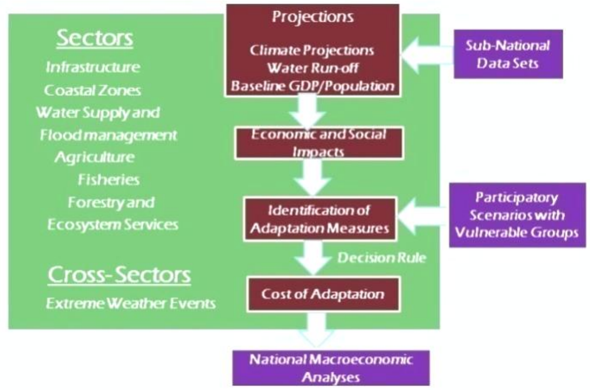
The Synthesis Report

The Synthesis Report being launched in the Bonn COP sits at the apex of a *global study* report and seven *country case study* reports. The global study consists of a number of sector studies, which were commissioned by the EACC project. Country case study reports present findings from sector analyses conducted at the national level, and include analysis of three to five sectors, depending on the country. The Diagram below depicts graphically the various EACC study components and their links.



Methodology

To estimate the impacts of climate change and then the costs of adaption, it is necessary to compare, for each time period, the difference between the world with climate change and the world without climate change. To do this, we first projected what the world will look like between now and 2050, our planning horizon. This projected world without climate change is the baseline. Climate models are then chosen to capture a range of climate scenarios. The changes in climate are used to predict what the world would look like under the new climate conditions, meaning the impacts of changes in climate on the various economic activities, on people's behavior and on environmental conditions. The last step consists of identifying alternative adaptation strategies and costing them. A macroeconomic modeling framework was additionally used in the country studies allowing for the analysis of macroeconomic and cross-sectoral effects of the impacts and adaptation to climate change. They also included a social component.

Global track	Country track
	

<u>Main findings</u>

- *The cost of developing countries to adapt to climate change between 2010 and 2050 is estimated at US$70 billion to US$100 billion a year at 2005 prices. This amounts to about "only" 0.2% of the projected GDP of all developing countries in the current decade and at the same time to as much as 80% of total disbursement of ODA.*

- *Economic development is a central element of adaptation to climate change, but it should not be business as usual.*

- *Invest in human capital, develop competent and flexible institutions, focus on weather resilience and adaptive capacity, and tackle the root causes of poverty. Eliminating poverty is central to both development and adaptation, since poverty exacerbates vulnerability to weather variability as well as climate change.*

- *Do not rush into making long-lived investments in adaptation unless these are robust to a wide range of climate outcomes or until the range of uncertainty about future weather variability and climate has narrowed. Start with low-regret options.*

- *Adaptation to climate change should start with the adoption of measures that tackle the weather risks that countries already face, e.g. more investment in water storage in drought-prone basins or protection against storms and flooding in coastal zones and/or urban areas. Climate change will exacerbate these risks.*

- *Beware of creating incentives that encourage development in locations exposed to severe weather risks. Where possible build future cities out of harm's way – flood plains or coastal zones that are exposed to sea level rise and storm surges.*

- *Hard and soft approaches to adaptation are two sides of the same coin. Good policies, planning and institutions are essential to ensure that more capital-intensive measures are used in the right circumstances and yield the expected benefits.*

Global costs of adaptation by region

Aggregation type/Scenario	East Asia & Pacific	Europe & Centr.Asia	Lat.America & Caribbean	Middle East/ North Africa	South Asia	Sub-Saharan Africa	Total
Gross-sum/Wet	25.7	12.6	21.3	3.6	17.1	17.1	97.5
X-sum/Dry	17.9	6.9	14.8	2.5	15	14.1	71.2

Global costs of adaptation by sector

Sector	NCAR (Wet)	CSIRO (Dry)
Infrastructure	27.5	13.0
Coastal zones	28.5	27.6
Water supply and flood protection	14.4	19.7
Agriculture, forestry, fisheries	2.6	2.5
Human health	2.0	1.5
Extreme weather events	6.7	6.4
Total	81.5	71.2

Country specific lessons

The three African case-study countries: Mozambique, Ethiopia and Ghana

Mozambique is subject to frequent droughts, floods, and tropical cyclones. Drought is the most frequent disaster, with an average incidence of every 3-4 years, and has contributed to an estimated 4,000 deaths between 1980 and 2000. Twenty flood events were recorded in the period 1958 – 2008 affecting more than nine million people. These extreme events have been followed by outbreaks of disease causing even more death and economic loss.

