SEA-LEVEL RISE

ESTIMATES GLOBAL CLIMATE IMPACT

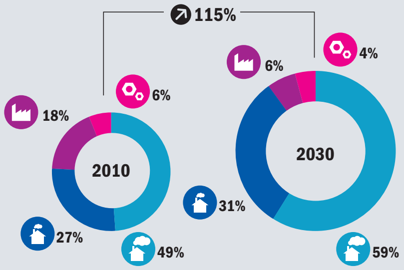
2010 EFFECT TODAY

USD **LOSS** PER YEAR **85 BILLION**

2030 EFFECT TOMORROW

USD **LOSS** PER YEAR **550 BILLION**

ECONOMIC IMPACT



CONFIDENCE
ROBUST

SEVERITY	
AFFECTED	
INJUSTICE	
PRIORITY	
MDG EFFECT	

- Melting of the polar ice sheets and mountain ice and glaciers is increasing the amount of water supplied to the oceans, causing sea-levels to rise relative to land
- The oceans heat up together with the atmosphere as the planet warms, and in so doing expand, leading to a greater and growing sea-level rise effect
- The rate of global sea-level rise is gradual—currently about 1cm every three years—but the effects are so comprehensive that its costs are already large-scale and growing
- Tackling sea-level rise is a monumental challenge and will significantly inhibit development in coastal areas attempting to stem growing damage

RELATIVE IMPACT

	2010	2030
$ (red)	135	90
$ (light green)	1	2
$ (green)	1	

HOTSPOTS

2010	$	2030
15,000	**CHINA**	150,000
4,000	**VIETNAM**	40,000
4,500	**INDIA**	30,000
4,500	**ARGENTINA**	25,000
1,250	**BANGLADESH**	20,000

GEOPOLITICAL VULNERABILITY

SIDSs
OECD
LDCs
BRIC
G20
G8

Economic Cost (2010 PPP non-discounted)
Developing Country Low Emitters
Developed
Developing Country High Emitters
Other Industrialized

$ = Losses per 1,000 USD of GDP

Change in relation to overall global population and/or GDP

$ = Millions of USD (2010 PPP non-discounted)

Sea-level rise resulting from climate change has the potential to threaten the survival of whole nations, such as low-lying Maldives in the Indian Ocean, of which 80% are one metre or less above sea level; their highest elevation is a sand dune 4 metres above sea-level (Maldives MEEW, 2007). Low-elevation coastal zones, however, are common around the world (CReSIS, 2012). In general, where there is inhabited coastline, there will be vulnerability and economic and social impacts. Sea-level rise is therefore one of the most significant economic effects of climate change. For countries with a substantial proportion of the population and economy situated within reach of the shorefront at low elevation, the impacts of sea-level rise are a constant and crippling economic cost. Scientists have asserted that climate change will "shrink nations and change world maps" (Hansen, 2006).

CLIMATE MECHANISM

As the planet warms and the temperature rises, heat is melting glaciers and ice on land around the world, including the polar ice caps (Olsen et al., 2011). All of the world's glaciers have been in long-term retreat or have already disappeared (NSIDC, 2008). Arctic sea ice used to cover over 7 million square kilometres during the height of summer. As this report went to publication, sea ice was at a record low, close to 3 million km² in the Arctic Sea (NSIDC, 2012). Much of the heat in the atmosphere is also absorbed by the oceans, which release it back into the atmosphere (Hansen et al., 2005). In the meantime, as the oceans absorb more and more heat, they expand in accordance with the basic laws of physics. Viewed from land, this so-called "thermal expansion" is also a significant contributor to sea-level rise (RSNZ, 2010). Overall, sea-level rise is currently about 3mm per year, or 3cm a decade (NASA Climate, 2012). Current estimations point to increases in that rate, with several experts recently estimating a possible maximum of two or more metres of sea-level rise by the end of the century (Pfeffer et al., 2008; Grinstead et al., 2009; Füssel, 2012).

