CLIMATE

ENVIROMENTAL DISASTERS

DROUGHT

FLOODS & LANDSLIDES

STORMS

WILDFIRES

$	**5** BILLION LOSS	2010
	20 BILLION LOSS	2030

☠	**2,750**	2010
	3,500	2030
$	**10** BILLION LOSS	2010
	95 BILLION LOSS	2030

☠	**2,500**	2010
	3,500	2030
$	**15** BILLION LOSS	2010
	100 BILLION LOSS	2030

$	**15** BILLION GAIN	2010
	92 BILLION GAIN	2030

DROUGHT

ESTIMATES GLOBAL CLIMATE IMPACT

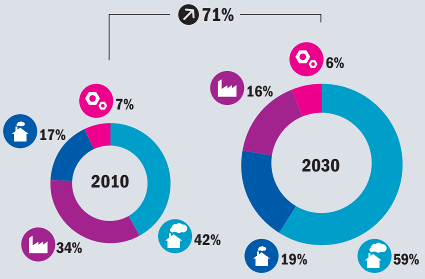
2010 EFFECT TODAY

$ USD **LOSS** PER YEAR **5 BILLION**

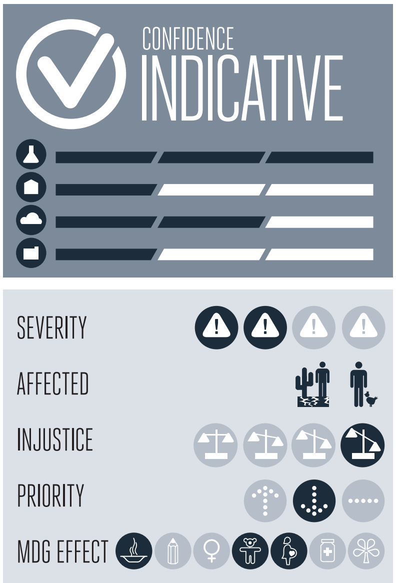
2030 EFFECT TOMORROW

$ USD **LOSS** PER YEAR **20 BILLION**

ECONOMIC IMPACT

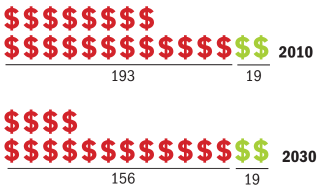


CONFIDENCE
INDICATIVE



- ➔ As the planet's temperatures reach new highs drought will become more common and more severe
- ➔ Climate change also means more rain, but most of it is falling in the far north or far south where fewer people live, and much of this rain falls during the wet season while dry seasons tend to become drier
- ➔ When drought hits, agriculture comes under extreme pressure, crops may fail and livestock perish with important localized economic, health and social repercussions
- ➔ Catching and conserving water will be critical to ensure a resilient agricultural sector and food and water security during periods of extreme drought

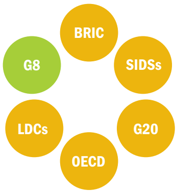
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
800	**CHINA**	6,250
300	**INDIA**	1,500
200	**IRAN**	1,500
500	**UNITED STATES**	1,250
200	**SPAIN**	650

GEOPOLITICAL VULNERABILITY



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

$ = Losses per million USD of GDP

➚ Change in relation to overall global population and/or GDP

$ Millions of USD (2010 PPP non-discounted)

The increase in heat is already being experienced. It is virtually certain to increase in the coming years (IPCC, 2007). Parts of the world experiencing additional rainfall will also experience drought (Sheffield and Wood, 2008; Helm et al., 2010).

Drought can diminish crop yields and kill livestock, generating serious economic losses for affected communities (Pandey et al. (eds.), 2007). Some of the world's major agriculturally productive regions, such as Brazil and Australia, are already affected (Saleska et al., 2011; LeBlanc et al., 2009). Deforestation and other forms of environmental degradation only worsen risk of drought (Turner II et al., 2007). Reducing losses and safeguarding communities will require the tackling of these problems as well stimulating increased water availability through effective capture, storage and distribution measures and policies (McKinsey & Company, 2009). Displacing risks to the insurance industry would also alleviate the severity of losses to individuals and communities (Linnerooth-Bayer and Mechler, 2006).

CLIMATE MECHANISM

A hotter planet not unsurprisingly implies more drought (Sheffield and Wood, 2008). This is qualified by the fact that because of climate change there will also be more moisture and rain in the atmosphere (Allen and Ingram, 2002; Huntington, 2006; Kharin et al., 2007). Additional rain however tends to fall far north or south, where it is not lacking, and less rain tends to fall in the tropical areas of the planet which are already near thermal maximums and where a majority of the world's population live (Helm et al., 2010; Sherwood and Huber, 2010). In parts of the tropics, clouds are gaining in altitude and failing to deposit their moisture on mountain ranges (Malhi et al., 2008). As evidenced in cities, even if more rain falls, provided heat rises faster, any additional water would evaporate and not benefit the soil and its vegetation (Schmidt in Hao et al. (eds.), 2009). Hence, global aridity has increased and is expected to continue increasing, including in areas like the US, which have largely escaped the most severe forms of drought to date (Dai, 2011). Even where rainfall is declining, it is becoming more concentrated generating longer dry spells (Trenberth, 2011). Moreover, country level analysis in Vietnam for instance shows how in regions prone to extreme heat rain will likely decline in dry seasons and only increase in wet seasons when there will be an overabundance (Vietnam MONRE, 2010). Extreme forms of heat experienced today, such as the European heat wave of 2003, the Russian heat wave of 2010, or the extreme summer temperatures of 2011 in Texas would have been extremely unlikely to occur in the absence of climate change (Hansen et al., 2012).

When drought hits, plant productivity is directly affected and the mortality risk for livestock, such as cattle or birds, is greatly raised and indirectly can create vulnerabilities which invasive pests can exploit, further increasing damage (Chaves et al., 2009; Lesnoff et al., 2012; Wolf, 2009; Cherwin, 2009). Economic losses clearly result (Pandey et al. (eds.) 2007; Ding et al., 2011). Drought also damages buildings and infrastructure due to the shrinking and swelling of soil under extreme heat and aridity. This can lead to structural failure or accelerate asset depreciation (Corti et al., 2009).

IMPACTS

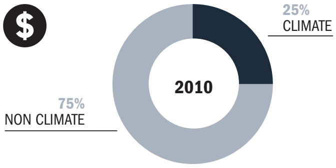
The global impact of climate change on drought is estimated to cause close to four billion dollars in damage a year in 2010, set to increase as a share of GDP to 2030 when average annual losses would reach close to 20 billion dollars a year.

The impact is very widespread with some 160 countries experiencing high vulnerability to drought by 2030. There are many regions which are seriously affected, especially the wider Mediterranean basin and Black Sea, North Africa, the Middle East and southern and eastern Europe. In addition, parts of Central Asia and Southern Africa are also expected to experience severe effects. While mainly developing countries are affected, since developed nations in general are located geographically in the far north or south, a handful of major advanced economies are exposed to the most severe effects, in particular Spain, Portugal, Greece and Australia. Large numbers of least developed countries figure among those countries with Acute or Severe levels of vulnerability.

The largest total impact is felt in China whose estimated losses in 2010 of 800 million dollars would surpass six billion dollars a year in damage by 2030. Other countries with particularly large-scale impacts include India, Iran, the US, Spain, Mexico, Brazil and Russia – several are estimated to experience impacts in excess of 1 billion dollars in annual losses by 2030.

BIGGER PICTURE

$

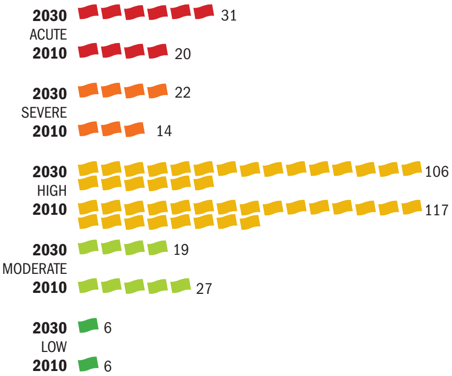


SURGE

OCCURRENCE

N/A

VULNERABILITY SHIFT



PEAK IMPACT

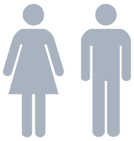
☠

2002	**MALAWI**	500
2006	**CHINA**	134
2005	**BURUNDI**	120
2004	**KENYA**	80
2002	**UGANDA**	79

$

2011	**UNITED STATES**	8,000
2009	**CHINA**	3,600
2002	**AUSTRALIA**	2,000
2004	**BRAZIL**	1,650
2010	**RUSSIA**	1,400

GENDER BIAS



INDICATOR INFORMATION

MODEL: Corti et al., 2009; Hoekstra et al., 2010; Rubel and Kottek, 2010; Sheffield and Wood, 2007

EMISSION SCENARIO: SRES A1B (IPCC, 2007)

BASE DATA: Corti et al., 2009; CRED EM-DAT, 2012

$ = Millions of USD (historic)

● Acute ● Severe ● High ● Moderate ● Low

▬ = 5 countries (rounded)

THE BROADER CONTEXT

Virtually all of the costliest drought years have occurred in the last two decades (CRED/EM-DAT, 2012). For statistical reasons it is still difficult to conclusively discern and pronounce on any global trends in drought losses; however the IPCC and insurance industry have reported increases in drought impact, and regional drought has become extreme in recent years (Quarantelli, 2001; IPCC, 2007; Bouwer, 2011). Major agricultural zones of Australia have experienced prolonged drought for a decade, not attenuated by a return to pre-drought levels of rainfall as the heat rises (LeBlanc et al., 2009). A 2010 drought in Brazil and across the Amazon regions was one of the worst ever (Saleska et al., 2011). The insurance industry is gauging growing losses as a result of drought-triggered soil subsidence and damage to buildings and infrastructure, estimated to cost €340 million per year in France alone (Swiss Re, 2010).

VULNERABILITIES AND WIDER OUTCOMES

Geography is a prime vulnerability, since countries in the far north receive considerably more rainfall (IPCC, 2007; Helm et al., 2010). Demand for water is another key determinant of vulnerability, since drought in the middle of the Sahara is of little consequence, while drought in the southern US, Europe or India is a major concern. Global water demand is expected to almost double by 2030, in particular due to increased water withdrawals in the agricultural sector – just as climate change will deprive many of the world's productive regions of water (McKinsey & Company, 2009; Sheffield and Wood, 2008). Land degradation from over-intensive agricultural exploitation or over-grazing and deforestation also greatly increase susceptibility to drought – another 30 % loss of forest in the Amazon could push the entire region into permanent aridity (Malhi et al., 2008). A lack of adequate irrigation and water infrastructure exacerbates drought since water captured in other periods of the year cannot be drawn upon during periods of prolonged aridity. In general, water-deprived economies have been understood to be less prosperous (Brown and Lall, 2006). The human health consequences of drought are principally accounted for under the Hunger indicator of the Monitor.

RESPONSES

Any response to drought must face up to two key concerns: 1) increasing water availability, and 2) dealing with building and infrastructure damage due to sinking or destabilized land. Increasing water availability will be met at the market cost of supplying water, which varies from region to region depending on the degree of water scarcity currently prevailing locally (McKinsey & Company, 2009). Effective governments would anticipate any shortfall and stimulate action to meet any expected water demand shortfall in order to avoid economic losses and loss of tax revenues. Addressing soil subsidence through design could involve the retrofitting of buildings to withstand soil movements linked to drought. Both drought and soil subsidence impacts can be dealt with by displacing risks to the insurance (and micro-insurance) industry through policies enabling businesses and home-owners to safeguard against potential damages (Swiss Re, 2011; Churchill and Matul, 2012).

THE INDICATOR

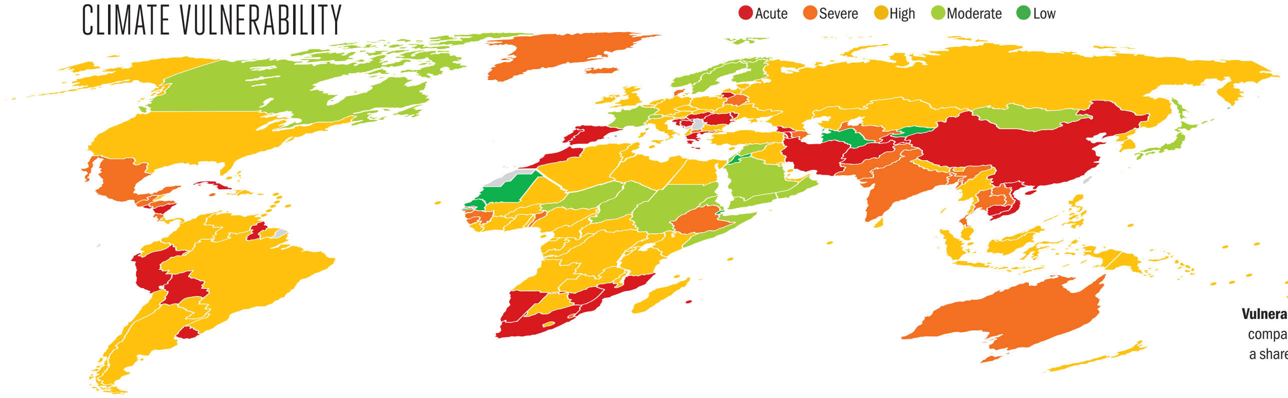
The indicator measures the impact of climate change on drought, defined as a consecutive sequence of months with "anomalously low soil moisture". It measures the change in both disaster damages and depreciation of property due to soil subsidence damages. The change in the number of droughts expected to occur is estimated using an ensemble of eight climate models (Sheffield and Wood, 2008). Baseline data for disaster damages is derived from the main international disaster database, but is known to be incomplete (CRED/EM-DAT, 2012). Accelerated depreciation of infrastructure due to soil subsidence uses a model based on France and extrapolated based on GDP per capita and population density, but excluding arid countries where the effect is considered less relevant (Corti et al., 2009; Hoekstra et al., 2010). Limitations and uncertainties relate to difficulties in estimating rainfall change for certain regions, the simplistic 1:1 damage assumption implied and to the extrapolation used for the soil subsidence indicator.

ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	$ 2010	$ 2030
ACUTE		
Afghanistan	5	40
Armenia	5	25
Bolivia	5	45
Bosnia and Herzegovina	15	100
Cambodia	5	60
China	800	6,250
Croatia	15	85
Cuba	10	65
El Salvador	10	70
Gambia		1
Georgia	10	50
Greece	35	95
Guyana	1	15
Hungary	15	90
Iran	200	1,500
Lithuania	10	45
Mauritius	5	25
Moldova	10	65
Morocco	40	300
Mozambique	1	10
Namibia	1	10
Nicaragua	1	15
Peru	25	150
Portugal	45	150
Romania	20	100
South Africa	50	250
Spain	200	650
Tajikistan	5	20
Uruguay	5	40
Vietnam	40	350
Zimbabwe	1	10
SEVERE		
Australia	45	100
Azerbaijan	5	30
Bangladesh	15	75
Belarus	10	35
Benin	1	5
Costa Rica	1	15
Denmark	10	25
Ethiopia	5	20
Guatemala	5	20
Guinea	1	1
Guinea-Bissau		1
Honduras	1	10
India	300	1,500
Jamaica	1	5
Laos	1	5
Macedonia	1	5
Mexico	95	600
Pakistan	35	200
Sierra Leone		1
Swaziland		1
Thailand	40	200
Uzbekistan	5	30
HIGH		
Albania	1	5
Algeria	5	30
Angola	5	15
Antigua and Barbuda		
Argentina	25	150
Austria	10	10
Bahamas		1
Bahrain	1	5
Barbados		1
Belgium	10	15
Belize		1
Bhutan		1
Botswana	1	5
Brazil	95	550
Brunei	1	5
Bulgaria	5	20
Burkina Faso	1	1
Burundi		1
Cameroon	1	5
Cape Verde		
Central African Republic		1
Chile	15	70
Colombia	15	80
Comoros		
Congo	1	1
Cote d'Ivoire	1	5
Cyprus	1	1
Czech Republic	10	40
Dominica		
Dominican Republic	5	20
DR Congo	1	5
Ecuador	5	30
Egypt	10	50
Equatorial Guinea	1	5
Estonia	1	5
Fiji		1
Gabon	1	5
Germany	70	100
Ghana	5	15
Grenada		

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

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY

	$	
COUNTRY	2010	2030
Haiti	1	1
Iceland		1
Indonesia	40	200
Iraq	5	15
Ireland	5	5
Italy	55	150
Kazakhstan	5	20
Kenya	1	5
Kiribati		
Kuwait	5	20
Latvia	1	5
Lebanon	1	10
Lesotho		1
Liberia		
Libya	1	10
Madagascar	1	5
Malawi	1	1
Malaysia	20	80
Maldives		
Mali	1	1
Malta		1
Marshall Islands		
Micronesia		
Myanmar	1	10
Nepal	1	10
Netherlands	15	25
New Zealand	5	5
Nigeria	15	70
North Korea	1	10
Palau		
Panama	1	10
Papua New Guinea	1	1
Paraguay	1	5
Philippines	20	85
Poland	30	100
Qatar	5	20
Russia	90	400
Rwanda	1	1
Saint Lucia		1
Saint Vincent		
Samoa		
Sao Tome and Principe		
Seychelles		1
Singapore	10	40
Slovakia	5	15
Slovenia	1	10
Solomon Islands		
South Korea	55	250
Sri Lanka	5	25
Suriname		1
Tanzania	5	15
Timor-Leste		1
Togo		1
Tonga		
Trinidad and Tobago	1	5
Tunisia	5	15
Turkey	35	65
Tuvalu		
Uganda	1	10
Ukraine	20	75
United Arab Emirates	5	25
United Kingdom	55	90
United States	500	1,250
Vanuatu		
Venezuela	10	45
Zambia	1	1
MODERATE		
Canada	25	45
Chad		
Eritrea		
Finland	1	1
France	45	75
Israel	1	15
Japan	90	150
Luxembourg	1	1
Mongolia		1
Niger		1
Norway	1	5
Oman	1	5
Saudi Arabia	1	10
Somalia		
Sudan/South Sudan	1	10
Sweden	5	10
Switzerland	5	10
Syria	1	5
Yemen	1	5
LOW		
Djibouti		
Jordan		
Kyrgyzstan		
Mauritania		
Senegal		
Turkmenistan		