Ethiopia's geographical location and topography in combination with low adaptive capacity entail a high vulnerability to the impacts of climate change. Historically the country has been prone to extreme weather variability – rainfall is highly erratic, most rain falls with high intensity, and there is a high degree of variability in both time and space. Since the early 1980s, the country has suffered seven major droughts – five of which have led to famines – in addition to dozens of local droughts. Six major floods also occurred in different parts of the country since 1988.

Ghana is highly vulnerable to climate change and variability and the economy is particularly vulnerable because it is heavily dependent on climate-sensitive sectors such as agriculture, forestry, and hydropower. The agricultural sector, in particular, in highly vulnerable because it is largely rain-fed with a low-level of irrigation development. The country has a 565 km long coastline which is inhabited by about a quarter of the population and is the location of significant physical infrastructure.

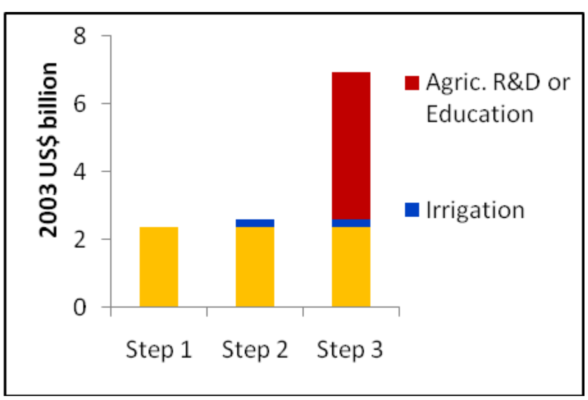
EACC approach and methodology. In the three African countries, using a timeframe of 2050, development baselines are first developed for each sector. The baseline represents the growth path the economy would follow in the absence of climate change over a period of 40 years that can be used as a basis of comparison with the climate change scenario. The changes in climate are provided by a few different climate models that attempt to represent the most extreme variations in the main two variables – temperature and precipitation. They are used to predict impacts on economic sectors (agriculture, water, infrastructure, others). In Mozambique and Ghana, simulations of sea level rise were constructed independently of the climate scenarios with the use of an integrated model of coastal systems. The final steps involve identifying and costing adaptation options for the key sectors. The costs of adaptation comprise the costs of public policy adaptation measures and exclude the costs of private (autonomous) adaptation.

To complement the economic modeling component, a social component developed vulnerability assessments in socio-geographic hotspots in order to understand the socially differentiated nature of vulnerability. Part of this methodology included conducting numerous participatory scenario development workshops in the three case countries in order to characterize various future adaptation pathways possible for different livelihood groups, given their identified vulnerabilities and assets.

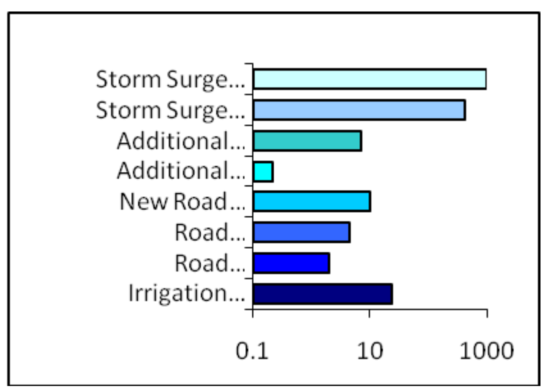
Results

Mozambique. The main issues for Mozambique were a reduction in crop productivity due to changes in climate plus damage to unpaved roads. The analysis considered potential measures in four sectors: (i) investment in roads, and then the same change plus (ii) increased agricultural research and extension, (iii) enhanced irrigation, and (iv) enhanced investment in education. The results suggest that with small additional costs, sealing unpaved roads restores approximately 1/3 of the welfare loss due to climate change. Remaining welfare losses could be regained with improved agricultural productivity or human capital accumulation. Irrigation investments appear to be a poor alternative. Investment costs are less than US$390 million per year over 40 years.

Reduction in CC damages, 2003-2050, 5% discount

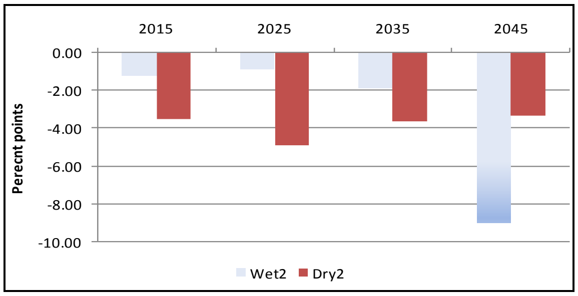


Adaptation costs in 2041-2050, US$ millions



Ethiopia. The primary losses due to climate change in Ethiopia arise from the effect of extreme weather events – both droughts and flooding – on agricultural production and infrastructure. The worst outcome (under the Wet 2 scenario) is driven by the effects of flooding on unpaved roads.