Sea-level rise not only leads to coastal erosion and flooding, it also increases risks from storm surges and seasonal high tides. It can unfavourably increase the salinity of river ways and brackish aquaculture production ponds, contaminate coastal groundwater sources with salt, and damage agricultural production through gradual salt intrusion into the surrounding soil (Nicholls and Cazenave, 2010; Füssel, 2012).

IMPACTS

The global impact of climate-driven sea-level rise on the world's coastlines is estimated to cost 85 billion dollars a year today, increasing to over 500 billion dollars a year by 2030, with a doubling of costs as a share of GDP over this period.

China suffers the largest impact today at 15 billion dollars a year, set to grow to almost 150 billion dollars a year in losses by 2030, reaching 0.3% of China's projected GDP. By 2030, more than 15 countries will experience annual losses around or in excess of 10 billion dollars, including developing countries such as Bangladesh, Indonesia, or Vietnam, as well as developed countries such as the US and South Korea.

Worst affected by share of GDP are small island states, especially in the Pacific, and several coastal African countries. For a handful of countries—the Marshall Islands, Guinea-Bissau, the Solomon Islands, and Kiribati—costs could represent as much as 20% or more of GDP in 2030.

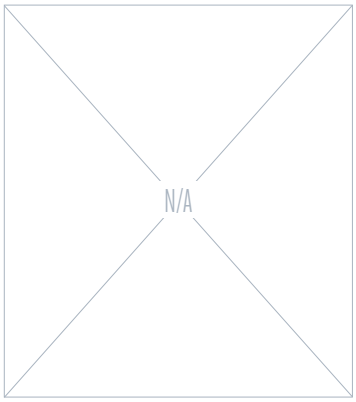
In general, lower-income and least developed countries, especially small island developing states, dominate the ranks of those most vulnerable to the effects of climate-related sea-level rise, with serious implications for human development progress in these areas.

THE BROADER CONTEXT

Coastal erosion and geological subsidence, or the sinking of land due to earth plate tectonics and associated factors, are completely natural phenomena which are part of the basic geological processes sustaining the planet. When land surfaces are lowered near the sea, the result is indistinguishable from sea-level rise, when viewed from a local perspective (Törnqvist et al., 2008).

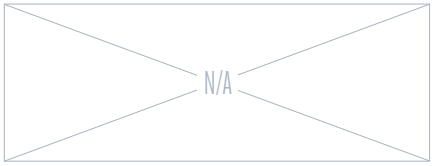
Likewise, several issues related to the human presence in the environment have serious effects for coastal erosion. Groundwater pumping for irrigation or municipal/industrial purposes near shorelines can cause land to subside or become lower in relation to the sea (Larson et al., 2001). Coastal defences or port structures and other built infrastructure can alter or deflect sea currents and lead to serious erosion in adjacent

BIGGER PICTURE

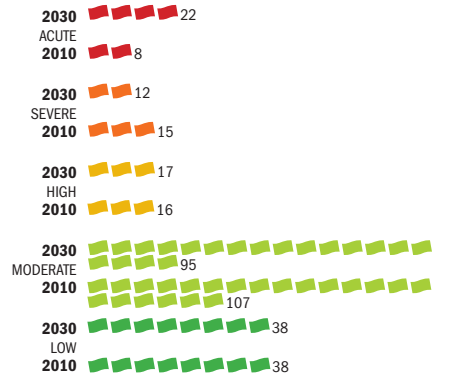


SURGE

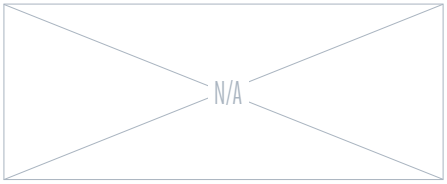
OCCURRENCE



VULNERABILITY SHIFT



PEAK IMPACT



GENDER BIAS

INDICATOR INFORMATION

MODEL: DIVA, 2003

EMISSION SCENARIO: A1F1 (IPCC, 2000)