FLOODS & LANDSLIDES

ESTIMATES GLOBAL CLIMATE IMPACT

2010 EFFECT TODAY

2,750 DEATHS PER YEAR

10 BILLION USD LOSS PER YEAR

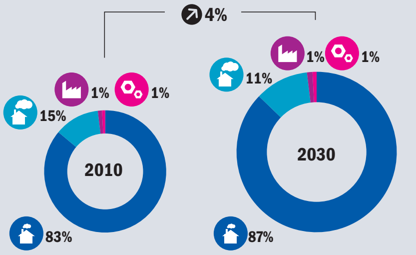
2030 EFFECT TOMORROW

3,500 DEATHS PER YEAR

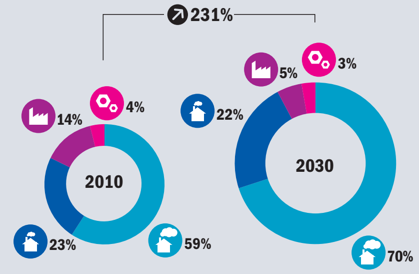
95 BILLION USD LOSS PER YEAR

- Heavy rainfall, the main trigger of flooding and landslides, is on the rise
- Spring comes earlier and releases more water from mountains and glaciers which adds further to flood risks
- Future increases in these effects may coincide, generating more mega disasters of the scale of the 2010 Pakistan floods
- Comprehensive risk reduction efforts in implementation of the Hyogo Framework for Action are helping to reduce vulnerabilities, even as world population and exposed infrastructure expand
- Parallel efforts are not being made to deliberately adjust humanitarian relief systems to growing flood dange

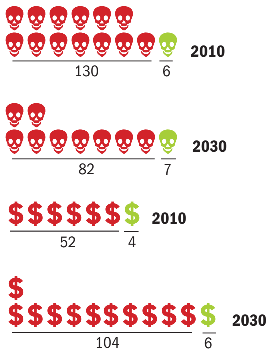
MORTALITY IMPACT



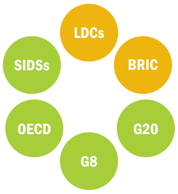
ECONOMIC IMPACT



RELATIVE IMPACT



GEOPOLITICAL VULNERABILITY



HOTSPOTS

2010	Deaths	2030
2,000	**INDIA**	2,500
200	**CHINA**	150
75	**BANGLADESH**	100
50	**VIETNAM**	55
30	**PAKISTAN**	45

2010	$	2030
4,500	**CHINA**	50,000
1,250	**INDIA**	10,000
550	**NORTH KOREA**	6,750
350	**PAKISTAN**	3,250
300	**BANGLADESH**	2,750

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

Deaths = Deaths per 100 million
$ = Losses per 100,000 USD of GDP
Change in relation to overall global population and/or GDP

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

Flooding is a common natural hazard from increases in rainfall due to climate change. Floods are expected to worsen practically everywhere, even in areas facing declining annual rainfall, as heavy downpours become more common (IPCC, 2007). More floods mean more deaths and injuries, more damaged property and infrastructure, and growing disruption of economic activities. Where large countries like China, Pakistan, or the US are affected, the lives of millions of people may be disrupted and billions of dollars of economic damage inflicted (CRED/EM-DAT, 2012). However, the risk of death due to flooding is heavily concentrated in low-income countries, which face significant risks of setbacks in development gains, with women particularly vulnerable (UNISDR, 2011; Nelleman et al., 2011). Highly cost-effective including "low-regrets" measures to limit damages and speed recovery are also inaccessible to many for lack of the capacity and up-front resources to implement them (IPCC, 2012a). Social and political factors, including illiteracy and the over-exploitation of resources often exacerbate these problems (UNISDR, 2009).

CLIMATE MECHANISM

A warmer planet means a more active hydrological system, as water is evaporated faster from oceans and land, generating cloud and rainfall (Dore, 2005; Kharin et al., 2007). That means more rain overall and more energy in general in the global climate system as it heats up, leading to heavier downpours of rain, more variable or erratic rainfall, and more frequent heavy precipitation. Coupled with an earlier spring that discharges more water as glaciers continue to decline, the implications are that risk of flooding and landslides caused by weather, and not earthquakes or otherwise, are on an increase (Hidalgo et al., 2009; Radi⊠ and Hock, 2011; IPCC, 2007; Mirza et al., 2003; Jonkman et al., 2008; Bouwer et al., 2010). The evidence base for the flood trend is low, in particular due to inadequate gauge station records and confounding information linked to land use and engineering (IPCC, 2012a). The increase in heavy rainfall during short periods of time is assured and is not only the main trigger of flooding, but the main input variable to early warning tools to predict flooding (Prudhomme et al., 2002; Harris et al., 2007).

IMPACTS

Globally, climate change is already estimated to be responsible for close to an average of 3,000 deaths per year and around 10 billion dollars in economic losses through flooding and landslides. For every death, there can be as many as 10,000 people in need of emergency assistance; each year, over 25 million more people are affected than in earlier periods when climate change was not so marked. Over the next 20 years, the climate-related flood death toll is expected to increase only modestly to 3,500 deaths per year with economic losses more than tripling as a share of global GDP, reaching 95 billion dollars per year by 2030.

Approximately two-thirds of these losses are incurred in China and India alone. Populous emerging economies in Asia, such as Bangladesh, Pakistan, and Vietnam are particularly vulnerable, as are mountainous developing countries, such as Bhutan and Nepal. Effects are widely distributed around the world, with the number of countries labeled "Acute" doubling by 2030. Low-lying small island states, such as the Maldives, are unaffected by non-coastal flooding and landslides, whereas mountainous small islands, such as Haiti or Fiji are at high risk.

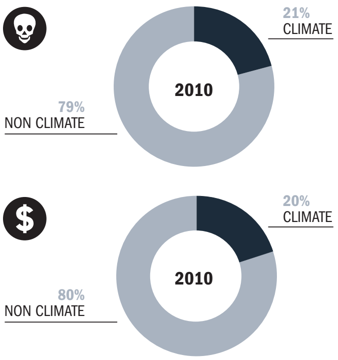
THE BROADER CONTEXT

The significance of socio-economic determinants of risk mean climate change is only one factor in the scale of damage generated by so-called natural disasters. Mortality risk due to extreme weather is known to fall over time with rising incomes (Peduzzi et al., 2012). However, economic losses show increases in recent years (CRED/EM-DAT, 2012; Munich Re, 2012). These observations support the UN's analysis that as socio-economic development improves, fewer people are killed, but infrastructure is at greater risk (UNISDR, 2009 and 2011).

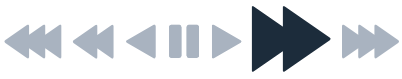
VULNERABILITIES AND WIDER OUTCOMES

Vulnerability levels are often dictated by socio-economic development standing and the associated effectiveness of governments in putting in place measures that can limit dangers for populations. Poorly located, unprotected flood plain settlements are also at high risk, but sound governance should prevent or rationalize this type of development. Environmental degradation and unwise patterns of land

BIGGER PICTURE

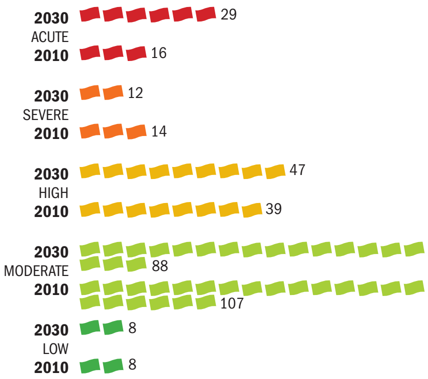


SURGE



OCCURRENCE

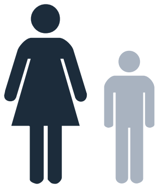
VULNERABILITY SHIFT



PEAK IMPACT

	☠			$	
2004	**HAITI**	2,665	2010	**CHINA**	18,930
2005	**INDIA**	2,129	2002	**GERMANY**	11,600
2010	**PAKISTAN**	2,113	2008	**UNITED STATES**	10,002
2010	**CHINA**	1,911	2010	**PAKISTAN**	9,500
2007	**BANGLADESH**	1,230	2007	**UNITED KINGDOM**	8,448

GENDER BIAS



INDICATOR INFORMATION

MODEL: Kharin et al., 2007

EMISSION SCENARIO: SRES A1B (IPCC, 2007)

BASE DATA: CRED EM-DAT, 2012; Munich Re NATCAT, 2010 (economic data); UNEP GRID, 2012 (mortality data)

$ = Millions of USD (historic)

Estimated time between major weather events (years)

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

usage, particularly deforestation, further exacerbate localized vulnerabilities, for example, by destabilizing hillsides and by increasing the flow of rainwater over land—effects especially significant in developing countries (Brashshaw et al., 2007). High rates of urbanization, common in most developing countries around the world today, often lead rural-urban migrants to settle in flood plain shanty towns adjacent to major urban centres, adding to the level of risk (Quarantelli, 2003).

Flooding carries serious consequences for economic activity, especially for lower-income communities where insurance that otherwise speeds economic rebound is least prevalent (Dodman and Satterthwaite, 2008).

Harm to poverty-reduction efforts has been shown to result more from widespread and regularly occurring small- to medium-scale disasters, since they repeatedly frustrate development progress, even though freak, high-profile, catastrophes typically receive more attention (Lavell, 2008). Flood damage—particularly ecological and social costs or diffuse disruptions to broad economic activities—is also difficult to fully quantify, and in extreme cases can persist for months (Messner and Meyer, 2005).

RESPONSES

Like other disasters, floods are considered to have three core components: hazard, exposure, and vulnerability. Hazard is a variable largely beyond immediate human control, so responses either aim to decrease vulnerability or exposure to hazard, or both. Measures such as rapid early warning systems, disaster education, building codes and their regulation, environmental protection against deforestation and land degradation, insurance for infrastructure or other economic assets, flood defences and storm drains, strengthening of local ecosystems, disaster volunteer programmes all reduce vulnerabilities, but may demand resources which many countries simply do not possess. Under pressure of economic and population growth, most increases in exposure are inevitable. But strategic municipal planning for infrastructure development can help minimize the extent of new exposure to risk. Urban centres with elevated population densities are also high-dividend opportunities for reducing possible disasters, provided urban authorities are willing and able to meet the needs of their residents in managing risks (Dodman and Satterthwaite, 2008).

The capacity of governments to develop and implement a range of risk-reduction measures is considered a fundamental determinant of the success of national disaster prevention and recovery strategies; this includes the ability to incorporate considerations of disaster risk into wide-ranging state agendas, from education to municipal planning and fiscal tools. Capacity to do so is also most deficient in highly vulnerable, low-income settings (Ahrens and Rudolph, 2006).

A number of low-income countries, such as Bangladesh have nevertheless managed to reduce levels of vulnerability through cost-effective community and volunteer-based efforts, as alternatives to more resource-intensive measures (Khan, 2007). On the other hand, recent floods along the Mississippi and Missouri rivers in the US have shown how even the highly developed countries can be overwhelmed by large-scale events (Olson and Morton, 2012). New extremes and delays in policy changes to increase resilience mean that the world's humanitarian system should prepare for serious increases in flood response in the years ahead.

THE INDICATOR

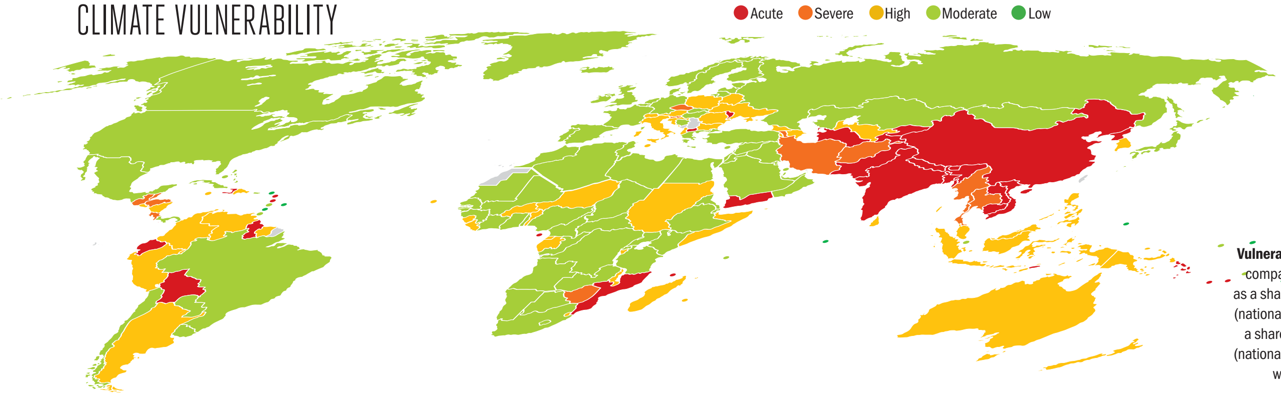
The indicator combines exposure to floods and landslides with modeled mortality risk for estimations of deaths with socio-economic adjustments. For economic losses, a combination of 20 years of disaster data from different sources is relied upon as a baseline. The indicator then estimates how the change in, or increases in the occurrence of, heavy precipitation events would alter the current picture of flood and landslide risk. Uncertainty regarding precipitation change in some areas is an impediment to reliable national-level estimates of these changes. Likewise, country-specific variation in the effects of increased heavy rainfall is not accounted for, except through the worsening of the pre-existing topography of risk, as reflected in historic and modeled disaster data. Although records of floods are unreliable, models of the effects of climate change on heavy precipitation and observed rainfall changes do reveal the increasing trend (IPCC, 2007, IPCC, 2012a; Kharin et al.).

ESTIMATES COUNTRY-LEVEL IMPACT

	☠		$		🧍	
COUNTRY	2010	2030	2010	2030	2010	2030
ACUTE						
Bangladesh	75	100	300	3,000	600,000	900,000
Bhutan	1	1		1	15,000	25,000
Bolivia	1	1	30	300	10,000	15,000
Cambodia	10	10	20	200	65,000	65,000
China	200	150	4,500	50,000	2,000,000	1,500,000
Comoros	5	10			45,000	85,000
Dominica	1	1			2,500	3,000
Ecuador	1	5	30	300	25,000	30,000
Fiji	1	1	1	10	4,000	3,500
Guyana			10	100	2,000	1,500
Haiti	5	5	5	35	30,000	40,000
India	2,000	2,500	1,000	10,000	20,000,000	25,000,000
Kyrgyzstan	1	1	5	35	9,500	15,000
Laos	5	10	1	15	55,000	70,000
Macedonia			5	50	1,500	1,000
Moldova	1	1	15	100	5,500	5,000
Mozambique	1	5	10	85	20,000	30,000
Nepal	10	15	15	150	85,000	100,000
North Korea	10	10	550	6,500	100,000	85,000
Pakistan	30	45	350	3,000	300,000	450,000
Saint Lucia	1	1		1	6,000	6,000
Sao Tome and Principe	1	1			15,000	25,000
Solomon Islands	1	1			5,000	9,000
Tajikistan	5	5	40	300	30,000	45,000
Timor-Leste	1	1			25,000	25,000
Turkmenistan	5	10	5	25	55,000	80,000
Vanuatu		1		1	2,500	4,000
Vietnam	50	55	150	2,000	500,000	500,000
Yemen	1	1	35	250	7,500	25,000
SEVERE						
Afghanistan	5	10	5	35	55,000	90,000
Armenia	1	1		1	20,000	25,000
Belize				1	1,500	2,000
Costa Rica	1	1	5	55	6,500	10,000
Czech Republic			55	350	2,000	1,500
Guatemala	5	10	5	60	45,000	90,000
Honduras	1	1	5	70	15,000	20,000
Iran	10	10	200	1,500	40,000	50,000
Myanmar	35	45	5	40	250,000	350,000
Slovenia			15	95	2,000	1,500
Thailand	15	10	100	1,000	150,000	100,000
Zimbabwe	1	1	5	25	15,000	25,000
HIGH						
Albania	1	1	1	10	5,000	6,500
Argentina	5	5	70	700	15,000	20,000
Australia	1	1	65	200	2,500	5,500
Austria	1	1	30	90	5,000	6,500
Azerbaijan	1	1	5	30	10,000	10,000
Belarus	1	1	5	35	6,500	5,500
Benin	1	1	1	5	7,500	15,000
Brunei					1,500	1,500
Bulgaria	1	1	10	70	3,000	1,500
Burkina Faso	1	1	1	15	3,000	7,500
Burundi	1	1		1	10,000	20,000
Cape Verde					1,500	2,000
Colombia	10	10	50	450	35,000	45,000
Croatia	1	1	10	85	4,000	3,000
Dominican Republic	1	1	1	25	7,500	8,000
El Salvador	1	5		1	20,000	30,000
Equatorial Guinea		1			2,000	3,500
Gabon	1	1			1,500	3,000
Georgia	1	1	1	10	30,000	20,000
Indonesia	25	30	75	650	250,000	250,000
Italy	1	1	150	500	5,500	7,000
Jamaica	1	1	1	20	3,500	4,000
Liberia	1	1			5,500	15,000
Madagascar	5	5	1	15	30,000	55,000
Malawi	1	1	1	5	15,000	25,000
Malaysia	5	5	20	200	15,000	15,000
Malta			1	1	200	300
Mauritius		1			1,500	1,500
New Zealand	1	1	5	15	4,500	9,500
Nicaragua	1	5	1	5	20,000	40,000
Niger	1	5	1	10	10,000	25,000
Papua New Guinea	1	5	1	5	30,000	40,000
Peru	5	5	15	150	15,000	20,000
Philippines	25	25	30	300	200,000	250,000
Poland	1	1	85	600	5,500	4,000
Romania	1	1	40	300	8,500	6,000
Sierra Leone	1	5		1	15,000	30,000
Somalia	1	5	1	1	20,000	45,000
South Korea	5	5	95	800	25,000	20,000
Sri Lanka	5	5	15	150	45,000	40,000
Sudan/South Sudan	5	5	5	40	40,000	55,000
Suriname					550	650
Swaziland		1			3,000	4,000
Switzerland	1	1	25	75	2,000	3,000
Ukraine	1	1	40	300	25,000	15,000
Uzbekistan	10	15		1	95,000	150,000
Venezuela	5	5	30	300	15,000	15,000
MODERATE						
Algeria	5	5	5	60	15,000	20,000
Angola	1	5		1	20,000	45,000
Bahamas						
Bahrain				1	650	850

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

CLIMATE VULNERABILITY



Vulnerability measure: comparative mortality as a share of population (national) and losses as a share of GDP in USD (national) with same full weighting to both