Percent deviations of GDP from Baseline



Costs of the adaptation strategy ($ billions)

Climate Scenario	Total 2010-2050	NPV	Annual Average
Wet2	10.67	3.32	0.260
Wet1	13.05	3.58	0.318
Dry1	17.75	4.65	0.433
Dry2	25.18	6.90	0.614

NPV: Net Present Value of adaptation costs, 2010-50

Adaptation strategies considered in Ethiopia consisted of additions to – or modifications of – current government programs – e.g., increasing cropland area that is irrigated, increasing the share of paved and hardened roads, altering the scale and timing of planned hydro projects plus various "soft" measures. An increase of annual foreign aid by about 10% would be required to finance Ethiopia's adaptation investment. Adaptation lowers income variability and reduces the welfare losses by about 50%. To address such residual damage, a program of educational investment is included in the adaptation strategy, more than offsetting the negative impacts of climate change. Overall, the study highlights the potential benefits of accelerating the diversification of the economy away from climate sensitive sectors, such as agriculture.

Ghana. Climate change causes a reduction in real household consumption of 5-10% in 2050 with rural households suffering greater reductions, primarily through its impact on agricultural production. Adaptation focused on roads, agriculture, hydropower and coastal protection. Changes in road design standards alone provide significant reductions in welfare losses with the notable exception of Ghana Dry. The combination of better road design and investments in agriculture or agriculture and hydropower would minimize or even reverse the losses caused by climate change. Finally, investment in education spurs growth performance in general in order to reduce vulnerability to negative climate change shocks.

Real welfare change, alternative adaptation strategies (NPV, $ billions)

No Adaptation scenario		Road Design	Adaptation Investment in		
			Agriculture	Hydro /Agric.	Education
Global Dry	-16.017	-13.171	0.461	0.299	-4.774
Global Wet	-25.731	-21.561	-0.988	-1.071	-8.264
Ghana Dry	-4.825	-5.130	-0.867	-0.426	-2.552
Ghana Wet	-1.926	1.456	3.376	3.081	2.506

<u>Asia and Latin America case-study countries: Bangladesh, Bolivia, Vietnam and Samoa</u>

Bangladesh is one of the most vulnerable countries to climate risks, being the most vulnerable to tropical cyclones. Between 1877 and 1995 Bangladesh was hit by 154 cyclones (including 43 severe cyclonic storms and 68 tropical depressions) – one severe cyclone every three to five years. The largest damages from a cyclone result from the induced-storm surges, and Bangladesh is on the receiving end of about 40% of the impact of total storm surges in the world. Bangladesh also experiences severe monsoon flooding, on average also once every three years, resulting in significant damage to crops and properties.

Bolivia. The Bolivian population has always been exposed to hydro-meteorological extremes and climate variability, particularly because of the influence of the El Niño oscillation (ENSO) which, regardless of climate change, occurs periodically in different areas across the country. The impact of El Niño 2006-2007 in Bolivia cost approximately US$ 443.3 million in damages, half of which were direct damage to property and the remaining were losses in cash flow, declines in production, reduced income and disruption of services. Floods, landslides, and droughts, are other common climate related events.

Vietnam. Vietnam's exposure to weather-related events and disasters ranks among the highest among all developing countries. Storms and floods occasionally resulting from tropical cyclones have caused extensive and repeated damages to buildings and infrastructure, agriculture and fisheries sectors, and resulted in a large number of fatalities. In the course of the 20th century, approximately 25,000 lives have been lost in Vietnam as a direct result of climate related events, more than 8,000 people were killed by natural disasters, an estimated 9,000 boats were sunk and 6 million houses were destroyed. The total economic value of losses for this period alone was estimated at USD 2.8 billion.

Samoa. Samoa is a country at extreme risk from a variety of natural disasters including tropical cyclones and tsunamis caused by earthquakes. Two major cyclones (Ofa & Val) hit or passed near to one of the two main islands in 1990-1991, damaging a majority of buildings and causing a total economic loss of about US$550 million at 2005 prices, equivalent to about <u>3.75 times GDP</u> in 1990. While these events were considered to be unprecedented within the previous 100 years, an increase in the probability of such large losses from 1 in 100 years to 1 in 50 years or even 1 in 25 years would clearly be very significant. Many climate scientists believe that climate change will lead to some increase in the intensity of tropical cyclones accompanied by greater variability of rainfall with more frequent episodes of very heavy rainfall and drought.