BASE DATA: DIVA, 2003

= 5 countries (rounded)

Acute Severe High Moderate Low

coastal areas (Appeaning Addo and Labri, 2009). Destruction of coastal ecosystems, such as mangrove forests, reduces coastal integrity and triggers erosion (Wilkinson and Salvat, 2012). In river estuaries, upstream dams for irrigation or in some cases hydro energy can be detrimental to the delta downstream, if river flow is reduced (due to diverted water), or if sediment that would otherwise have flowed to the sea is retained (Ly, 1980; Yang et al., 2005; Boateng, 2009; Baran, 2010; Fredén, 2011).

VULNERABILITIES AND WIDER OUTCOMES

Length of coastline is not the main determinant of vulnerability to sea-level rise. Vulnerability is more closely related to the relative value of land in coastal areas, reflecting the concentration of populations and productive sectors of the economy under stress. It is also closely relates to topography and geology: with current rates of sea-level rise, steep rocky coastlines are much less cause for concern than low-lying, sand-based atolls or river estuaries. Vulnerabilities can be higher, depending on whether or not adjacent communities build coastal defences, which can alter wave dynamics and exacerbate erosion in nearby zones (Appeaning Addo and Labri, 2009). This will pose an important challenge for international adaptation responses along contiguous coastlines under threat, as was illustrated in this report's Ghana country study.

As mentioned earlier, unsustainable resource use, such as water withdrawals that lead to subsidence or the destruction of mangrove forests, only heightens vulnerabilities.

Where populations rely on ground water for irrigation or drinking water, particularly in small islands, salt intrusion is a further serious concern (Werner and Simmons, 2009). Lower-income communities generally cannot marshal the resources needed to protect against the effects of sea-level rise, and so must suffer the consequences of not adapting: loss of land, contamination of water sources, and growing dangers from extreme weather. As is highlighted in both the Ghana and Vietnam country studies in this report, international assistance is most often required to support adaptation. Furthermore, subsistence farmers who may not have their land submerged may see production decrease due to gradual salt intrusion into soils. These effects frustrate poverty reduction efforts in affected areas and drive rural-urban migration (Dasgupta et al., 2009).

RESPONSES

Four different types of approaches can be combined in a variety of ways: 1) coastal defences, whether "hard" through infrastructure defences (gyrones, polders, sea walls, dykes) or "soft", such as sand-banking, ecosystem, or a combination of these; 2) addressing human activities that aggravate sea-level rise, from intensive farming to ground water pumping for irrigation, or upstream dams in delta areas; 3) support programmes for affected communities, such as rainwater harvesting programmes; and 4), retreat or land sacrifices, including relocation and abandonment.

If the value of the land is deemed less than the costs of protecting it, then land is most likely to be let go (DIVA, 2003). However, if communities are involved, they would normally need support to obtain new property and/or migrate and resettle elsewhere (Warner et al., 2009). As mentioned earlier, reducing upstream irrigation loads, and retrofitting dam infrastructure to allow more water and sediment to flow downstream can help counteract localized sea-level rise.

THE INDICATOR

The indictor is deemed robust for several reasons: first, the science is firm on the increase in sea levels over time around the world, as recognized by the IPCC (IPCC, 2007). Second, there is relatively low uncertainty compared to other areas of climate change regarding the scale and rates of change between different models in the near term (Rahmstorf, 2009). Third, the indicator is built on a high-resolution global model (DIVA, 2003). Improvements in the estimation of the complex set of costs involved across countries and in the actual model resolution, now 75km segments, could nevertheless further improve the analysis going forward.