CLIMATE UNCERTAINTY

	☠		$		🚹	
COUNTRY	2010	2030	2010	2030	2010	2030
Belgium		1	1	5	1,500	2,000
Bosnia and Herzegovina	1	1	1	5	3,000	2,000
Botswana				1	650	700
Brazil	5	10	20	200	30,000	30,000
Cameroon	5	5		1	35,000	50,000
Canada	1	5	30	100	9,000	20,000
Central African Republic	1	1			6,000	9,500
Chad	1	1		1	9,500	20,000
Chile	1	1	5	50	4,000	4,500
Congo	1	1			7,000	15,000
Cote d'Ivoire	1	1			20,000	30,000
Cuba	1	1	1	20	2,500	2,500
Cyprus					750	1,500
Denmark				1	250	350
Djibouti					200	250
DR Congo	10	25		1	90,000	200,000
Egypt	5	10	5	30	65,000	80,000
Eritrea	1	1			4,500	7,500
Estonia					750	450
Ethiopia	10	15	1	5	75,000	150,000
Finland				1		
France	1	1	60	200	9,000	15,000
Gambia					1,000	1,500
Germany	1	1	100	350	4,500	6,500
Ghana	1	1	1	5	6,500	10,000
Greece	1	1	10	30	2,000	3,000
Guinea	1	5		1	15,000	25,000
Guinea-Bissau					950	1,500
Hungary			10	65	1,500	900
Iceland				1	150	250
Iraq	5	5			35,000	60,000
Ireland		1	5	15	1,000	2,500
Israel		1	1	5	1,500	2,000
Japan	5	5	150	400	20,000	35,000
Jordan				1	2,000	3,000
Kazakhstan	1	5	5	30	10,000	15,000
Kenya	5	5	1	10	40,000	50,000
Kuwait					150	200
Latvia					1,000	750
Lebanon	1	1			3,000	3,000
Lesotho					3,500	3,500
Libya			1	5	650	850
Lithuania					1,000	900
Luxembourg				1	200	500
Mali	1	1			10,000	20,000
Mauritania		1		1	2,000	4,500
Mexico	10	10	55	500	40,000	40,000
Micronesia						
Mongolia	1			1	4,500	3,500
Morocco	1	1	5	30	15,000	20,000
Namibia				1	1,000	1,500
Netherlands	1	1	15	40	2,000	3,500
Nigeria	10	15	1	20	85,000	150,000
Norway			1	5	700	1,000
Oman		1		1	1,500	3,000
Panama	1	1	1	5	2,000	2,000
Paraguay	1	1		1	10,000	20,000
Portugal	1	1	10	30	2,000	3,000
Qatar					300	350
Russia	10	5	75	550	35,000	25,000
Rwanda	1	1			15,000	25,000
Saint Vincent						
Samoa						
Saudi Arabia		1	10	90	1,500	3,000
Senegal	1	1	1	5	9,500	15,000
Seychelles						
Singapore			1	5		
Slovakia	1		5	30	2,500	2,000
South Africa	1	1	5	35	5,500	4,500
Spain	1	1	10	35	4,000	5,500
Sweden				1	400	600
Syria	1	5			30,000	45,000
Tanzania	1	5	1	10	20,000	30,000
Togo	1	1		1	5,000	9,000
Tonga						
Trinidad and Tobago				1	650	600
Tunisia		1	5	45	3,500	4,000
Turkey	5	10	30	100	15,000	35,000
Uganda	1	5		1	15,000	35,000
United Arab Emirates	1	1	1	20	2,500	3,000
United Kingdom	1	1	100	350	3,500	5,500
United States	5	5	600	2,000	15,000	35,000
Uruguay	1	1	1	5	1,500	1,500
Zambia	1	1		1	10,000	20,000
LOW						
Antigua and Barbuda						
Barbados						
Grenada						
Kiribati						
Maldives						
Marshall Islands						
Palau						
Tuvalu						

🚹 Additional persons affected/in need of emergency assistance due to climate change - yearly average

STORMS

ESTIMATES GLOBAL CLIMATE IMPACT

2010 EFFECT TODAY

DEATHS PER YEAR **2,500**

USD **LOSS** PER YEAR **15 BILLION**

2030 EFFECT TOMORROW

DEATHS PER YEAR **3,500**

USD **LOSS** PER YEAR **100 BILLION**

CONFIDENCE
SPECULATIVE

SEVERITY ● ● ● ○

AFFECTED

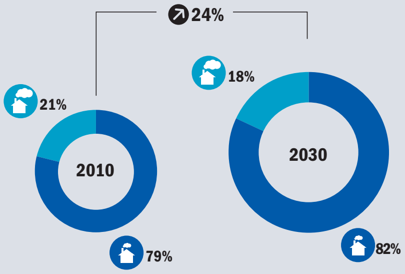
INJUSTICE ○ ● ○ ○

PRIORITY ○ ● ○

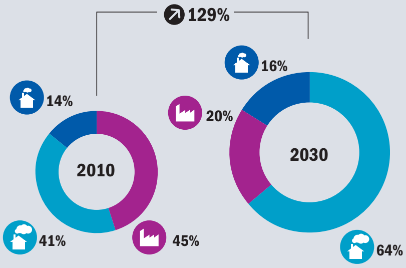
MDG EFFECT ● ○ ○ ○ ○ ○ ○

- All weather is affected by climate change because the Earth's atmosphere is warmer, moister, and more active today than in the recent past
- As a result, storms are becoming more extreme both in and outside of the tropics and will cause greater damage
- The location and extent of the additional damage is difficult to predict, as experts and their studies differ in their conclusions
- Countries already exposed to tropical cyclones or immediately adjacent to cyclone belts should prepare for growing risks and damages, especially in coastal areas

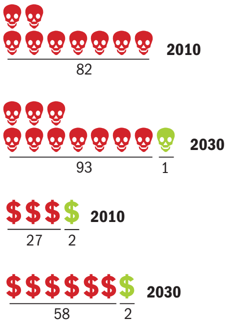
MORTALITY IMPACT



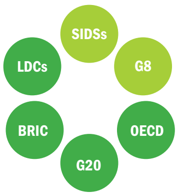
ECONOMIC IMPACT



RELATIVE IMPACT



GEOPOLITICAL VULNERABILITY



HOTSPOTS

2010	☠	2030
1,750	**BANGLADESH**	2,500
500	**MYANMAR**	600
150	**INDIA**	150
50	**MADAGASCAR**	100
45	**PHILIPPINES**	60

2010	$	2030
4,750	**CHINA**	50,000
4,000	**JAPAN**	10,000
2,500	**UNITED STATES**	8,250
550	**NORTH KOREA**	5,750
600	**SOUTH KOREA**	4,750

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

☠ = Deaths per 10 million
$ = Losses per 10,000 USD of GDP
↗ Change in relation to overall global population and/or GDP

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

Whether or not specific events can be identified as "caused" by climate change, all weather is now affected by a global climate system that is warmer, more active, and wetter (Trenberth, 2012).

As a result, it is evident that storms are generally becoming more extreme, particularly in terms of wind speeds and quantity of rainfall. Moreover, there is a pole-ward shift to the north and south of cyclone storm tracks, as parts of the world adjacent to the tropics are experiencing more "tropical" weather.

Where vulnerabilities to more severe storms are accentuated by environmental and income-related factors—such as for high-risk urban slums in low-lying coastal areas—the dangers of these changes are much higher (IPCC, 2012a). Corresponding measures will need to offset the additional risk by reducing community vulnerabilities and, where possible, limiting exposure, to storm hazards (UNISDR, 2009 and 2011).

Increased emergency assistance should also be foreseen in the coming years and decades.

CLIMATE MECHANISM

Climate change increases air and sea temperatures, boosting the level of moisture in the atmosphere; this leads to acceleration of the planet's hydrological system, heavier precipitation, higher maximum winds and a general tendency to more extreme weather (IPCC, 2007). These hallmarks have been recognized in storms, including cyclones (IPCC, 2012a).

Whether or not there has been a change in the frequency or overall number of cyclones in recent years can side-track the focus on other important factors, such as wind speed changes (Knutson et al. in Chan et al. (eds.), 2010). Simply counting the change in the number of cyclones often leads to the conclusion that there is less cyclone activity, since there is generally understood to be a slight increase in the most extreme cyclones, such as categories 3 to 5, but an overall decrease in the total number of cyclones since the reduction in less severe storms is expected to be greater (Knutson et al., 2010). It is not surprising that an increase in the most extreme cyclones, as measured on the well-known Saffir-Simpson scale results in fewer cyclones overall, since the scale itself is static, measures overall power, and is a rough proxy for the size of storms (Dolan and David, 1992; Irish et al., 2008). Larger more powerful storms absorb and dissipate considerably more energy than smaller ones, whose declining numbers have been attributed to an overall decline in cyclone frequency in recent times (IPCC, 2012a). Nor is the ultimate number of storms as important as the intensity or size of those storms: in the US, 85% of all cyclone damage is caused by the most extreme storms (Rudeva and Gulev, 2007; Pielke et al., 2008). A large share of the damage caused by cyclones is the result of storm surge, or inundations from rainfall, high winds, and freak waves caused by major storms, which have been worsened by heavier rainfall and sea-level rise, both of which are fuelled by climate change (Dasgupta et al., 2009).

IMPACTS

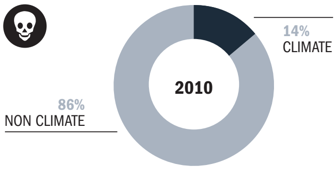
The impact of climate change on both tropical cyclones and major storms outside of the tropics (extra-tropical cyclones) is estimated to already cost 15 billion dollars and to be responsible for an average of almost 2,500 deaths each year, with around 1.5 million people affected and in need of emergency assistance.

In global terms, the number of countries experiencing extreme effects is limited, particularly since the great majority of losses relate to tropical cyclones, which are a serious concern for only 30 to 40 countries in the world's cyclone belts. A dozen countries in Asia, Africa, the Pacific, and the Caribbean are estimated to suffer Acute or Severe vulnerability to climate change-aggravated storm effects. The countries most vulnerable cut across the socio-economic spectrum from Japan to major emerging economies, such as China, least developed countries such as Madagascar, or small island developing states, such as Haiti.

Bangladesh is currently estimated to suffer the greatest human impact of these effects, with over 1,000 additional casualties due to climate change on an averaged yearly basis—major storms do not occur annually, but once in every 5 to 20 years. Myanmar and India are estimated to suffer the next greatest share of additional casualties. In overall economic terms, China, Japan, the US, North Korea, and South Korea experience the greatest estimated losses, incurring between 2 and 5 billion dollars a year in damages.

A number of small island countries, such as Antigua and Barbuda, Dominica, Grenada, and Vanuatu are identified as experiencing the most severe economic and human loss

BIGGER PICTURE

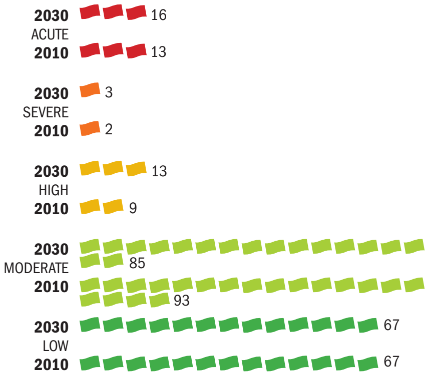


SURGE

OCCURRENCE

N/A

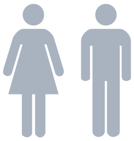
VULNERABILITY SHIFT



PEAK IMPACT

☠			$		
2008	**MYANMAR**	138,366	2005	**UNITED STATES**	158,230
2007	**BANGLADESH**	4,275	2004	**JAPAN**	15,144
2004	**HAITI**	2,757	2005	**MEXICO**	7,910
2005	**UNITED STATES**	1,882	2006	**CHINA**	7,859
2004	**PHILIPPINES**	1,861	2000	**NORTH KOREA**	6,000

GENDER BIAS



INDICATOR INFORMATION

MODEL: Donat et al, 2011; Mendelsohn et al., 2011

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: Tropical storms: Mendelsohn et al., 2011 (economic); Peduzzi et al., 2012 (mortality). Extra-tropical storms: CRED EM-DAT, 2012; Munich Re NATCAT, 2010 (economic)

$ = Millions of USD (historic)

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

relative to size. Several countries located on the Central American isthmus, such as Belize, El Salvador, and Honduras are exposed to tropical cyclones originating in both the Caribbean/Atlantic and Pacific Oceans, and are estimated to suffer extreme effects.

THE BROADER CONTEXT

As with other weather-related disasters, two key trends provide the context for the changes in extreme weather hazards which researchers increasingly attribute to climate change: 1) reductions in vulnerability due to continued economic growth especially in developing countries; and 2) an increase in the number of people and the amount of infrastructure exposed to extreme weather, due to the combined effects of population growth, urbanization, and economic development (UNISDR, 2011; Peduzzi et al., 2012). Correcting for these developments and other inconsistencies, evolution in reporting systems and biases in the statistical record have led to mixed interpretations of whether the scale of impacts due to climate change are increasing or decreasing (Mendelsohn et al., 2011; Pielke et al., 2008). The insurance industry has been registering greater and greater losses from weather-related catastrophes, including storms, over the past several years (Swiss Re, 2010, 2011, and 2012).

VULNERABILITIES AND WIDER OUTCOMES

Particularly noteworthy in terms of environmental vulnerabilities to storms are low-lying coastal communities which will bear the brunt of the increasing effects of climate change on heavy rainfall, wave height, and storm surge during cyclones (Füssel in Edenhofer et al. (eds.), 2012). Significantly altering the risk profile of countries are existing protection levels and capacities embodied in infrastructure, early warning systems, social and community response, support networks and levels of awareness about disasters. Likewise, government capacity to manage risks, as well as land use and environmental planning and protection can all affect the level of vulnerability, e.g., inappropriate urbanization or the clearing of coastal mangrove forests, which otherwise provide protection against winds and storm surges (UNISDR, 2009 and 2011; IPCC, 2012a). Migration patterns are fuelling rapid and inappropriate urbanization, leading to growing settlements in high-risk coastal flood zones, which themselves are seeing a depletion in natural protection, as from the destruction of mangrove forests (Donner and Rodriguez, 2008; Füssel in Edenhofer et al. (eds.), 2012).

Where insurance coverage is low, the ability of affected communities to rebound from disasters is greatly inhibited (Dodman and Satterthwaite, 2008). This is especially a concern among developing and lower-income countries, such as small island developing states, where the scale of impact can also generate important setbacks for development (Pelling and Uitto, 2001).

RESPONSES

Numerous preventive measures can be taken to reduce key vulnerabilities and minimize naturally increasing exposures to disaster. Possible efforts include education and communication programmes, promotion of community volunteer emergency organizations, supporting governments to develop and implement action plans to manage risks through sensible municipal planning, constructing protective infrastructure, reinforcing environmental protection to limit risk-multiplication, and promoting access to insurance products. Better management of urbanization and urban-rural migration flows would also help lower risks for coastal mega-cities (de Sherbinin et al., 2007). Progress in human development and poverty reduction will inevitably enhance capacities to withstand serious storms and limit the damage to the highest risk groups, requiring integrated strategies regarding climate change, disaster risk, and development strategies (Schipper and Pelling, 2006).

THE INDICATOR

Although the increasing severity of weather including tropical and extra-tropical cyclones is well established, the indicator is considered speculative because there is considerable disagreement among the models predicting change in cyclone intensity for different regions of the world. With the exception of the North Atlantic, where evidence of an increase in extreme weather is strongest, predictions of changes in cyclone activity in the Indian and Pacific oceans differ widely (Mendelsohn et al., 2011; IPCC, 2012a).

ESTIMATES COUNTRY-LEVEL IMPACT

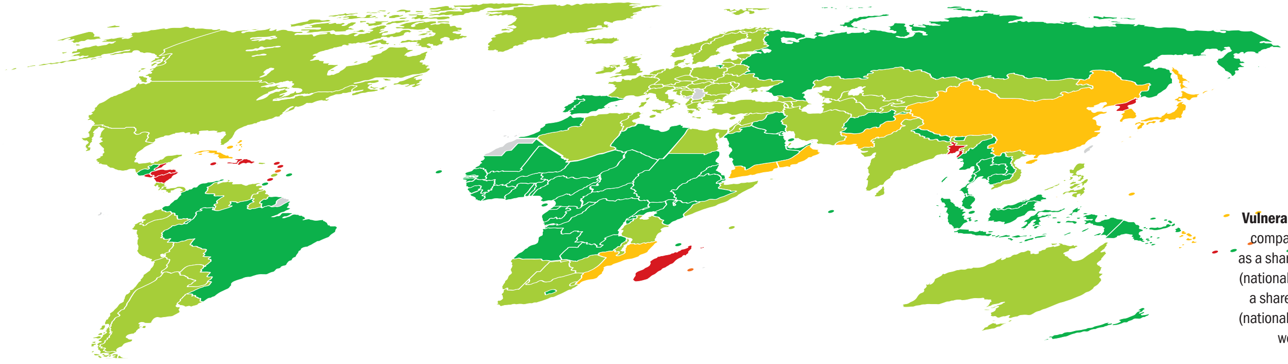
	☠		$		🧍	
COUNTRY	2010	2030	2010	2030	2010	2030
ACUTE						
Antigua and Barbuda			30	250	700	650
Bangladesh	1,750	2,500	150	1,250	400,000	600,000
Belize			30	250	550	700
Dominica			15	150	-90	-100
Dominican Republic	10	10	200	1,750	20,000	20,000
El Salvador			250	1,750	5	15
Grenada			25	200	-35	-60
Haiti	15	20	25	200	5,750	8,500
Honduras	1	1	200	1,500	200	350
Jamaica		1	100	800	1,000	2,500
Madagascar	50	100	40	250	150,000	300,000
Myanmar	500	600	1	20	10,000	15,000
Nicaragua	1	1	50	350	250	550
North Korea			550	5,750	2,250	-950
Tonga		1			-3,750	20,000
Vanuatu	5	10		-1	7,250	15,000
SEVERE						
Mauritius	1	1	25	150	500	400
Saint Lucia			1	20	15	10
Samoa		1		-1	750	5,750
HIGH						
Bahamas		1			400	450
China	1	-5	4,750	50,000	100,000	-250,000
Cuba	-1	-1	100	850	-75,000	-200,000
Japan	-10	-20	4,000	10,000	-10,000	-30,000
Marshall Islands					55	650
Micronesia					1	25
Mozambique	15	25	1	15	150,000	200,000
Oman			75	550		
Pakistan	5	5	250	2,250	4,500	8,750
Palau					200	450
Solomon Islands	1	1			8,500	20,000
South Korea		-1	600	4,750	-25	-200
Yemen			25	200		
MODERATE						
Albania						
Algeria				1		
Argentina			1	10		
Armenia						
Australia	1	1	-1	-1	100,000	150,000
Austria			5	10		1
Azerbaijan						
Belarus						
Belgium			1	10	1	1
Bolivia						
Bosnia and Herzegovina						
Botswana						
Bulgaria						
Canada			1	5		
Chile			1	10		
Costa Rica			1	10	950	1,250
Croatia						
Cyprus						
Czech Republic			1	5	550	1,000
Denmark			5	15	10	20
Djibouti						
Ecuador						
Egypt						
Estonia			1	1		
Finland				1		
France		1	40	95	3,250	6,000
Georgia				1		
Germany			100	350	25	50
Greece			1	5		
Guyana				1		
Hungary				1		
Iceland						
India	150	150	550	4,250	300,000	350,000
Iran			250	1,750		
Ireland			1	1		
Israel			1	10		
Italy			1	5		
Jordan				1		
Kazakhstan						
Kuwait			1	15		
Kyrgyzstan						
Latvia			1	10	400	750
Lebanon			1	5		
Lithuania				1	250	500
Luxembourg			1	1		
Macedonia						
Malawi				1		
Malta						
Mexico	10	15	150	1,250	70,000	85,000
Moldova			1	5		
Mongolia						
Namibia						
Netherlands			1	5	90	200
Norway			1	5		
Panama					25	30
Paraguay						
Peru			1	10		
Philippines	45	60	15	100	200,000	250,000
Poland			1	10	1	1
Qatar			1	10		