EACC approach and results

Bangladesh. The case study focuses on two specific climate hazards – storm surges induced by tropical cyclones, and inland flooding. Cyclone-induced storm surges due to climate change are expected to inundate an additional 15% of the coastal area and also increase the inundation depth in these areas. The damages from a single typical severe cyclone with a return period of 10 years is expected to rise nearly fivefold to over $9 billion by 2050, accounting for 0.6% of GDP, with the burden likely falling disproportionately on the poorest households. Adaptation measures evaluated were (i) embankments, (ii) afforestation, (iii) cyclone shelters, and (iv) early warning systems. The total estimated cost to address storm surge risk is $2.4 billion in initial investment and $50 million in annual recurrent costs.

<u>Inland flooding</u>. The depth and extent of inundation is expected to increase with climate change due to the warmer and wetter climate and rising sea levels. However, compared to the baseline scenario the increases are greater than 15cm in only 544 km^2, or less than 0.5% of the country. Furthermore, the rural population exposed to flooding declines from current levels due to projected rural-urban migration. The adaptation analysis focuses on infrastructure measures to avoid further damage from additional inundation – road network and railways, river embankments and embankments to protect highly

productive agricultural lands, drainage systems, and erosion control measures. The total estimated cost to address inland flooding risk is $2.7 billion in initial investment and $54 million in annual recurrent costs. Eighty percent of these costs are due to road height enhancement.

Cost of adapting to tropical cyclones and storm surges by 2050, $ millions

Adaptation Option	Baseline Scenario		CC Scenario	
	IC	ARC	IC	ARC
Polders	2,462	49	3,355	67
Afforestation			75	
Cyclone shelters	628	13	1,847	37
Resistant housing			200	
Early warning system			39	8+
Total	3,090	62	5,516	112+

CC = climate change; IC = investment cost; ARC = annual recurrent cost

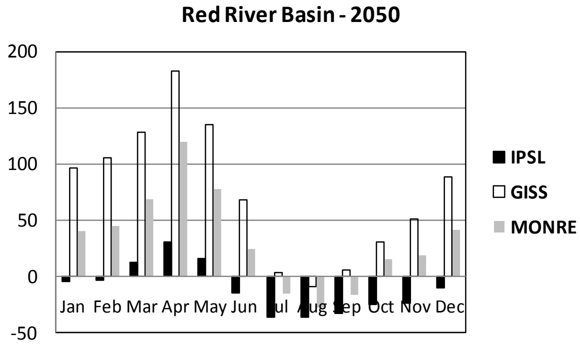
Bolivia. Based on continuous dialogue with the government, the EACC study in Bolivia focused on two vulnerable sectors only: agriculture and water resources. Climate models do not agree with regards to rainfall projections in terms of sign of the change, intensity and geographical distribution, showing a range of plausible wet and dry scenarios. Yet, improving the water storage efficiency of wet periods to meet irrigation demands in deficit areas such as the south of the Altiplano and El Chaco is essential. At the same time, if the dry scenarios are correct, then the benefits of higher temperatures will be more than offset by more frequent and severe periods of low rainfall, also making the case for improved water storage and irrigation infrastructure. Potential yields increases for maize and soybeans could be 40%-45%, while those for potatoes and quinoa by 60%-90%.

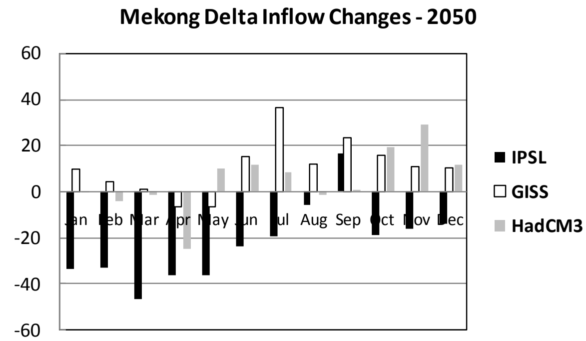
An exercise was also made in the Bolivia case study to explore the effect of climate change on a Government's planned investment program for the Mizque watershed. Seventy four potential projects have been identified in 16 of the 22 sub-basins. Incorporating the effects of climate change appears to modify the original development plan only slightly. Most of the proposed irrigation investments are strongly robust to climate outcomes. A budgetary decentralized management at the sub-watershed level overwhelms the effect of climate change, regardless whether the objective is to maximize social benefits or to maximize the number of families directly benefitting from the projects.