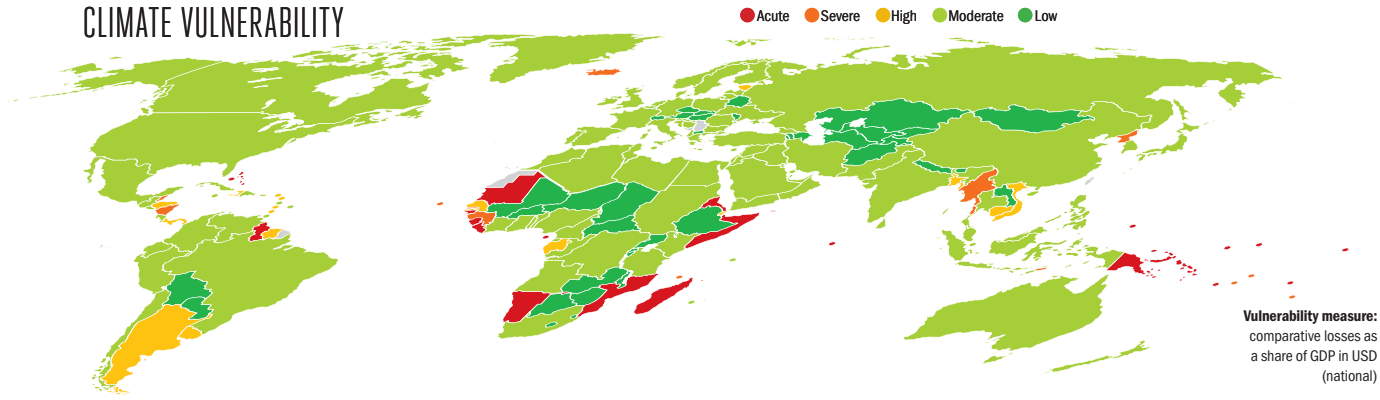
ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	$ 2010	$ 2030	2010	2030	2010	2030
ACUTE						
Bahamas	300	4,000	90	100	90	200
Eritrea	150	650	10	15	20	55
Gambia	150	750	80	100	40	100
Guinea-Bissau	400	2,250	150	200	50	150
Guyana	200	1,000	150	150	15	40
Kiribati	90	550	80	85	100	250
Liberia	80	400			30	75
Madagascar	850	4,000	100	200	45	100
Maldives	150	900	250	300		
Marshall Islands	90	550	50	55	1	1
Mauritania	250	1,500	15	20	350	900
Micronesia	30	200	15	15		
Mozambique	1,000	5,250	3,250	4,750	100	300
Namibia	10	5,250	1	1	850	2,000
Palau	10	60	5	5	1	1
Papua New Guinea	550	3,250	150	150	550	1,500
Sao Tome and Principe	15	80				
Sierra Leone	200	1,000	45	65	35	85
Solomon Islands	300	1,750	60	65	10	20
Somalia	750	3,750	75	100	45	150
Tuvalu	1	10	5	5		
Vanuatu	100	700	15	20	1	1
SEVERE						
Belize	70	400	20	25	25	40
Cape Verde	40	200	45	65	1	1
Comoros	25	150	20	30		
Fiji	150	800	50	55	10	25
Guinea	250	1,500	5	10	45	100
Iceland	350	700	30	35	40	150
Myanmar	1,750	9,500	2,250	2,500	350	1,250
Nicaragua	400	2,250	15	20	40	100
North Korea	1,750	10,000	1,250	1,250	10	30
Samoa	20	150	15	15		
Timor-Leste	95	600	25		1	
Tonga	20	100	70	75	1	1
HIGH						
Antigua and Barbuda	10	70	55	70	1	1
Argentina	4,500	25,000	650	800	150	300
Bangladesh	1,250	20,000	40,000	45,000	200	450
Cambodia	250	1,750	20	25	20	45
Djibouti	25	150	60	85		1
Dominica	15	95	55	75		1
Estonia	250	1,250	10	10	60	200
Gabon	400	2,000	15	25	150	200
Grenada	15	80	20	25	1	1
Haiti	100	650	100	150	5	15
Honduras	250	1,500	50	65	200	500
Panama	300	2,000	90	100	150	400
Saint Vincent	10	70	20	25		
Senegal	200	1,250	350	550	35	75
Suriname	70	400	80	95	40	100
Uruguay	500	3,250	150	200	5	10
Vietnam	4,000	40,000	20,000	25,000	150	300
MODERATE						
Albania	40	200	45	50	5	5
Algeria	95	550	450	600	40	70
Angola	100	650	550	800	400	950
Australia	800	1,500	2,250	2,250	2,500	7,250
Bahrain	35	95	150	250		1
Barbados	10	35	30	35	1	1
Belgium	350	25	2,250	2,250	10	15
Benin	25	150			60	85
Bosnia and Herzegovina	1	5				
Brazil	3,250	20,000	6,750	8,250	850	2,500
Brunei	50	100	100	150	5	10
Bulgaria	30	150	10	10		
Cameroon	100	850	1,250	1,750	45	100
Canada	1,500	3,500	900	1,000	700	3,000
Chile	550	2,750	400	500	2,000	4,500
China	15,000	150,000	40,000	45,000	250	350
Colombia	350	2,250	400	450	350	600
Congo	30	150	100	150	5	5
Costa Rica	90	650	10	15	55	100
Cote d,Ivoire	150	750			10	25
Croatia	150	700	20	20	25	35
Cuba	550	3,000	350	450	1,500	3,500
Cyprus	20	45	20	20		1
Denmark	550	1,000	1,000	1,250	100	250
Dominican Republic	100	700	30	35	150	300
DR Congo	15	75	1	1	20	50
Ecuador	150	1,000	450	500	400	900
Egypt	1,500	10,000	2,250	3,250	200	450
El Salvador	55	300	50	60	5	15
Equatorial Guinea	50	250			25	60
Finland	85	150	250	250	15	50
France	700	1,250	2,750	2,750	100	150
Georgia	60	300	65	70	50	100
Germany	1,000	1,750	2,750	3,000	85	150
Ghana	200	850			15	35
Greece	250	500	300	350	30	50
Guatemala	60	400	35	45	10	20
India	4,500	30,000	30,000	35,000	450	1,000
Indonesia	2,750	15,000	15,000	15,000	2,000	4,500
Iran	350	2,000	100	150	200	400
Iraq	20	150	250	350	1	1