☠ Additional mortality due to climate change - yearly average

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

CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure: comparative mortality as a share of population (national) and losses as a share of GDP in USD (national) with same full weighting to both

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable

	☠		$		🧍	
COUNTRY	2010	2030	2010	2030	2010	2030
Romania			1	1		
Saint Vincent			1	5	-150	-150
Seychelles				1		
Slovakia			1	5		
Slovenia			1	5		
Somalia				1		
South Africa			5	20		
Sri Lanka			5	35	2,500	60
Swaziland						
Sweden			5	10	10	15
Switzerland			5	15	65	100
Syria						
Tajikistan			1	15		
Tanzania			15	90		
Tunisia						
Turkey						
Turkmenistan						
Ukraine			1	5		
United Kingdom			20	60	55	150
United States	1	1	2,500	8,250	4,750	6,500
Uruguay				1		
Uzbekistan						
Venezuela				1		
Vietnam	10	10	-5	-75	15,000	15,000
Zimbabwe	1	5			6,500	15,000
LOW						
Afghanistan						
Angola						
Bahrain			-5	-35		
Barbados				1	-90	-250
Benin						
Bhutan						

	☠		$		🧍	
COUNTRY	2010	2030	2010	2030	2010	2030
Brazil						
Brunei						
Burkina Faso						
Burundi						
Cambodia						
Cameroon						
Cape Verde						
Central African Republic						
Chad						
Colombia						
Comoros						
Congo						
Cote d'Ivoire						
DR Congo						
Equatorial Guinea						
Eritrea						
Ethiopia						
Fiji	1	-1	-10	-75	5,250	-2,000
Gabon						
Gambia						
Ghana						
Guatemala		1	-1	-10	150	250
Guinea						
Guinea-Bissau						
Indonesia			-50	-400		
Iraq						
Kenya				-1		
Kiribati						
Laos	1	1	-5	-35	5,750	8,750
Lesotho						
Liberia						
Libya						

	☠		$		🧍	
COUNTRY	2010	2030	2010	2030	2010	2030
Malaysia			-1	-10		
Maldives				-1	5	15
Mali						
Mauritania						
Morocco						
Nepal						
New Zealand			-5	-15	150	150
Niger						
Nigeria						
Papua New Guinea						
Portugal						
Russia	-1	-5	1	10	-150	-300
Rwanda						
Sao Tome and Principe						
Saudi Arabia			-30	-250		
Senegal						
Sierra Leone						
Singapore						
Spain			-1	-10		
Sudan/South Sudan						
Suriname						
Thailand			-5	-35	750	650
Timor-Leste						
Togo			-1	-10		
Trinidad and Tobago		-1			-250	-1,250
Tuvalu						
Uganda						
United Arab Emirates			-10	-85		
Zambia						

🧍 Additional persons affected/in need of emergency assistance due to climate change - yearly average

WILDFIRES

ESTIMATES GLOBAL CLIMATE IMPACT

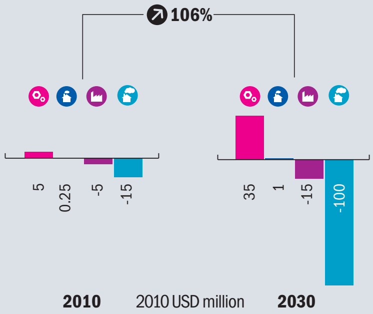
2010 EFFECT TODAY

$ USD **GAIN** PER YEAR **15 MILLION**

2030 EFFECT TOMORROW

$ USD **GAIN** PER YEAR **90 MILLION**

$ ECONOMIC IMPACT



CONFIDENCE

INDICATIVE

SEVERITY	● ○ ○ ○
AFFECTED	
INJUSTICE	● ○ ○ ○
PRIORITY	○ ○ ●
MDG EFFECT	○ ○ ○ ○ ○ ○ ○

- ➔ Global impact of climate change on wildfires may have a neutral effect as a warmer planet brings more rain, dampening fires
- ➔ Shifts in wildfire may occur where forested areas become drier and hotter, severely affecting populated parts of Russia, Mongolia, or Australia
- ➔ The marginal effect of climate change is difficult to predict because of wind and rain uncertainties and because good international data monitoring fire damages is lacking
- ➔ Wildfire occurrence has links to now more prevalent heat extremes and drought which increase the probability of fires

RELATIVE IMPACT

2010 2

2030 2

$$$ 25 $ 1 **2010**

$$$$$ 49 $ 1 **2030**

HOTSPOTS

2010	$	2030
5	**RUSSIA**	40
1	**MONGOLIA**	15
0	**NICARAGUA**	1
0	**SOUTH AFRICA**	1
1	**CANADA**	1

GEOPOLITICAL VULNERABILITY

G20
BRIC
OECD
G8
LDCs
SIDSs

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

= Deaths per 100 million
$ = Losses per 10 million USD of GDP
Change in relation to overall global population and/or GDP

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

Wildfires—the uncontrolled burning of forests, grasslands or brush—will generally become more frequent and damaging for drought-prone parts of the world. But it is certain that climate change will reduce disturbances from wildfires in some areas where rainfall is significantly increasing. The 2010 wildfires in Russia, as well as the recent fires in Australia, Greece, and the US, are clearly linked to warm, dry temperatures, if not drought (UNISDR, 2011). However, the additional losses incurred by those worst affected are likely to be offset on a global scale by a reduction in wildfire activity in other parts of the world. It is expected that Vietnam may see increased rainfall in some seasons, but declining rain and rising heat during the dry periods would favour wildfire onset, even if more rain overall falls in a given year (Vietnam MONRE, 2010). Tackling an additional burden of wildfire in affected areas will be great, since suppressing fires is costly: the US Forest Service spent 1 billion dollars on fire suppression in the year 2000 alone, with costs growing significantly over time—2.5 million dollars in losses were reported for that year. But expenditures were undoubtedly warranted in most cases, since wildfires can be extremely deadly: in February 2009, one series of fires alone in Australia killed 180 people (WFLC, 2004; CRED/EM-DAT, 2012).

CLIMATE MECHANISM

Wildfires are affected by three key factors: 1) availability of vegetation to burn; 2) environmental conditions, such as temperature, wind, and humidity or rainfall but also topography and ecosystem type—tropical forests for example are more humid and burn less than temperate forests; and 3) varying ignition sources of fires (Krawchuk et al., 2009). Climate change affects all of these elements: it influences vegetation growth and health along with the expanse of different ecosystem areas (Gonzalez et al., 2010). In regions with less rain and more heat, the declining vegetation will offer less available material for burning and will ultimately reduce disturbances from wildfires. Heat is increasing relatively uniformly around the world due to climate change. Less predictable rainfall and vegetation changes add considerable uncertainty to whether or not fires ultimately retreat or advance with global warming. Climate change has also been shown to potentially alter electrical activity in the atmosphere, giving rise to lightning, the principal initial trigger of wildfires (Reeve and Toumi, 1999).

IMPACTS

Drawing on recent research, the Monitor estimates the global impact of climate change on wildfire to be close to zero in 2010 and in 2030 (Krawchuk et al., 2009). Estimates of impact include around 3 million dollars of additional losses a year in 2010, and some 15 million dollars of additional losses in 2030. “Gains” of 25 and 150 million dollars a year in 2010 and 2030, respectively, outweigh considerably any losses incurred elsewhere in the world, but overall totals are small. “Gains” represent avoided wildfires that would have taken place without climate change. The largest negative effects in absolute terms are estimated to occur in Russia, Mongolia, Canada, Australia, and South Africa, while the US and Indonesia are expected to reap the most benefits overall. Within large countries like the US, it is possible that increased fire activity may well be experienced in certain areas but will be counterbalanced with decreased activity in other parts of the country. In general, wildfires mainly concern industrialized or developed countries.

THE BROADER CONTEXT

There has been a considerable increase in wildfire damage recorded in recent years (CRED/EM-DAT, 2012). However, improvements in the actual reporting systems themselves—advances in technology and information sharing—have allowed the reporting of increasing numbers of phenomena (UNISDR, 2009). However, satellite analysis has shown that the annual burned area has grown since the 1970s (UNEP, 2002). Several other factors, such as land usage change, could be contributing to increasing fire damage. As with other weather-related disasters, growing exposure to wildfires through economic development, population growth, and an expansion in infrastructure at risk should also increase damages.

VULNERABILITIES AND WIDER OUTCOMES

Countries with large areas of non-tropical vegetation and a propensity to drought are particularly vulnerable to the effects of climate change

BIGGER PICTURE

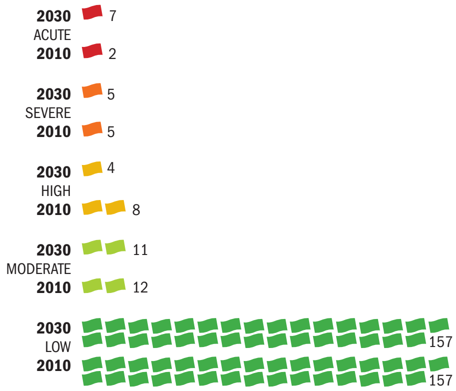
N/A

SURGE

OCCURRENCE

N/A

VULNERABILITY SHIFT



PEAK IMPACT

☠			$		
2009	**AUSTRALIA**	180	2003	**UNITED STATES**	3,500
2007	**GREECE**	70	2005	**SPAIN**	2,050
2010	**RUSSIA**	61	2010	**RUSSIA**	1,800
2008	**MOZAMBIQUE**	49	2007	**GREECE**	1,750
2010	**ISRAEL**	44	2003	**PORTUGAL**	1,730

GENDER BIAS

INDICATOR INFORMATION

MODEL: Krawchuk et al., 2009

EMISSION SCENARIO: SRES A2 (IPCC, 2000)

BASE DATA: CRED EM-DAT, 2012

$ = Millions of USD (historic)

● Acute ● Severe ● High ● Moderate ● Low

▬ = 5 countries (rounded)

on wildfires. Coniferous forests are especially risky areas for fire outbreak during extended warm, dry periods (Cruz and Alexander, 2010).

The full extent of increased wildfires is difficult to estimate, but given the incredible potential for the rapid and uncontrolled spread of fires, growing fire dangers in some parts of the world could carry serious risks for public safety. The 2010 Russian wildfires, for example, burned some 4,000 hectares of land– contaminated, moreover, by radioactive material from the Chernobyl disaster–the full consequences of which are not yet known; the fires also threatened functioning nuclear power plants and research facilities (Munich Re, 2010).

RESPONSES

Responding to wildfires is extremely costly requires highly sophisticated technology. Some early detection and warning systems are capable of identifying a fire within 5 minutes of its ignition (Bridge, 2010). Thus, such systems represent an investment that could significantly reduce overall expenditures on suppressing fires that would otherwise end up destroying thousands or millions of hectares. Fire safety and education programmes may reduce the potential for fires set by human hands by up to 80% (UNEP, 2002).

Of course, as is well known, not all wildfires are bad. Natural habitats have evolved to cope with wildfires over time and to support biodiversity and processes of regeneration (Parker et al., 2006). Therefore, many countries also practice what is called “prescribed burning,” effectively a “let-burn” policy, in which human settlements are not endangered. But while such practices may lower fire prevention costs and help support ecosystems, if fires subsequently reach a large-scale and deviate to threaten settlements, the costs of fire suppression can rapidly and counter-productively escalate (UNEP, 2002).

THE INDICATOR

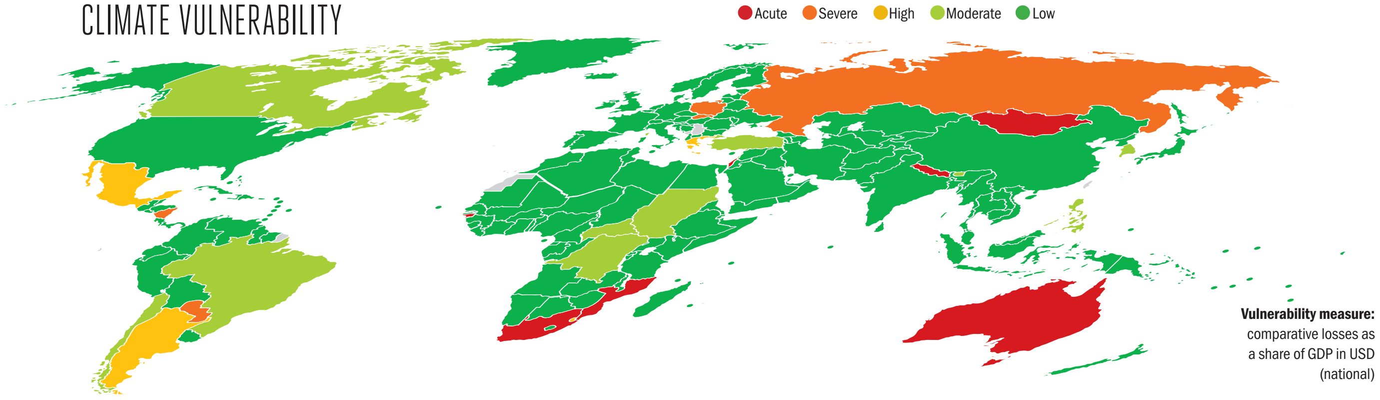
The indicator relies on a high-resolution global pyrogeography model for the effect of climate change on fire disturbances, used to estimate impact for populated areas (Krawchuk et al., 2009). Limitations relate to uncertain future rainfall and the restricted socio-economic base data set, which may underestimate costs (CRED/EM-DAT, 2012). Regarding base data, the major wildfires that affected Russia in 2010 are recorded in the reference database at 1.8 billion dollars in losses and 61 deaths. The major reinsurer, Munich Re, on the other hand estimates the total cost of the fires at 3.3 billion dollars and over 50,000 indirect deaths from both extreme heat and the significantly higher than normal air particle loads and their effect on chronic respiratory and cardiovascular disease sufferers (Munich Re, 2010). Historical base data would also give a misleading trend if fires spread to areas where damage in the past was unusual, underestimating future losses.

ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	$ 2010	$ 2030
ACUTE		
Australia	0.25	0.50
Guinea-Bissau		
Israel		
Mongolia	1	15
Mozambique		
Nepal		
South Africa	0.25	1
SEVERE		
Nicaragua	0.25	1
Paraguay		
Poland		
Russia	5	40
Slovakia		
HIGH		
Argentina		
Greece		
Mexico		
Swaziland		
MODERATE		
Bhutan		
Brazil		
Canada	0.50	1
Central African Republic		
Chile		
DR Congo		
Lebanon		
Philippines		
South Korea		
Sudan/South Sudan		
Turkey		
LOW		
Afghanistan		
Albania		
Algeria		
Angola		
Antigua and Barbuda		
Armenia		
Austria		
Azerbaijan		
Bahamas		
Bahrain		
Bangladesh		
Barbados		
Belarus		
Belgium		
Belize		
Benin		
Bolivia		
Bosnia and Herzegovina		
Botswana		
Brunei		
Bulgaria	-0.25	-1
Burkina Faso		
Burundi		
Cambodia		
Cameroon		
Cape Verde		
Chad		
China		
Colombia		
Comoros		
Congo		
Costa Rica		
Cote d'Ivoire		
Croatia		
Cuba		
Cyprus		
Czech Republic		
Denmark		
Djibouti		
Dominica		
Dominican Republic		
Ecuador		
Egypt		
El Salvador		
Equatorial Guinea		
Eritrea		
Estonia		
Ethiopia		
Fiji		
Finland		
France		
Gabon		
Gambia		
Georgia		
Germany		
Ghana		
Grenada		
Guatemala		
Guinea		
Guyana		
Haiti		
Honduras		
Hungary		

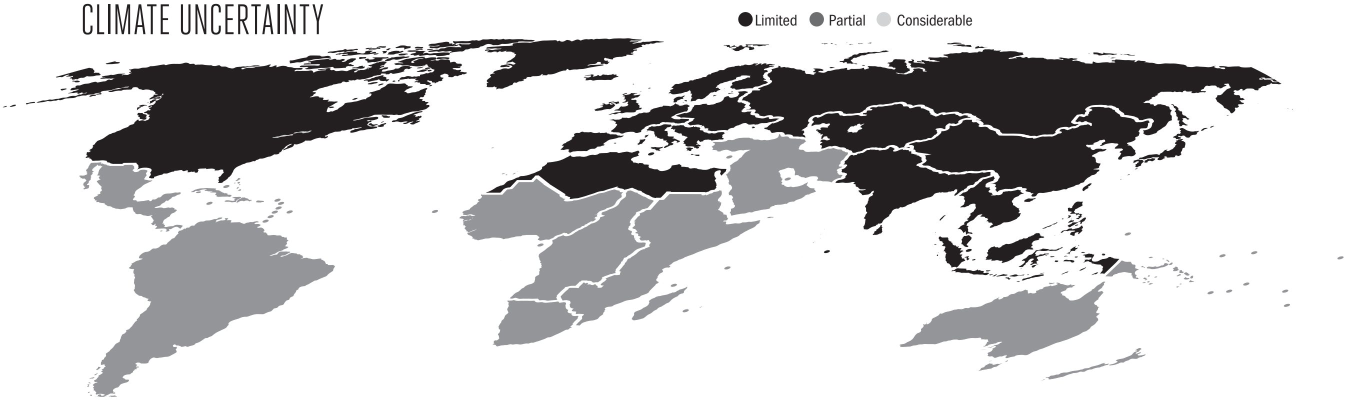
$ Additional economic costs due to climate change (million USD PPP) - yearly average

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY



COUNTRY	2010	2030
Iceland		
India		
Indonesia	-20	-150
Iran		
Iraq		
Ireland		
Italy	-1	-1
Jamaica		
Japan		
Jordan		
Kazakhstan		
Kenya		
Kiribati		
Kuwait		
Kyrgyzstan		
Laos		
Latvia		
Lesotho		
Liberia		
Libya		
Lithuania		
Luxembourg		
Macedonia		
Madagascar		
Malawi		
Malaysia	-0.25	-1
Maldives		
Mali		
Malta		
Marshall Islands		
Mauritania		
Mauritius		
Micronesia		
Moldova		
Morocco		
Myanmar		
Namibia		
Netherlands		
New Zealand		
Niger		
Nigeria		
North Korea		
Norway		
Oman		
Pakistan		
Palau		
Panama		
Papua New Guinea		
Peru		
Portugal	-0.25	-1
Qatar		
Romania		
Rwanda		
Saint Lucia		
Saint Vincent		
Samoa		
Sao Tome and Principe		
Saudi Arabia		
Senegal		
Seychelles		
Sierra Leone		
Singapore		
Slovenia		
Solomon Islands		
Somalia		
Spain	-0.25	-1
Sri Lanka		
Suriname		
Sweden		
Switzerland		
Syria		
Tajikistan		
Tanzania		
Thailand		
Timor-Leste		
Togo		
Tonga		
Trinidad and Tobago		
Tunisia		
Turkmenistan		
Tuvalu		
Uganda		
Ukraine		
United Arab Emirates		
United Kingdom		
United States	-5	-15
Uruguay		
Uzbekistan		
Vanuatu		
Venezuela		
Vietnam		
Yemen		
Zambia		
Zimbabwe		