Vietnam. Projections indicate that rainfall will be concentrated even more than now in the rainy season months, leading to an increase in the frequency, intensity, and duration of floods, and to an exacerbation of drought problems in the dry season. The figure below shows striking differences between the effects of climate change in the Red River and Mekong River basins.

Crop yield reductions vary widely across crops and agro-ecological zones under climate change. Country-wide, rice yield decreases between 10% and 20% in 2050 without CO_2 fertilization. The worst rice yield reductions are about 12% in the Mekong River Delta, while about 24% in the Red River Delta.

Percent changes in average monthly run-off by climate scenario





Like in the Africa cases, a CGE model has been used to examine the impacts of climate change on economic growth and welfare. Real GDP in 2050 is 2.4-2.3% lower than the baseline under the dry/wet scenarios. Regional GDP is severely affected in the Central Highlands with equivalent losses of nearly 25%. The impact on household incomes is also heavily skewed with much greater losses for those in the lowest quintile than for the top quintile. Adaptation options considered included relatively low cost changes in agricultural practices such as sowing dates, switching to drought-tolerant crops, adoption of salinity-tolerant varieties of rice, etc. The reduction in real GDP and real consumption is much less severe 'with adaptation', and they offset mostly the disproportionate impacts on poorer households.

Real aggregate consumption ($US billion)

Consumption	Climate change scenario		
	Dry	Wet	Monre
Annual average 2010-2050			
No adaptation	-4.1	-3.4	-1.3
With adaptation	-1.5	-2.0	0.7
Present value			
No adaptation (1)	-47.9	-37.8	-16.3
With adaptation (2)	-15.6	-24.7	7.8
Net benefit of adaptation = (2) – (1)	32.3	13.1	24.2

Samoa. The EACC study focuses on the impact of adaptation to a shift in the probability distribution of tropical storms affecting the islands. The severity of such storms is measured by their peak wind speed over a period of 10 minutes. Since storms which hit the islands and cause significant damage are infrequent events, the analysis examines how climate change will affect the expected annual value of storm damage expressed as a percentage of GDP under the alternative climate scenarios. The gross economic losses when there is climate change without adaptation are shown in Columns (1) and (2) of the Table. The impact of climate change is much larger for the CSIRO scenario and amounts to 0.9% of total GDP in the baseline scenario.

Losses due to climate change without and with adaptation

	Gross losses without adaptation		Net losses with adaptation		Net benefits of adaptation	
	NCAR	CSIRO	NCAR	CSIRO	NCAR	CSIRO
	(1)	(2)	(3)	(4)	(5)	(6)
Present value @ 5%, $ million	9.3	127.9	3.9	38.9	5.5	89.0
Annualized equivalent, $million/year	0.5	7.3	0.2	2.2	0.3	5.1
Loss/benefit as % of baseline GDP	0.1%	0.9%	0.0%	0.3%	0.0%	0.7%

The key form of adaptation is the implementation of design standards to ensure that buildings and other assets can cope with higher winds and more intense precipitation without damage. Adaptation has been assumed to involve the retention of the 1 in 10 year threshold for storm damage after taking account of the shift in the probability distribution of storms over a period of 50 years from the date of construction. The net benefits of adaptation amount to US$5.5 million at 2005 prices (58%) for the NCAR scenario and US$89 million (70%) for the CSIRO scenario. Raising the general level of design standards to cover 1 in 20 year or 1 in 50 year storms would be justified without any consideration of climate change. The adoption of more stringent design standards today would reduce the impact of the climate change in future and the residual damage after adaptation.

Recommendations for future work

Important shortcomings of this study relate to three broad categories: uncertainty, institutions, and modeling limitations. They are natural entry points for thinking about future work and knowledge needs.

EACC LIMITATION	RECOMMENDATION FOR FUTURE WORK
Use of mathematical models and no efficiency criterion	Include institutional, social, cultural and political perspectives to identify good policies. Find simpler rules for policymaking
Climate uncertainty	Consider more scenarios, Monte Carlo simulations and other probabilistic approaches
Growth uncertainty	Hard to improve other than through sensitivity analyses
Technological uncertainty	Incorporate better information from sector specialists and simulate the impact of potential advances.
Non-consideration to institutional issues	Context specific institutional capacity has to be assessed and considered to make recommendations realistic and feasible
Limited focus on migration and urbanization	Work with outside projections; limited current knowledge on cities and climate change
Limited range of adaptation	Include a broader range of strategies, including more local level
No environmental services	Pull better information and introduce more consistent estimates