$ Additional economic costs due to climate change (million USD PPP) - yearly average

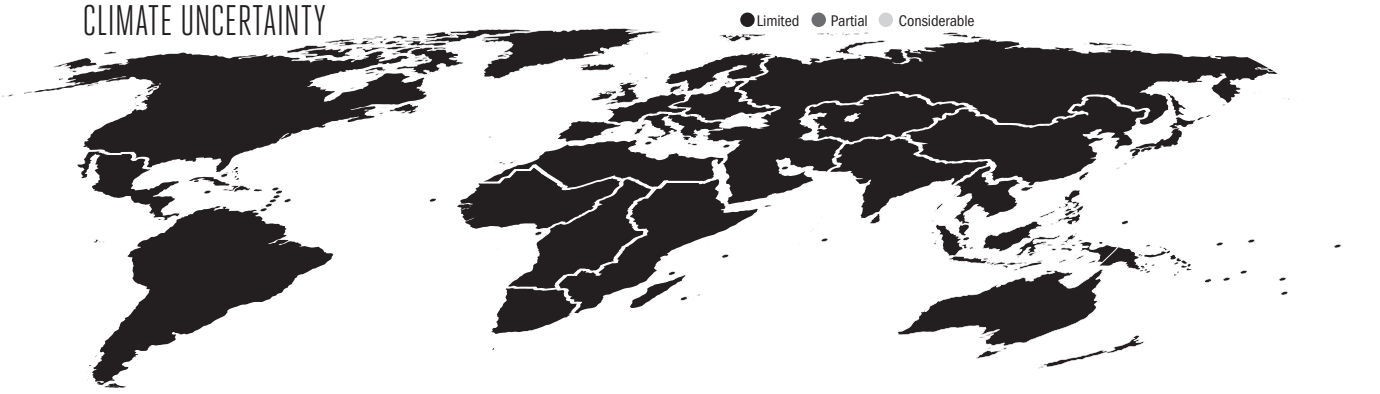
Additional persons affected due to climate change - yearly average