ENVIROMENTAL DISASTERS

DROUGHT

FLOODS & LANDSLIDES

STORMS

WILDFIRES

$	**5** BILLION LOSS	2010
	20 BILLION LOSS	2030
☠	**2,750**	2010
	3,500	2030
$	**10** BILLION LOSS	2010
	95 BILLION LOSS	2030
☠	**2,500**	2010
	3,500	2030
$	**15** BILLION LOSS	2010
	100 BILLION LOSS	2030
$	**15** BILLION GAIN	2010
	92 BILLION GAIN	2030

DROUGHT

ESTIMATES GLOBAL CLIMATE IMPACT

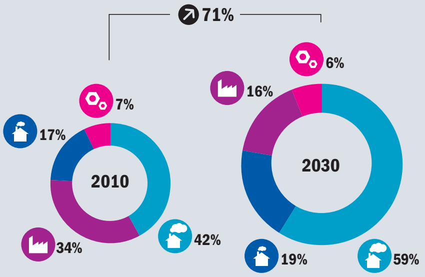
2010 EFFECT TODAY

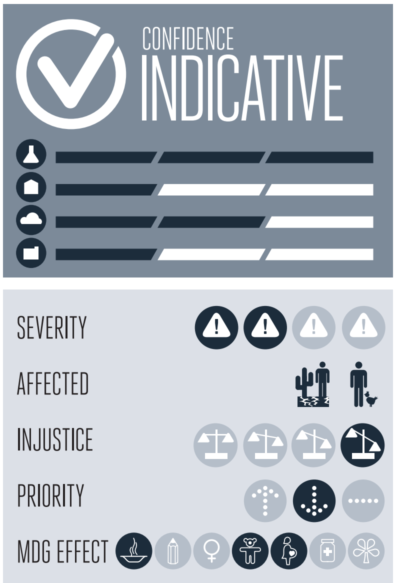
USD **LOSS** PER YEAR **5 BILLION**

2030 EFFECT TOMORROW

USD **LOSS** PER YEAR **20 BILLION**

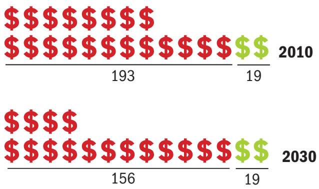
ECONOMIC IMPACT





- As the planet's temperatures reach new highs drought will become more common and more severe
- Climate change also means more rain, but most of it is falling in the far north or far south where fewer people live, and much of this rain falls during the wet season while dry seasons tend to become drier
- When drought hits, agriculture comes under extreme pressure, crops may fail and livestock perish with important localized economic, health and social repercussions
- Catching and conserving water will be critical to ensure a resilient agricultural sector and food and water security during periods of extreme drought

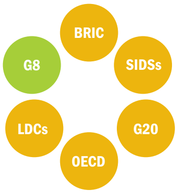
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
800	**CHINA**	6,250
300	**INDIA**	1,500
200	**IRAN**	1,500
500	**UNITED STATES**	1,250
200	**SPAIN**	650

GEOPOLITICAL VULNERABILITY



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

$ = Losses per million USD of GDP

↗ Change in relation to overall global population and/or GDP

$ Millions of USD (2010 PPP non-discounted)

The increase in heat is already being experienced. It is virtually certain to increase in the coming years (IPCC, 2007). Parts of the world experiencing additional rainfall will also experience drought (Sheffield and Wood, 2008; Helm et al., 2010). Drought can diminish crop yields and kill livestock, generating serious economic losses for affected communities (Pandey et al. (eds.), 2007). Some of the world's major agriculturally productive regions, such as Brazil and Australia, are already affected (Saleska et al., 2011; LeBlanc et al., 2009). Deforestation and other forms of environmental degradation only worsen risk of drought (Turner II et al., 2007). Reducing losses and safeguarding communities will require the tackling of these problems as well as stimulating increased water availability through effective capture, storage and distribution measures and policies (McKinsey & Company, 2009). Displacing risks to the insurance industry would also alleviate the severity of losses to individuals and communities (Linnerooth-Bayer and Mechler, 2006).

CLIMATE MECHANISM

A hotter planet not unsurprisingly implies more drought (Sheffield and Wood, 2008). This is qualified by the fact that because of climate change there will also be more moisture and rain in the atmosphere (Allen and Ingram, 2002; Huntington, 2006; Kharin et al., 2007). Additional rain however tends to fall far north or south, where it is not lacking, and less rain tends to fall in the tropical areas of the planet which are already near thermal maximums and where a majority of the world's population live (Helm et al., 2010; Sherwood and Huber, 2010). In parts of the tropics, clouds are gaining in altitude and failing to deposit their moisture on mountain ranges (Malhi et al., 2008). As evidenced in cities, even if more rain falls, provided heat rises faster, any additional water would evaporate and not benefit the soil and its vegetation (Schmidt in Hao et al. (eds.), 2009). Hence, global aridity has increased and is expected to continue increasing, including in areas like the US, which have largely escaped the most severe forms of drought to date (Dai, 2011). Even where rainfall is declining, it is becoming more concentrated generating longer dry spells (Trenberth, 2011). Moreover, country level analysis in Vietnam for instance shows how in regions prone to extreme heat rain will likely decline in dry seasons and only increase in wet seasons when there will be an overabundance (Vietnam MONRE, 2010). Extreme forms of heat experienced today, such as the European heat wave of 2003, the Russian heat wave of 2010, or the extreme summer temperatures of 2011 in Texas would have been extremely unlikely to occur in the absence of climate change (Hansen et al., 2012).

When drought hits, plant productivity is directly affected and the mortality risk for livestock, such as cattle or birds, is greatly raised and indirectly can create vulnerabilities which invasive pests can exploit, further increasing damage (Chaves et al., 2009; Lesnoff et al., 2012; Wolf, 2009; Cherwin, 2009). Economic losses clearly result (Pandey et al. (eds.) 2007; Ding et al., 2011). Drought also damages buildings and infrastructure due to the shrinking and swelling of soil under extreme heat and aridity. This can lead to structural failure or accelerate asset depreciation (Corti et al., 2009).

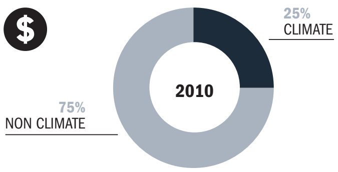
IMPACTS

The global impact of climate change on drought is estimated to cause close to four billion dollars in damage a year in 2010, set to increase as a share of GDP to 2030 when average annual losses would reach close to 20 billion dollars a year. The impact is very widespread with some 160 countries experiencing high vulnerability to drought by 2030. There are many regions which are seriously affected, especially the wider Mediterranean basin and Black Sea, North Africa, the Middle East and southern and eastern Europe. In addition, parts of Central Asia and Southern Africa are also expected to experience severe effects. While mainly developing countries are affected, since developed nations in general are located geographically in the far north or south, a handful of major advanced economies are exposed to the most severe effects, in particular Spain, Portugal, Greece and Australia. Large numbers of least developed countries figure among those countries with Acute or Severe levels of vulnerability.

The largest total impact is felt in China whose estimated losses in 2010 of 800 million dollars would surpass six billion dollars a year in damage by 2030. Other countries with particularly large-scale impacts include India, Iran, the US, Spain, Mexico, Brazil and Russia – several are estimated to experience impacts in excess of 1 billion dollars in annual losses by 2030.

BIGGER PICTURE

$

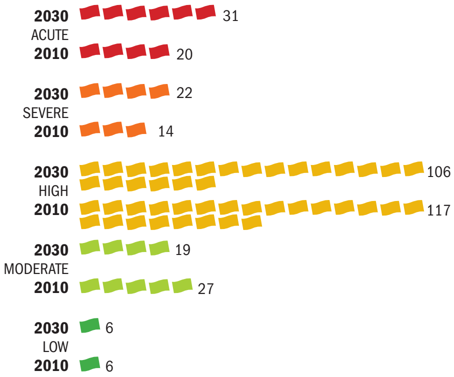


SURGE

OCCURRENCE

N/A

VULNERABILITY SHIFT



PEAK IMPACT

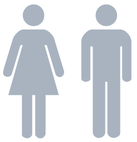
☠

2002	**MALAWI**	500
2006	**CHINA**	134
2005	**BURUNDI**	120
2004	**KENYA**	80
2002	**UGANDA**	79

$

2011	**UNITED STATES**	8,000
2009	**CHINA**	3,600
2002	**AUSTRALIA**	2,000
2004	**BRAZIL**	1,650
2010	**RUSSIA**	1,400

GENDER BIAS



INDICATOR INFORMATION

MODEL: Corti et al., 2009; Hoekstra et al., 2010; Rubel and Kottek, 2010; Sheffield and Wood, 2007

EMISSION SCENARIO: SRES A1B (IPCC, 2007)

BASE DATA: Corti et al., 2009; CRED EM-DAT, 2012

$ = Millions of USD (historic)

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

THE BROADER CONTEXT

Virtually all of the costliest drought years have occurred in the last two decades (CRED/EM-DAT, 2012). For statistical reasons it is still difficult to conclusively discern and pronounce on any global trends in drought losses; however the IPCC and insurance industry have reported increases in drought impact, and regional drought has become extreme in recent years (Quarantelli, 2001; IPCC, 2007; Bouwer, 2011). Major agricultural zones of Australia have experienced prolonged drought for a decade, not attenuated by a return to pre-drought levels of rainfall as the heat rises (LeBlanc et al., 2009). A 2010 drought in Brazil and across the Amazon regions was one of the worst ever (Saleska et al., 2011). The insurance industry is gauging growing losses as a result of drought-triggered soil subsidence and damage to buildings and infrastructure, estimated to cost €340 million per year in France alone (Swiss Re, 2010).

VULNERABILITIES AND WIDER OUTCOMES

Geography is a prime vulnerability, since countries in the far north receive considerably more rainfall (IPCC, 2007; Helm et al., 2010). Demand for water is another key determinant of vulnerability, since drought in the middle of the Sahara is of little consequence, while drought in the southern US, Europe or India is a major concern. Global water demand is expected to almost double by 2030, in particular due to increased water withdrawals in the agricultural sector – just as climate change will deprive many of the world's productive regions of water (McKinsey & Company, 2009; Sheffield and Wood, 2008). Land degradation from over-intensive agricultural exploitation or over-grazing and deforestation also greatly increase susceptibility to drought – another 30 % loss of forest in the Amazon could push the entire region into permanent aridity (Malhi et al., 2008). A lack of adequate irrigation and water infrastructure exacerbates drought since water captured in other periods of the year cannot be drawn upon during periods of prolonged aridity. In general, water-deprived economies have been understood to be less prosperous (Brown and Lall, 2006). The human health consequences of drought are principally accounted for under the Hunger indicator of the Monitor.

RESPONSES

Any response to drought must face up to two key concerns: 1) increasing water availability, and 2) dealing with building and infrastructure damage due to sinking or destabilized land. Increasing water availability will be met at the market cost of supplying water, which varies from region to region depending on the degree of water scarcity currently prevailing locally (McKinsey & Company, 2009). Effective governments would anticipate any shortfall and stimulate action to meet any expected water demand shortfall in order to avoid economic losses and loss of tax revenues. Addressing soil subsidence through design could involve the retrofitting of buildings to withstand soil movements linked to drought. Both drought and soil subsidence impacts can be dealt with by displacing risks to the insurance (and micro-insurance) industry through policies enabling businesses and home-owners to safeguard against potential damages (Swiss Re, 2011; Churchill and Matul, 2012).

THE INDICATOR

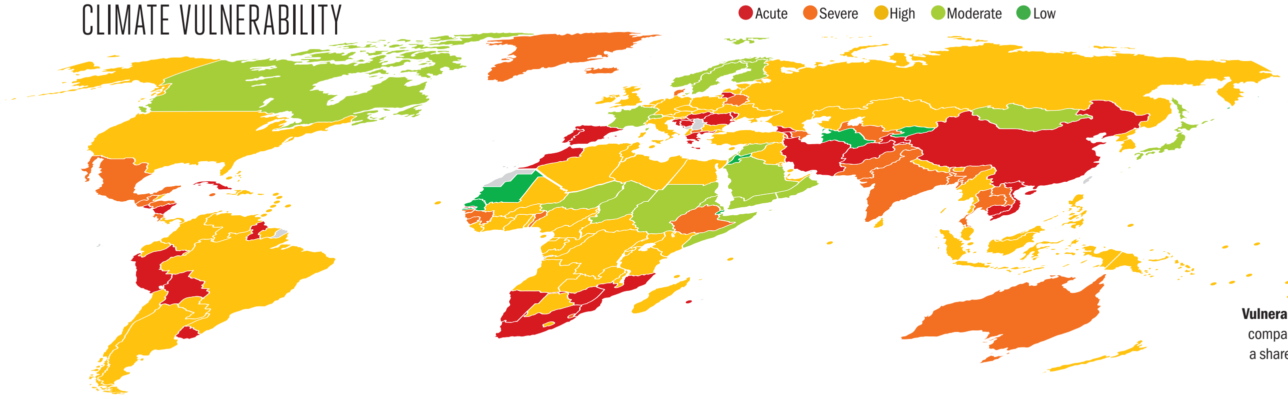
The indicator measures the impact of climate change on drought, defined as a consecutive sequence of months with "anomalously low soil moisture". It measures the change in both disaster damages and depreciation of property due to soil subsidence damages. The change in the number of droughts expected to occur is estimated using an ensemble of eight climate models (Sheffield and Wood, 2008). Baseline data for disaster damages is derived from the main international disaster database, but is known to be incomplete (CRED/EM-DAT, 2012). Accelerated depreciation of infrastructure due to soil subsidence uses a model based on France and extrapolated based on GDP per capita and population density, but excluding arid countries where the effect is considered less relevant (Corti et al., 2009; Hoekstra et al., 2010). Limitations and uncertainties relate to difficulties in estimating rainfall change for certain regions, the simplistic 1:1 damage assumption implied and to the extrapolation used for the soil subsidence indicator.

ESTIMATES COUNTRY-LEVEL IMPACT

	$	
COUNTRY	2010	2030
ACUTE		
Afghanistan	5	40
Armenia	5	25
Bolivia	5	45
Bosnia and Herzegovina	15	100
Cambodia	5	60
China	800	6,250
Croatia	15	85
Cuba	10	65
El Salvador	10	70
Gambia		1
Georgia	10	50
Greece	35	95
Guyana	1	15
Hungary	15	90
Iran	200	1,500
Lithuania	10	45
Mauritius	5	25
Moldova	10	65
Morocco	40	300
Mozambique	1	10
Namibia	1	10
Nicaragua	1	15
Peru	25	150
Portugal	45	150
Romania	20	100
South Africa	50	250
Spain	200	650
Tajikistan	5	20
Uruguay	5	40
Vietnam	40	350
Zimbabwe	1	10
SEVERE		
Australia	45	100
Azerbaijan	5	30
Bangladesh	15	75
Belarus	10	35
Benin	1	5
Costa Rica	1	15
Denmark	10	25
Ethiopia	5	20
Guatemala	5	20
Guinea	1	1
Guinea-Bissau		1
Honduras	1	10
India	300	1,500
Jamaica	1	5
Laos	1	5
Macedonia	1	5
Mexico	95	600
Pakistan	35	200
Sierra Leone		1
Swaziland		1
Thailand	40	200
Uzbekistan	5	30
HIGH		
Albania	1	5
Algeria	5	30
Angola	5	15
Antigua and Barbuda		
Argentina	25	150
Austria	10	10
Bahamas		1
Bahrain	1	5
Barbados		1
Belgium	10	15
Belize		1
Bhutan		1
Botswana	1	5
Brazil	95	550
Brunei	1	5
Bulgaria	5	20
Burkina Faso	1	1
Burundi		1
Cameroon	1	5
Cape Verde		
Central African Republic		1
Chile	15	70
Colombia	15	80
Comoros		
Congo	1	1
Cote d'Ivoire	1	5
Cyprus	1	1
Czech Republic	10	40
Dominica		
Dominican Republic	5	20
DR Congo	1	5
Ecuador	5	30
Egypt	10	50
Equatorial Guinea	1	5
Estonia	1	5
Fiji		1
Gabon	1	5
Germany	70	100
Ghana	5	15
Grenada		

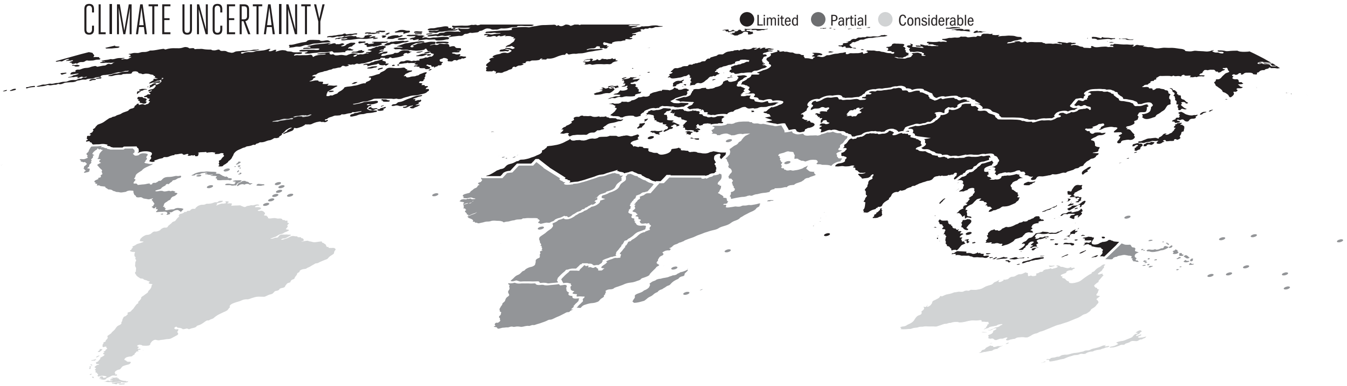
$ Additional economic costs due to climate change (million USD PPP) - yearly average

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY



COUNTRY	$ 2010	$ 2030
Haiti	1	1
Iceland		1
Indonesia	40	200
Iraq	5	15
Ireland	5	5
Italy	55	150
Kazakhstan	5	20
Kenya	1	5
Kiribati		
Kuwait	5	20
Latvia	1	5
Lebanon	1	10
Lesotho		1
Liberia		
Libya	1	10
Madagascar	1	5
Malawi	1	1
Malaysia	20	80
Maldives		
Mali	1	1
Malta		1
Marshall Islands		
Micronesia		
Myanmar	1	10
Nepal	1	10
Netherlands	15	25
New Zealand	5	5
Nigeria	15	70
North Korea	1	10
Palau		
Panama	1	10
Papua New Guinea	1	1
Paraguay	1	5
Philippines	20	85
Poland	30	100
Qatar	5	20
Russia	90	400
Rwanda	1	1
Saint Lucia		1
Saint Vincent		
Samoa		
Sao Tome and Principe		
Seychelles		1
Singapore	10	40
Slovakia	5	15
Slovenia	1	10
Solomon Islands		
South Korea	55	250
Sri Lanka	5	25
Suriname		1
Tanzania	5	15
Timor-Leste		1
Togo		1
Tonga		
Trinidad and Tobago	1	5
Tunisia	5	15
Turkey	35	65
Tuvalu		
Uganda	1	10
Ukraine	20	75
United Arab Emirates	5	25
United Kingdom	55	90
United States	500	1,250
Vanuatu		
Venezuela	10	45
Zambia	1	1
MODERATE		
Canada	25	45
Chad		
Eritrea		
Finland	1	1
France	45	75
Israel	1	15
Japan	90	150
Luxembourg	1	1
Mongolia		1
Niger		1
Norway	1	5
Oman	1	5
Saudi Arabia	1	10
Somalia		
Sudan/South Sudan	1	10
Sweden	5	10
Switzerland	5	10
Syria	1	5
Yemen	1	5
LOW		
Djibouti		
Jordan		
Kyrgyzstan		
Mauritania		
Senegal		
Turkmenistan		

FLOODS & LANDSLIDES

ESTIMATES GLOBAL CLIMATE IMPACT

2010 EFFECT TODAY

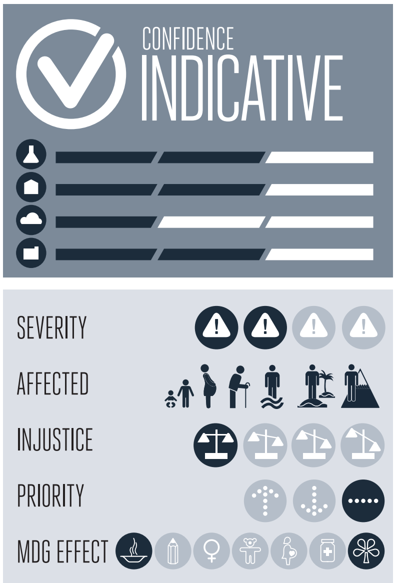
2,750 DEATHS PER YEAR

10 BILLION USD **LOSS** PER YEAR

2030 EFFECT TOMORROW

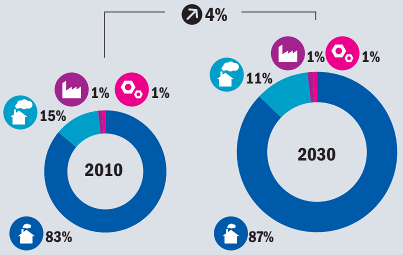
3,500 DEATHS PER YEAR

95 BILLION USD **LOSS** PER YEAR

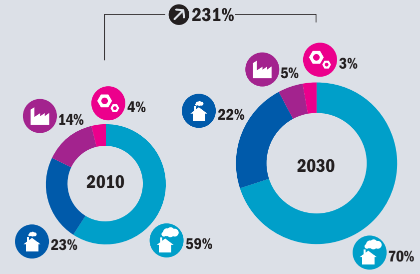


- Heavy rainfall, the main trigger of flooding and landslides, is on the rise
- Spring comes earlier and releases more water from mountains and glaciers which adds further to flood risks
- Future increases in these effects may coincide, generating more mega disasters of the scale of the 2010 Pakistan floods
- Comprehensive risk reduction efforts in implementation of the Hyogo Framework for Action are helping to reduce vulnerabilities, even as world population and exposed infrastructure expand
- Parallel efforts are not being made to deliberately adjust humanitarian relief systems to growing flood dangers implied y climate change

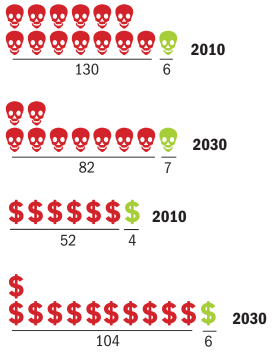
MORTALITY IMPACT



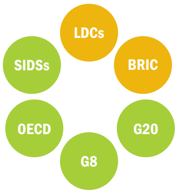
ECONOMIC IMPACT



RELATIVE IMPACT



GEOPOLITICAL VULNERABILITY



HOTSPOTS

2010	💀	2030
2,000	**INDIA**	2,500
200	**CHINA**	150
75	**BANGLADESH**	100
50	**VIETNAM**	55
30	**PAKISTAN**	45

2010	$	2030
4,500	**CHINA**	50,000
1,250	**INDIA**	10,000
550	**NORTH KOREA**	6,750
350	**PAKISTAN**	3,250
300	**BANGLADESH**	2,750

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

★ 💀 = Deaths per 100 million
$ = Losses per 100,000 USD of GDP
↗ Change in relation to overall global population and/or GDP

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

Flooding is a common natural hazard from increases in rainfall due to climate change. Floods are expected to worsen practically everywhere, even in areas facing declining annual rainfall, as heavy downpours become more common (IPCC, 2007). More floods mean more deaths and injuries, more damaged property and infrastructure, and growing disruption of economic activities. Where large countries like China, Pakistan, or the US are affected, the lives of millions of people may be disrupted and billions of dollars of economic damage inflicted (CRED/EM-DAT, 2012). However, the risk of death due to flooding is heavily concentrated in low-income countries, which face significant risks of setbacks in development gains, with women particularly vulnerable (UNISDR, 2011; Nelleman et al., 2011). Highly cost-effective including "low-regrets" measures to limit damages and speed recovery are also inaccessible to many for lack of the capacity and up-front resources to implement them (IPCC, 2012a). Social and political factors, including illiteracy and the over-exploitation of resources often exacerbate these problems (UNISDR, 2009).

CLIMATE MECHANISM

A warmer planet means a more active hydrological system, as water is evaporated faster from oceans and land, generating cloud and rainfall (Dore, 2005; Kharin et al., 2007). That means more rain overall and more energy in general in the global climate system as it heats up, leading to heavier downpours of rain, more variable or erratic rainfall, and more frequent heavy precipitation. Coupled with an earlier spring that discharges more water as glaciers continue to decline, the implications are that risk of flooding and landslides caused by weather, and not earthquakes or otherwise, are on an increase (Hidalgo et al., 2009; Radić and Hock, 2011; IPCC, 2007; Mirza et al., 2003; Jonkman et al., 2008; Bouwer et al., 2010). The evidence base for the flood trend is low, in particular due to inadequate gauge station records and confounding information linked to land use and engineering (IPCC, 2012a). The increase in heavy rainfall during short periods of time is assured and is not only the main trigger of flooding, but the main input variable to early warning tools to predict flooding (Prudhomme et al., 2002; Harris et al., 2007).

IMPACTS

Globally, climate change is already estimated to be responsible for close to an average of 3,000 deaths per year and around 10 billion dollars in economic losses through flooding and landslides. For every death, there can be as many as 10,000 people in need of emergency assistance; each year, over 25 million more people are affected than in earlier periods when climate change was not so marked. Over the next 20 years, the climate-related flood death toll is expected to increase only modestly to 3,500 deaths per year with economic losses more than tripling as a share of global GDP, reaching 95 billion dollars per year by 2030.

Approximately two-thirds of these losses are incurred in China and India alone. Populous emerging economies in Asia, such as Bangladesh, Pakistan, and Vietnam are particularly vulnerable, as are mountainous developing countries, such as Bhutan and Nepal. Effects are widely distributed around the world, with the number of countries labeled "Acute" doubling by 2030. Low-lying small island states, such as the Maldives, are unaffected by non-coastal flooding and landslides, whereas mountainous small islands, such as Haiti or Fiji are at high risk.

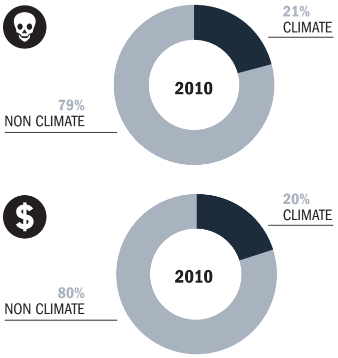
THE BROADER CONTEXT

The significance of socio-economic determinants of risk mean climate change is only one factor in the scale of damage generated by so-called natural disasters. Mortality risk due to extreme weather is known to fall over time with rising incomes (Peduzzi et al., 2012). However, economic losses show increases in recent years (CRED/EM-DAT, 2012; Munich Re, 2012). These observations support the UN's analysis that as socio-economic development improves, fewer people are killed, but infrastructure is at greater risk (UNISDR, 2009 and 2011).

VULNERABILITIES AND WIDER OUTCOMES

Vulnerability levels are often dictated by socio-economic development standing and the associated effectiveness of governments in putting in place measures that can limit dangers for populations. Poorly located, unprotected flood plain settlements are also at high risk, but sound governance should prevent or rationalize this type of development. Environmental degradation and unwise patterns of land

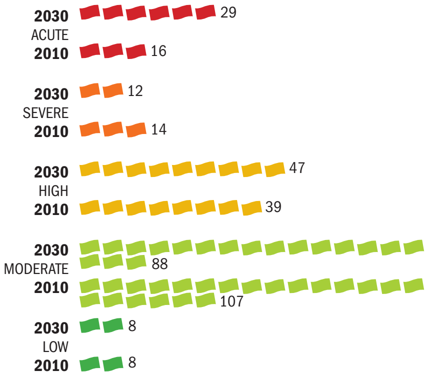
BIGGER PICTURE



SURGE

OCCURRENCE

VULNERABILITY SHIFT



PEAK IMPACT

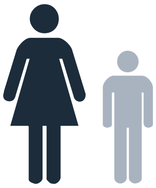
☠

2004 **HAITI** 2,665
2005 **INDIA** 2,129
2010 **PAKISTAN** 2,113
2010 **CHINA** 1,911
2007 **BANGLADESH** 1,230

$

2010 **CHINA** 18,930
2002 **GERMANY** 11,600
2008 **UNITED STATES** 10,002
2010 **PAKISTAN** 9,500
2007 **UNITED KINGDOM** 8,448

GENDER BIAS



INDICATOR INFORMATION

MODEL: Kharin et al., 2007

EMISSION SCENARIO: SRES A1B (IPCC, 2007)

BASE DATA: CRED EM-DAT, 2012; Munich Re NATCAT, 2010 (economic data); UNEP GRID, 2012 (mortality data)

$ = Millions of USD (historic)

Estimated time between major weather events (years)

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

usage, particularly deforestation, further exacerbate localized vulnerabilities, for example, by destabilizing hillsides and by increasing the flow of rainwater over land—effects especially significant in developing countries (Brashshaw et al., 2007). High rates of urbanization, common in most developing countries around the world today, often lead rural-urban migrants to settle in flood plain shanty towns adjacent to major urban centres, adding to the level of risk (Quarantelli, 2003).

Flooding carries serious consequences for economic activity, especially for lower-income communities where insurance that otherwise speeds economic rebound is least prevalent (Dodman and Satterthwaite, 2008). Harm to poverty-reduction efforts has been shown to result more from widespread and regularly occurring small- to medium-scale disasters, since they repeatedly frustrate development progress, even though freak, high-profile, catastrophes typically receive more attention (Lavell, 2008). Flood damage—particularly ecological and social costs or diffuse disruptions to broad economic activities—is also difficult to fully quantify, and in extreme cases can persist for months (Messner and Meyer, 2005).

RESPONSES

Like other disasters, floods are considered to have three core components: hazard, exposure, and vulnerability. Hazard is a variable largely beyond immediate human control, so responses either aim to decrease vulnerability or exposure to hazard, or both. Measures such as rapid early warning systems, disaster education, building codes and their regulation, environmental protection against deforestation and land degradation, insurance for infrastructure or other economic assets, flood defences and storm drains, strengthening of local ecosystems, disaster volunteer programmes all reduce vulnerabilities, but may demand resources which many countries simply do not possess. Under pressure of economic and population growth, most increases in exposure are inevitable. But strategic municipal planning for infrastructure development can help minimize the extent of new exposure to risk. Urban centres with elevated population densities are also high-dividend opportunities for reducing possible disasters, provided urban authorities are willing and able to meet the needs of their residents in managing risks (Dodman and Satterthwaite, 2008).

The capacity of governments to develop and implement a range of risk-reduction measures is considered a fundamental determinant of the success of national disaster prevention and recovery strategies; this includes the ability to incorporate considerations of disaster risk into wide-ranging state agendas, from education to municipal planning and fiscal tools. Capacity to do so is also most deficient in highly vulnerable, low-income settings (Ahrens and Rudolph, 2006).

A number of low-income countries, such as Bangladesh have nevertheless managed to reduce levels of vulnerability through cost-effective community and volunteer-based efforts, as alternatives to more resource-intensive measures (Khan, 2007). On the other hand, recent floods along the Mississippi and Missouri rivers in the US have shown how even the highly developed countries can be overwhelmed by large-scale events (Olson and Morton, 2012). New extremes and delays in policy changes to increase resilience mean that the world's humanitarian system should prepare for serious increases in flood response in the years ahead.

THE INDICATOR

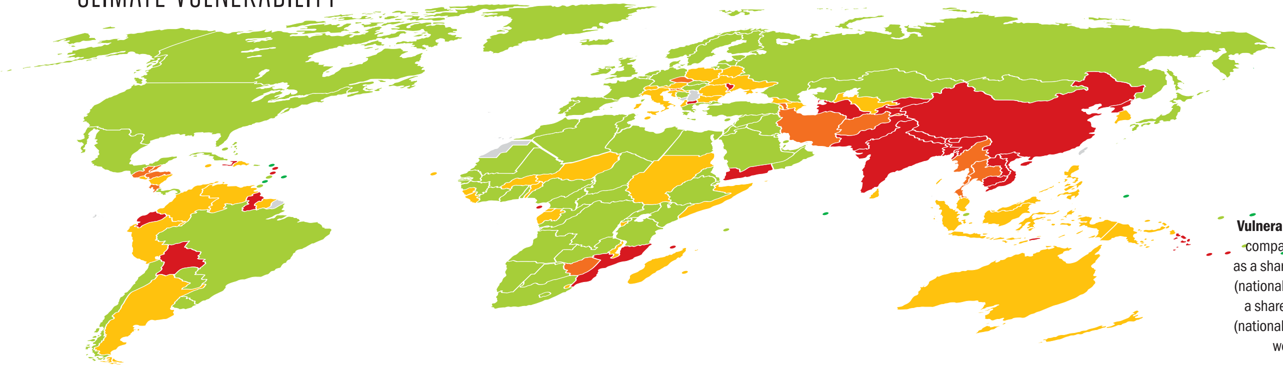
The indicator combines exposure to floods and landslides with modeled mortality risk for estimations of deaths with socio-economic adjustments. For economic losses, a combination of 20 years of disaster data from different sources is relied upon as a baseline. The indicator then estimates how the change in, or increases in the occurrence of, heavy precipitation events would alter the current picture of flood and landslide risk. Uncertainty regarding precipitation change in some areas is an impediment to reliable national-level estimates of these changes. Likewise, country-specific variation in the effects of increased heavy rainfall is not accounted for, except through the worsening of the pre-existing topography of risk, as reflected in historic and modeled disaster data. Although records of floods are unreliable, models of the effects of climate change on heavy precipitation and observed rainfall changes do reveal the increasing trend (IPCC, 2007, IPCC, 2012a; Kharin et al.).

ESTIMATES COUNTRY-LEVEL IMPACT

	☠		$		🧍	
COUNTRY	2010	2030	2010	2030	2010	2030
ACUTE						
Bangladesh	75	100	300	3,000	600,000	900,000
Bhutan	1	1		1	15,000	25,000
Bolivia	1	1	30	300	10,000	15,000
Cambodia	10	10	20	200	65,000	65,000
China	200	150	4,500	50,000	2,000,000	1,500,000
Comoros	5	10			45,000	85,000
Dominica	1	1			2,500	3,000
Ecuador	1	5	30	300	25,000	30,000
Fiji	1	1	1	10	4,000	3,500
Guyana			10	100	2,000	1,500
Haiti	5	5	5	35	30,000	40,000
India	2,000	2,500	1,000	10,000	20,000,000	25,000,000
Kyrgyzstan	1	1	5	35	9,500	15,000
Laos	5	10	1	15	55,000	70,000
Macedonia			5	50	1,500	1,000
Moldova	1	1	15	100	5,500	5,000
Mozambique	1	5	10	85	20,000	30,000
Nepal	10	15	15	150	85,000	100,000
North Korea	10	10	550	6,500	100,000	85,000
Pakistan	30	45	350	3,000	300,000	450,000
Saint Lucia	1	1		1	6,000	6,000
Sao Tome and Principe	1	1			15,000	25,000
Solomon Islands	1	1			5,000	9,000
Tajikistan	5	5	40	300	30,000	45,000
Timor-Leste	1	1			25,000	25,000
Turkmenistan	5	10	5	25	55,000	80,000
Vanuatu		1		1	2,500	4,000
Vietnam	50	55	150	2,000	500,000	500,000
Yemen	1	1	35	250	7,500	25,000
SEVERE						
Afghanistan	5	10	5	35	55,000	90,000
Armenia	1	1		1	20,000	25,000
Belize				1	1,500	2,000
Costa Rica	1	1	5	55	6,500	10,000
Czech Republic			55	350	2,000	1,500
Guatemala	5	10	5	60	45,000	90,000
Honduras	1	1	5	70	15,000	20,000
Iran	10	10	200	1,500	40,000	50,000
Myanmar	35	45	5	40	250,000	350,000
Slovenia			15	95	2,000	1,500
Thailand	15	10	100	1,000	150,000	100,000
Zimbabwe	1	1	5	25	15,000	25,000
HIGH						
Albania	1	1	1	10	5,000	6,500
Argentina	5	5	70	700	15,000	20,000
Australia	1	1	65	200	2,500	5,500
Austria	1	1	30	90	5,000	6,500
Azerbaijan	1	1	5	30	10,000	10,000
Belarus	1	1	5	35	6,500	5,500
Benin	1	1	1	5	7,500	15,000
Brunei					1,500	1,500
Bulgaria	1	1	10	70	3,000	1,500
Burkina Faso	1	1	1	15	3,000	7,500
Burundi	1	1		1	10,000	20,000
Cape Verde					1,500	2,000
Colombia	10	10	50	450	35,000	45,000
Croatia	1	1	10	85	4,000	3,000
Dominican Republic	1	1	1	25	7,500	8,000
El Salvador	1	5		1	20,000	30,000
Equatorial Guinea		1			2,000	3,500
Gabon	1	1			1,500	3,000
Georgia	1	1	1	10	30,000	20,000
Indonesia	25	30	75	650	250,000	250,000
Italy	1	1	150	500	5,500	7,000
Jamaica	1	1	1	20	3,500	4,000
Liberia	1	1			5,500	15,000
Madagascar	5	5	1	15	30,000	55,000
Malawi	1	1	1	5	15,000	25,000
Malaysia	5	5	20	200	15,000	15,000
Malta			1	1	200	300
Mauritius		1			1,500	1,500
New Zealand	1	1	5	15	4,500	9,500
Nicaragua	1	5	1	5	20,000	40,000
Niger	1	5	1	10	10,000	25,000
Papua New Guinea	1	5	1	5	30,000	40,000
Peru	5	5	15	150	15,000	20,000
Philippines	25	25	30	300	200,000	250,000
Poland	1	1	85	600	5,500	4,000
Romania	1	1	40	300	8,500	6,000
Sierra Leone	1	5		1	15,000	30,000
Somalia	1	5	1	1	20,000	45,000
South Korea	5	5	95	800	25,000	20,000
Sri Lanka	5	5	15	150	45,000	40,000
Sudan/South Sudan	5	5	5	40	40,000	55,000
Suriname					550	650
Swaziland		1			3,000	4,000
Switzerland	1	1	25	75	2,000	3,000
Ukraine	1	1	40	300	25,000	15,000
Uzbekistan	10	15		1	95,000	150,000
Venezuela	5	5	30	300	15,000	15,000
MODERATE						
Algeria	5	5	5	60	15,000	20,000
Angola	1	5		1	20,000	45,000
Bahamas						
Bahrain				1	650	850