CLIMATE VULNERABILITY



Vulnerability measure: comparative losses as a share of GDP in USD (national)

CLIMATE UNCERTAINTY



COUNTRY	$ 2010	$ 2030	2010	2030	2010	2030
Ireland	250	500	300	300	5	10
Israel	10	40	10	15	1	1
Italy	250	550	1,250	1,500	30	50
Jamaica	75	450	20	25	75	95
Japan	950	2,000	6,000	6,250	50	80
Jordan	1	5				
Kenya	200	900	200	300	20	60
Kuwait	55	500	100	150	5	15
Latvia	90	400	55	60	1	5
Lebanon	15	95	150	200		
Libya	200	1,000	80	100	90	250
Lithuania	40	200	30	35	1	10
Malaysia	900	5,750	2,250	2,500	250	450
Malta	1	5	25	30		
Mauritius	20	100			1	1
Mexico	2,250	15,000	1,250	1,750	1,000	2,000
Morocco	250	1,750	1,250	1,750	15	30
Netherlands	1,250	1,250	15,000	15,000	20	25
New Zealand	200	400	600	650	450	1,250
Nigeria	500	2,500	150	200	750	2,000
Norway	500	1,250	250	250	25	75
Oman	100	600	35	45	10	20
Pakistan	500	2,750	1,000	1,250	100	250
Peru	150	1,000	350	450	60	80
Philippines	850	4,750	3,500	4,000	350	850
Poland	200	850	200	200	15	35
Portugal	100	200	400	400	25	40
Qatar	45	250	60	85		1
Romania	80	400	150	150	90	200
Russia	3,000	10,000	1,750	1,750	400	1,000
Saint Lucia	10	60	15	15		
Saudi Arabia	300	1,500	75	100	40	90
Seychelles	15	60	20	25	10	25
Singapore	10	55	600	700		
Slovenia	1	5	1	1		
South Africa	600	3,000	100	200	65	200
South Korea	2,500	10,000	2,500	2,500	10	15
Spain	200	450	1,000	1,250	35	65
Sri Lanka	150	1,000	800	1,000	45	75
Sudan/South Sudan	50	300	1	1	10	30
Sweden	150	300	550	600	5	10
Syria	10	65	10	15		
Tanzania	200	1,250	1,500	2,000	25	70
Thailand	1,500	6,750	5,250	6,250	65	150
Togo	10	55			10	25
Trinidad and Tobago	50	300	65	80	1	1
Tunisia	500	2,750	500	700	20	45
Turkey	300	750	850	1,250	55	85
Ukraine	1,000	5,250	2,000	2,250	45	95
United Arab Emirates	50	250	20	30	1	5
United Kingdom	1,500	2,750	5,000	5,250	100	300
United States	4,250	9,000	10,000	15,000	10,000	25,000
Venezuela	850	5,000	1,000	1,250	200	400
Yemen	150	1,250	70	100	45	150

LOW

COUNTRY	$ 2010	$ 2030	2010	2030	2010	2030
Afghanistan						
Armenia						
Austria						
Azerbaijan						
Belarus						
Bhutan						
Bolivia						
Botswana						
Burkina Faso						
Burundi						
Central African Republic						
Chad						
Czech Republic						
Ethiopia						
Hungary						
Kazakhstan						
Kyrgyzstan						
Laos						
Lesotho						
Luxembourg						
Macedonia						
Malawi						
Mali						
Moldova						
Mongolia						
Nepal						
Niger						
Paraguay						
Rwanda						
Slovakia						
Swaziland						
Switzerland						
Tajikistan						
Turkmenistan						
Uganda						
Uzbekistan						
Zambia						
Zimbabwe						

Additional land lost due climate change (km³) - yearly average