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

CLIMATE VULNERABILITY



Vulnerability measure: comparative mortality as a share of population (national) and losses as a share of GDP in USD (national) with same full weighting to both

CLIMATE UNCERTAINTY

	☠		$		🧍	
COUNTRY	2010	2030	2010	2030	2010	2030
Belgium		1	1	5	1,500	2,000
Bosnia and Herzegovina	1	1	1	5	3,000	2,000
Botswana				1	650	700
Brazil	5	10	20	200	30,000	30,000
Cameroon	5	5		1	35,000	50,000
Canada	1	5	30	100	9,000	20,000
Central African Republic	1	1			6,000	9,500
Chad	1	1		1	9,500	20,000
Chile	1	1	5	50	4,000	4,500
Congo	1	1			7,000	15,000
Cote d'Ivoire	1	1			20,000	30,000
Cuba	1	1	1	20	2,500	2,500
Cyprus					750	1,500
Denmark				1	250	350
Djibouti					200	250
DR Congo	10	25		1	90,000	200,000
Egypt	5	10	5	30	65,000	80,000
Eritrea	1	1			4,500	7,500
Estonia					750	450
Ethiopia	10	15	1	5	75,000	150,000
Finland				1		
France	1	1	60	200	9,000	15,000
Gambia					1,000	1,500
Germany	1	1	100	350	4,500	6,500
Ghana	1	1	1	5	6,500	10,000
Greece	1	1	10	30	2,000	3,000
Guinea	1	5		1	15,000	25,000
Guinea-Bissau					950	1,500
Hungary			10	65	1,500	900
Iceland				1	150	250
Iraq	5	5			35,000	60,000
Ireland		1	5	15	1,000	2,500
Israel		1	1	5	1,500	2,000
Japan	5	5	150	400	20,000	35,000
Jordan				1	2,000	3,000
Kazakhstan	1	5	5	30	10,000	15,000
Kenya	5	5	1	10	40,000	50,000
Kuwait					150	200
Latvia					1,000	750
Lebanon	1	1			3,000	3,000
Lesotho					3,500	3,500
Libya			1	5	650	850
Lithuania					1,000	900
Luxembourg				1	200	500
Mali	1	1			10,000	20,000
Mauritania		1		1	2,000	4,500
Mexico	10	10	55	500	40,000	40,000
Micronesia						
Mongolia	1			1	4,500	3,500
Morocco	1	1	5	30	15,000	20,000
Namibia				1	1,000	1,500
Netherlands	1	1	15	40	2,000	3,500
Nigeria	10	15	1	20	85,000	150,000
Norway			1	5	700	1,000
Oman		1		1	1,500	3,000
Panama	1	1	1	5	2,000	2,000
Paraguay	1	1		1	10,000	20,000
Portugal	1	1	10	30	2,000	3,000
Qatar					300	350
Russia	10	5	75	550	35,000	25,000
Rwanda	1	1			15,000	25,000
Saint Vincent						
Samoa						
Saudi Arabia		1	10	90	1,500	3,000
Senegal	1	1	1	5	9,500	15,000
Seychelles						
Singapore			1	5		
Slovakia	1		5	30	2,500	2,000
South Africa	1	1	5	35	5,500	4,500
Spain	1	1	10	35	4,000	5,500
Sweden				1	400	600
Syria	1	5			30,000	45,000
Tanzania	1	5	1	10	20,000	30,000
Togo	1	1		1	5,000	9,000
Tonga						
Trinidad and Tobago				1	650	600
Tunisia		1	5	45	3,500	4,000
Turkey	5	10	30	100	15,000	35,000
Uganda	1	5		1	15,000	35,000
United Arab Emirates	1	1	1	20	2,500	3,000
United Kingdom	1	1	100	350	3,500	5,500
United States	5	5	600	2,000	15,000	35,000
Uruguay	1	1	1	5	1,500	1,500
Zambia	1	1		1	10,000	20,000
LOW						
Antigua and Barbuda						
Barbados						
Grenada						
Kiribati						
Maldives						
Marshall Islands						
Palau						
Tuvalu						

🧍 Additional persons affected/in need of emergency assistance due to climate change - yearly average

STORMS

ESTIMATES GLOBAL CLIMATE IMPACT

2010 EFFECT TODAY

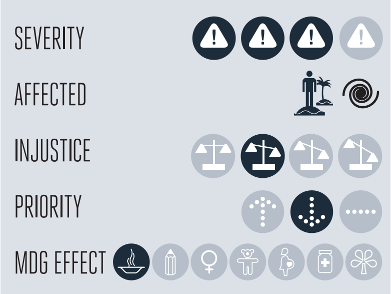
DEATHS PER YEAR **2,500**

USD LOSS PER YEAR **15 BILLION**

2030 EFFECT TOMORROW

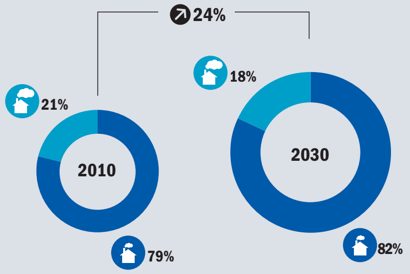
DEATHS PER YEAR **3,500**

USD LOSS PER YEAR **100 BILLION**

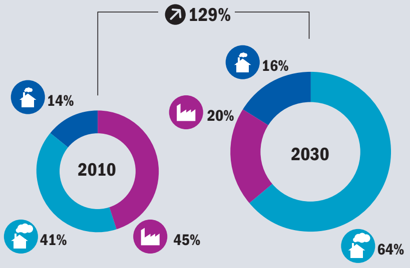


- All weather is affected by climate change because the Earth's atmosphere is warmer, moister, and more active today than in the recent past
- As a result, storms are becoming more extreme both in and outside of the tropics and will cause greater damage
- The location and extent of the additional damage is difficult to predict, as experts and their studies differ in their conclusions
- Countries already exposed to tropical cyclones or immediately adjacent to cyclone belts should prepare for growing risks and damages, especially in coastal areas

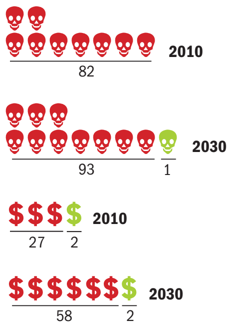
MORTALITY IMPACT



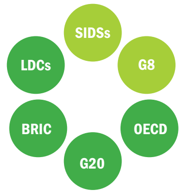
ECONOMIC IMPACT



RELATIVE IMPACT



GEOPOLITICAL VULNERABILITY



HOTSPOTS

2010	Deaths	2030
1,750	**BANGLADESH**	2,500
500	**MYANMAR**	600
150	**INDIA**	150
50	**MADAGASCAR**	100
45	**PHILIPPINES**	60

2010	$	2030
4,750	**CHINA**	50,000
4,000	**JAPAN**	10,000
2,500	**UNITED STATES**	8,250
550	**NORTH KOREA**	5,750
600	**SOUTH KOREA**	4,750

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

Deaths = Deaths per 10 million
$ = Losses per 10,000 USD of GDP
↗ Change in relation to overall global population and/or GDP

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

Whether or not specific events can be identified as "caused" by climate change, all weather is now affected by a global climate system that is warmer, more active, and wetter (Trenberth, 2012).

As a result, it is evident that storms are generally becoming more extreme, particularly in terms of wind speeds and quantity of rainfall. Moreover, there is a pole-ward shift to the north and south of cyclone storm tracks, as parts of the world adjacent to the tropics are experiencing more "tropical" weather.

Where vulnerabilities to more severe storms are accentuated by environmental and income-related factors—such as for high-risk urban slums in low-lying coastal areas—the dangers of these changes are much higher (IPCC, 2012a). Corresponding measures will need to offset the additional risk by reducing community vulnerabilities and, where possible, limiting exposure, to storm hazards (UNISDR, 2009 and 2011).

Increased emergency assistance should also be foreseen in the coming years and decades.

CLIMATE MECHANISM

Climate change increases air and sea temperatures, boosting the level of moisture in the atmosphere; this leads to acceleration of the planet's hydrological system, heavier precipitation, higher maximum winds and a general tendency to more extreme weather (IPCC, 2007). These hallmarks have been recognized in storms, including cyclones (IPCC, 2012a).

Whether or not there has been a change in the frequency or overall number of cyclones in recent years can side-track the focus on other important factors, such as wind speed changes (Knutson et al. in Chan et al. (eds.), 2010). Simply counting the change in the number of cyclones often leads to the conclusion that there is less cyclone activity, since there is generally understood to be a slight increase in the most extreme cyclones, such as categories 3 to 5, but an overall decrease in the total number of cyclones since the reduction in less severe storms is expected to be greater (Knutson et al., 2010). It is not surprising that an increase in the most extreme cyclones, as measured on the well-known Saffir-Simpson scale results in fewer cyclones overall, since the scale itself is static, measures overall power, and is a rough proxy for the size of storms (Dolan and David, 1992; Irish et al., 2008). Larger more powerful storms absorb and dissipate considerably more energy than smaller ones, whose declining numbers have been attributed to an overall decline in cyclone frequency in recent times (IPCC, 2012a). Nor is the ultimate number of storms as important as the intensity or size of those storms: in the US, 85% of all cyclone damage is caused by the most extreme storms (Rudeva and Gulev, 2007; Pielke et al., 2008). A large share of the damage caused by cyclones is the result of storm surge, or inundations from rainfall, high winds, and freak waves caused by major storms, which have been worsened by heavier rainfall and sea-level rise, both of which are fuelled by climate change (Dasgupta et al., 2009).

IMPACTS

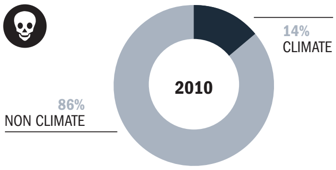
The impact of climate change on both tropical cyclones and major storms outside of the tropics (extra-tropical cyclones) is estimated to already cost 15 billion dollars and to be responsible for an average of almost 2,500 deaths each year, with around 1.5 million people affected and in need of emergency assistance.

In global terms, the number of countries experiencing extreme effects is limited, particularly since the great majority of losses relate to tropical cyclones, which are a serious concern for only 30 to 40 countries in the world's cyclone belts. A dozen countries in Asia, Africa, the Pacific, and the Caribbean are estimated to suffer Acute or Severe vulnerability to climate change-aggravated storm effects. The countries most vulnerable cut across the socio-economic spectrum from Japan to major emerging economies, such as China, least developed countries such as Madagascar, or small island developing states, such as Haiti.

Bangladesh is currently estimated to suffer the greatest human impact of these effects, with over 1,000 additional casualties due to climate change on an averaged yearly basis—major storms do not occur annually, but once in every 5 to 20 years. Myanmar and India are estimated to suffer the next greatest share of additional casualties. In overall economic terms, China, Japan, the US, North Korea, and South Korea experience the greatest estimated losses, incurring between 2 and 5 billion dollars a year in damages.

A number of small island countries, such as Antigua and Barbuda, Dominica, Grenada, and Vanuatu are identified as experiencing the most severe economic and human loss

BIGGER PICTURE

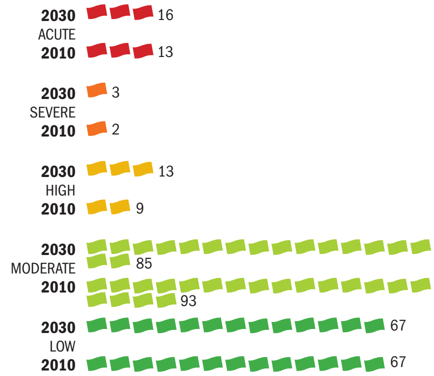


SURGE

OCCURRENCE

N/A

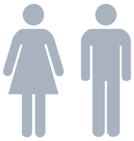
VULNERABILITY SHIFT



PEAK IMPACT

2008	**MYANMAR**	138,366	2005	**UNITED STATES**	158,230
2007	**BANGLADESH**	4,275	2004	**JAPAN**	15,144
2004	**HAITI**	2,757	2005	**MEXICO**	7,910
2005	**UNITED STATES**	1,882	2006	**CHINA**	7,859
2004	**PHILIPPINES**	1,861	2000	**NORTH KOREA**	6,000

GENDER BIAS



INDICATOR INFORMATION

MODEL: Donat et al, 2011; Mendelsohn et al., 2011

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: Tropical storms: Mendelsohn et al., 2011 (economic); Peduzzi et al., 2012 (mortality). Extra-tropical storms: CRED EM-DAT, 2012; Munich Re NATCAT, 2010 (economic)

$ = Millions of USD (historic)

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

relative to size. Several countries located on the Central American isthmus, such as Belize, El Salvador, and Honduras are exposed to tropical cyclones originating in both the Caribbean/Atlantic and Pacific Oceans, and are estimated to suffer extreme effects.

THE BROADER CONTEXT

As with other weather-related disasters, two key trends provide the context for the changes in extreme weather hazards which researchers increasingly attribute to climate change: 1) reductions in vulnerability due to continued economic growth especially in developing countries; and 2) an increase in the number of people and the amount of infrastructure exposed to extreme weather, due to the combined effects of population growth, urbanization, and economic development (UNISDR, 2011; Peduzzi et al., 2012). Correcting for these developments and other inconsistencies, evolution in reporting systems and biases in the statistical record have led to mixed interpretations of whether the scale of impacts due to climate change are increasing or decreasing (Mendelsohn et al., 2011; Pielke et al., 2008). The insurance industry has been registering greater and greater losses from weather-related catastrophes, including storms, over the past several years (Swiss Re, 2010, 2011, and 2012).

VULNERABILITIES AND WIDER OUTCOMES

Particularly noteworthy in terms of environmental vulnerabilities to storms are low-lying coastal communities which will bear the brunt of the increasing effects of climate change on heavy rainfall, wave height, and storm surge during cyclones (Füssel in Edenhofer et al. (eds.), 2012). Significantly altering the risk profile of countries are existing protection levels and capacities embodied in infrastructure, early warning systems, social and community response, support networks and levels of awareness about disasters. Likewise, government capacity to manage risks, as well as land use and environmental planning and protection can all affect the level of vulnerability, e.g., inappropriate urbanization or the clearing of coastal mangrove forests, which otherwise provide protection against winds and storm surges (UNISDR, 2009 and 2011; IPCC, 2012a). Migration patterns are fuelling rapid and inappropriate urbanization, leading to growing settlements in high-risk coastal flood zones, which themselves are seeing a depletion in natural protection, as from the destruction of mangrove forests (Donner and Rodriguez, 2008; Füssel in Edenhofer et al. (eds.), 2012).

Where insurance coverage is low, the ability of affected communities to rebound from disasters is greatly inhibited (Dodman and Satterthwaite, 2008). This is especially a concern among developing and lower-income countries, such as small island developing states, where the scale of impact can also generate important setbacks for development (Pelling and Uitto, 2001).

RESPONSES

Numerous preventive measures can be taken to reduce key vulnerabilities and minimize naturally increasing exposures to disaster. Possible efforts include education and communication programmes, promotion of community volunteer emergency organizations, supporting governments to develop and implement action plans to manage risks through sensible municipal planning, constructing protective infrastructure, reinforcing environmental protection to limit risk-multiplication, and promoting access to insurance products. Better management of urbanization and urban-rural migration flows would also help lower risks for coastal mega-cities (de Sherbinin et al., 2007). Progress in human development and poverty reduction will inevitably enhance capacities to withstand serious storms and limit the damage to the highest risk groups, requiring integrated strategies regarding climate change, disaster risk, and development strategies (Schipper and Pelling, 2006).

THE INDICATOR

Although the increasing severity of weather including tropical and extra-tropical cyclones is well established, the indicator is considered speculative because there is considerable disagreement among the models predicting change in cyclone intensity for different regions of the world. With the exception of the North Atlantic, where evidence of an increase in extreme weather is strongest, predictions of changes in cyclone activity in the Indian and Pacific oceans differ widely (Mendelsohn et al., 2011; IPCC, 2012a).

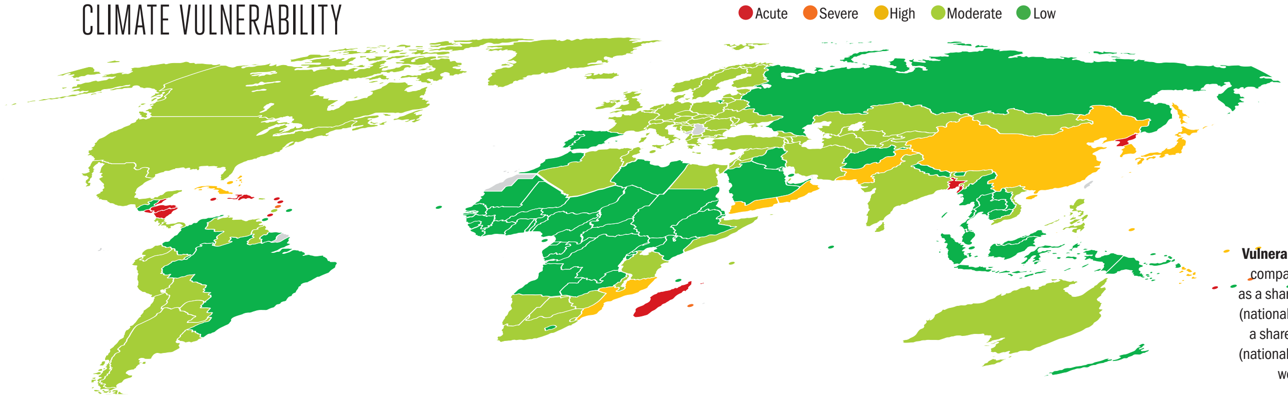
ESTIMATES COUNTRY-LEVEL IMPACT

	☠		$		👤	
COUNTRY	2010	2030	2010	2030	2010	2030
ACUTE						
Antigua and Barbuda			30	250	700	650
Bangladesh	1,750	2,500	150	1,250	400,000	600,000
Belize			30	250	550	700
Dominica			15	150	-90	-100
Dominican Republic	10	10	200	1,750	20,000	20,000
El Salvador			250	1,750	5	15
Grenada			25	200	-35	-60
Haiti	15	20	25	200	5,750	8,500
Honduras	1	1	200	1,500	200	350
Jamaica		1	100	800	1,000	2,500
Madagascar	50	100	40	250	150,000	300,000
Myanmar	500	600	1	20	10,000	15,000
Nicaragua	1	1	50	350	250	550
North Korea			550	5,750	2,250	-950
Tonga		1			-3,750	20,000
Vanuatu	5	10		-1	7,250	15,000
SEVERE						
Mauritius	1	1	25	150	500	400
Saint Lucia			1	20	15	10
Samoa		1		-1	750	5,750
HIGH						
Bahamas		1			400	450
China	1	-5	4,750	50,000	100,000	-250,000
Cuba	-1	-1	100	850	-75,000	-200,000
Japan	-10	-20	4,000	10,000	-10,000	-30,000
Marshall Islands					55	650
Micronesia					1	25
Mozambique	15	25	1	15	150,000	200,000
Oman			75	550		
Pakistan	5	5	250	2,250	4,500	8,750
Palau					200	450
Solomon Islands	1	1			8,500	20,000
South Korea		-1	600	4,750	-25	-200
Yemen			25	200		
MODERATE						
Albania						
Algeria				1		
Argentina			1	10		
Armenia						
Australia	1	1	-1	-1	100,000	150,000
Austria			5	10		1
Azerbaijan						
Belarus						
Belgium			1	10	1	1
Bolivia						
Bosnia and Herzegovina						
Botswana						
Bulgaria						
Canada			1	5		
Chile			1	10		
Costa Rica			1	10	950	1,250
Croatia						
Cyprus						
Czech Republic			1	5	550	1,000
Denmark			5	15	10	20
Djibouti						
Ecuador						
Egypt						
Estonia			1	1		
Finland				1		
France		1	40	95	3,250	6,000
Georgia				1		
Germany			100	350	25	50
Greece			1	5		
Guyana				1		
Hungary				1		
Iceland						
India	150	150	550	4,250	300,000	350,000
Iran			250	1,750		
Ireland			1	1		
Israel			1	10		
Italy			1	5		
Jordan				1		
Kazakhstan						
Kuwait			1	15		
Kyrgyzstan						
Latvia			1	10	400	750
Lebanon			1	5		
Lithuania				1	250	500
Luxembourg			1	1		
Macedonia						
Malawi				1		
Malta						
Mexico	10	15	150	1,250	70,000	85,000
Moldova			1	5		
Mongolia						
Namibia						
Netherlands			1	5	90	200
Norway			1	5		
Panama					25	30
Paraguay						
Peru			1	10		
Philippines	45	60	15	100	200,000	250,000
Poland			1	10	1	1
Qatar			1	10		

☠ Additional mortality due to climate change - yearly average

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

CLIMATE VULNERABILITY



Vulnerability measure: comparative mortality as a share of population (national) and losses as a share of GDP in USD (national) with same full weighting to both

CLIMATE UNCERTAINTY

	☠		$		👤	
COUNTRY	2010	2030	2010	2030	2010	2030
Romania			1	1		
Saint Vincent			1	5	-150	-150
Seychelles				1		
Slovakia			1	5		
Slovenia			1	5		
Somalia				1		
South Africa			5	20		
Sri Lanka			5	35	2,500	60
Swaziland						
Sweden			5	10	10	15
Switzerland			5	15	65	100
Syria						
Tajikistan			1	15		
Tanzania			15	90		
Tunisia						
Turkey						
Turkmenistan						
Ukraine			1	5		
United Kingdom			20	60	55	150
United States	1	1	2,500	8,250	4,750	6,500
Uruguay				1		
Uzbekistan						
Venezuela				1		
Vietnam	10	10	-5	-75	15,000	15,000
Zimbabwe	1	5			6,500	15,000
LOW						
Afghanistan						
Angola						
Bahrain			-5	-35		
Barbados				1	-90	-250
Benin						
Bhutan						
Brazil						
Brunei						
Burkina Faso						
Burundi						
Cambodia						
Cameroon						
Cape Verde						
Central African Republic						
Chad						
Colombia						
Comoros						
Congo						
Cote d'Ivoire						
DR Congo						
Equatorial Guinea						
Eritrea						
Ethiopia						
Fiji	1	-1	-10	-75	5,250	-2,000
Gabon						
Gambia						
Ghana						
Guatemala		1	-1	-10	150	250
Guinea						
Guinea-Bissau						
Indonesia			-50	-400		
Iraq						
Kenya				-1		
Kiribati						
Laos	1	1	-5	-35	5,750	8,750
Lesotho						
Liberia						
Libya						
Malaysia			-1	-10		
Maldives				-1	5	15
Mali						
Mauritania						
Morocco						
Nepal						
New Zealand			-5	-15	150	150
Niger						
Nigeria						
Papua New Guinea						
Portugal						
Russia	-1	-5	1	10	-150	-300
Rwanda						
Sao Tome and Principe						
Saudi Arabia			-30	-250		
Senegal						
Sierra Leone						
Singapore						
Spain			-1	-10		
Sudan/South Sudan						
Suriname						
Thailand			-5	-35	750	650
Timor-Leste						
Togo			-1	-10		
Trinidad and Tobago		-1			-250	-1,250
Tuvalu						
Uganda						
United Arab Emirates			-10	-85		
Zambia						

👤 Additional persons affected/in need of emergency assistance due to climate change - yearly average

WILDFIRES

ESTIMATES GLOBAL CLIMATE IMPACT

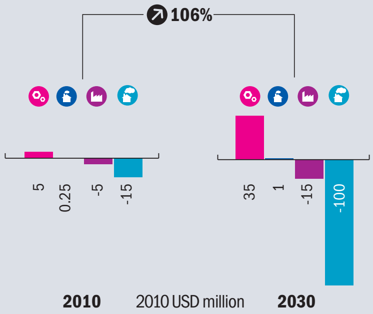
2010 EFFECT TODAY

USD **GAIN** PER YEAR **15 MILLION**

2030 EFFECT TOMORROW

USD **GAIN** PER YEAR **90 MILLION**

ECONOMIC IMPACT



CONFIDENCE

INDICATIVE

SEVERITY ● ○ ○ ○

AFFECTED

INJUSTICE ● ○ ○ ○

PRIORITY ○ ○ ●

MDG EFFECT ○ ○ ○ ○ ○ ○ ○

- ➔ The global impact of climate change on wildfires may have a neutral effect as a warmer planet brings more rain, dampening fires
- ➔ Shifts in wildfire may occur where forested areas become drier and hotter, severely affecting populated parts of Russia, Mongolia, or Australia
- ➔ The marginal effect of climate change is difficult to predict because of wind and rain uncertainties and because good international data monitoring fire damages is lacking
- ➔ Wildfire occurrence has links to now more prevalent heat extremes and drought which increase the probability of fires

RELATIVE IMPACT

☠ **2010**
2

☠ **2030**
2

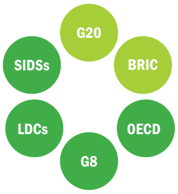
$$$ $ **2010**
25 1

$$$$$ $ **2030**
49 1

HOTSPOTS

2010	$	2030
5	**RUSSIA**	40
1	**MONGOLIA**	15
0	**NICARAGUA**	1
0	**SOUTH AFRICA**	1
1	**CANADA**	1

GEOPOLITICAL VULNERABILITY



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

✱ ☠ = Deaths per 100 million
$ = Losses per 10 million USD of GDP
↗ Change in relation to overall global population and/or GDP

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

Wildfires—the uncontrolled burning of forests, grasslands or brush—will generally become more frequent and damaging for drought-prone parts of the world. But it is certain that climate change will reduce disturbances from wildfires in some areas where rainfall is significantly increasing. The 2010 wildfires in Russia, as well as the recent fires in Australia, Greece, and the US, are clearly linked to warm, dry temperatures, if not drought (UNISDR, 2011). However, the additional losses incurred by those worst affected are likely to be offset on a global scale by a reduction in wildfire activity in other parts of the world. It is expected that Vietnam may see increased rainfall in some seasons, but declining rain and rising heat during the dry periods would favour wildfire onset, even if more rain overall falls in a given year (Vietnam MONRE, 2010). Tackling an additional burden of wildfire in affected areas will be great, since suppressing fires is costly: the US Forest Service spent 1 billion dollars on fire suppression in the year 2000 alone, with costs growing significantly over time—2.5 million dollars in losses were reported for that year. But expenditures were undoubtedly warranted in most cases, since wildfires can be extremely deadly: in February 2009, one series of fires alone in Australia killed 180 people (WFLC, 2004; CRED/EM-DAT, 2012).

CLIMATE MECHANISM

Wildfires are affected by three key factors: 1) availability of vegetation to burn; 2) environmental conditions, such as temperature, wind, and humidity or rainfall but also topography and ecosystem type—tropical forests for example are more humid and burn less than temperate forests; and 3) varying ignition sources of fires (Krawchuk et al., 2009). Climate change affects all of these elements: it influences vegetation growth and health along with the expanse of different ecosystem areas (Gonzalez et al., 2010). In regions with less rain and more heat, the declining vegetation will offer less available material for burning and will ultimately reduce disturbances from wildfires. Heat is increasing relatively uniformly around the world due to climate change. Less predictable rainfall and vegetation changes add considerable uncertainty to whether or not fires ultimately retreat or advance with global warming. Climate change has also been shown to potentially alter electrical activity in the atmosphere, giving rise to lightning, the principal initial trigger of wildfires (Reeve and Toumi, 1999).

IMPACTS

Drawing on recent research, the Monitor estimates the global impact of climate change on wildfire to be close to zero in 2010 and in 2030 (Krawchuk et al., 2009). Estimates of impact include around 3 million dollars of additional losses a year in 2010, and some 15 million dollars of additional losses in 2030. “Gains” of 25 and 150 million dollars a year in 2010 and 2030, respectively, outweigh considerably any losses incurred elsewhere in the world, but overall totals are small. “Gains” represent avoided wildfires that would have taken place without climate change. The largest negative effects in absolute terms are estimated to occur in Russia, Mongolia, Canada, Australia, and South Africa, while the US and Indonesia are expected to reap the most benefits overall. Within large countries like the US, it is possible that increased fire activity may well be experienced in certain areas but will be counterbalanced with decreased activity in other parts of the country. In general, wildfires mainly concern industrialized or developed countries.

THE BROADER CONTEXT

There has been a considerable increase in wildfire damage recorded in recent years (CRED/EM-DAT, 2012). However, improvements in the actual reporting systems themselves—advances in technology and information sharing—have allowed the reporting of increasing numbers of phenomena (UNISDR, 2009). However, satellite analysis has shown that the annual burned area has grown since the 1970s (UNEP, 2002). Several other factors, such as land usage change, could be contributing to increasing fire damage. As with other weather-related disasters, growing exposure to wildfires through economic development, population growth, and an expansion in infrastructure at risk should also increase damages.

VULNERABILITIES AND WIDER OUTCOMES

Countries with large areas of non-tropical vegetation and a propensity to drought are particularly vulnerable to the effects of climate change

BIGGER PICTURE

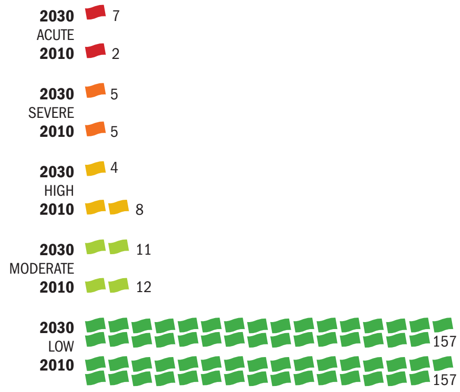
N/A

SURGE

OCCURRENCE

N/A

VULNERABILITY SHIFT



PEAK IMPACT

☠	$
2009 **AUSTRALIA** 180	2003 **UNITED STATES** 3,500
2007 **GREECE** 70	2005 **SPAIN** 2,050
2010 **RUSSIA** 61	2010 **RUSSIA** 1,800
2008 **MOZAMBIQUE** 49	2007 **GREECE** 1,750
2010 **ISRAEL** 44	2003 **PORTUGAL** 1,730

GENDER BIAS

INDICATOR INFORMATION

MODEL: Krawchuk et al., 2009

EMISSION SCENARIO: SRES A2 (IPCC, 2000)

BASE DATA: CRED EM-DAT, 2012

$ = Millions of USD (historic)

● Acute ● Severe ● High ● Moderate ● Low

▬ = 5 countries (rounded)

on wildfires. Coniferous forests are especially risky areas for fire outbreak during extended warm, dry periods (Cruz and Alexander, 2010).

The full extent of increased wildfires is difficult to estimate, but given the incredible potential for the rapid and uncontrolled spread of fires, growing fire dangers in some parts of the world could carry serious risks for public safety. The 2010 Russian wildfires, for example, burned some 4,000 hectares of land— contaminated, moreover, by radioactive material from the Chernobyl disaster—the full consequences of which are not yet known; the fires also threatened functioning nuclear power plants and research facilities (Munich Re, 2010).

RESPONSES

Responding to wildfires is extremely costly requires highly sophisticated technology. Some early detection and warning systems are capable of identifying a fire within 5 minutes of its ignition (Bridge, 2010). Thus, such systems represent an investment that could significantly reduce overall expenditures on suppressing fires that would otherwise end up destroying thousands or millions of hectares. Fire safety and education programmes may reduce the potential for fires set by human hands by up to 80% (UNEP, 2002).

Of course, as is well known, not all wildfires are bad. Natural habitats have evolved to cope with wildfires over time and to support biodiversity and processes of regeneration (Parker et al., 2006). Therefore, many countries also practice what is called "prescribed burning," effectively a "let-burn" policy, in which human settlements are not endangered. But while such practices may lower fire prevention costs and help support ecosystems, if fires subsequently reach a large-scale and deviate to threaten settlements, the costs of fire suppression can rapidly and counter-productively escalate (UNEP, 2002).

THE INDICATOR

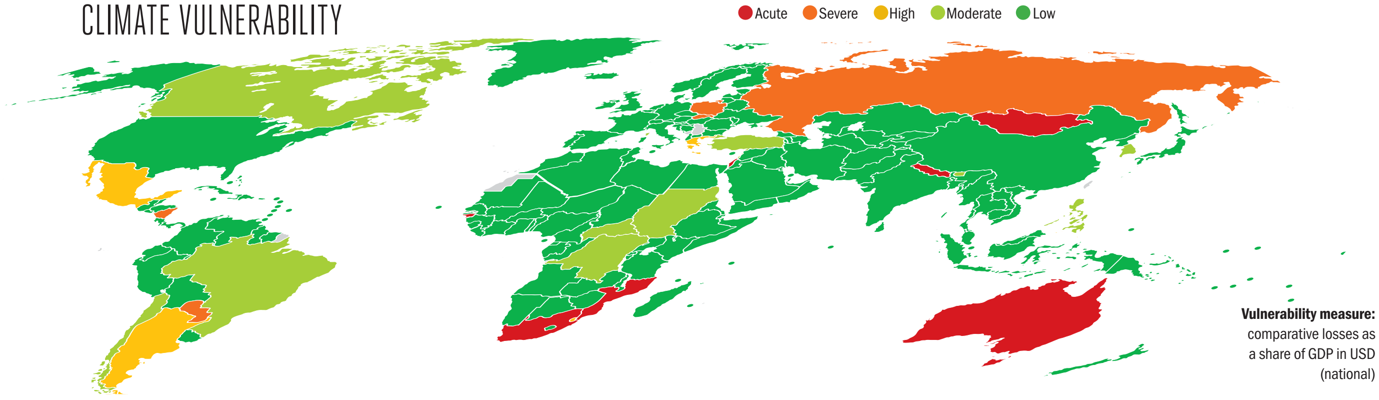
The indicator relies on a high-resolution global pyrogeography model for the effect of climate change on fire disturbances, used to estimate impact for populated areas (Krawchuk et al., 2009). Limitations relate to uncertain future rainfall and the restricted socio-economic base data set, which may underestimate costs (CRED/EM-DAT, 2012). Regarding base data, the major wildfires that affected Russia in 2010 are recorded in the reference database at 1.8 billion dollars in losses and 61 deaths. The major reinsurer, Munich Re, on the other hand estimates the total cost of the fires at 3.3 billion dollars and over 50,000 indirect deaths from both extreme heat and the significantly higher than normal air particle loads and their effect on chronic respiratory and cardiovascular disease sufferers (Munich Re, 2010). Historical base data would also give a misleading trend if fires spread to areas where damage in the past was unusual, underestimating future losses.

ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	$ 2010	$ 2030
ACUTE		
Australia	0.25	0.50
Guinea-Bissau		
Israel		
Mongolia	1	15
Mozambique		
Nepal		
South Africa	0.25	1
SEVERE		
Nicaragua	0.25	1
Paraguay		
Poland		
Russia	5	40
Slovakia		
HIGH		
Argentina		
Greece		
Mexico		
Swaziland		
MODERATE		
Bhutan		
Brazil		
Canada	0.50	1
Central African Republic		
Chile		
DR Congo		
Lebanon		
Philippines		
South Korea		
Sudan/South Sudan		
Turkey		
LOW		
Afghanistan		
Albania		
Algeria		
Angola		
Antigua and Barbuda		
Armenia		
Austria		
Azerbaijan		
Bahamas		
Bahrain		
Bangladesh		
Barbados		
Belarus		
Belgium		
Belize		
Benin		
Bolivia		
Bosnia and Herzegovina		
Botswana		
Brunei		
Bulgaria	-0.25	-1
Burkina Faso		
Burundi		
Cambodia		
Cameroon		
Cape Verde		
Chad		
China		
Colombia		
Comoros		
Congo		
Costa Rica		
Cote d'Ivoire		
Croatia		
Cuba		
Cyprus		
Czech Republic		
Denmark		
Djibouti		
Dominica		
Dominican Republic		
Ecuador		
Egypt		
El Salvador		
Equatorial Guinea		
Eritrea		
Estonia		
Ethiopia		
Fiji		
Finland		
France		
Gabon		
Gambia		
Georgia		
Germany		
Ghana		
Grenada		
Guatemala		
Guinea		
Guyana		
Haiti		
Honduras		
Hungary		

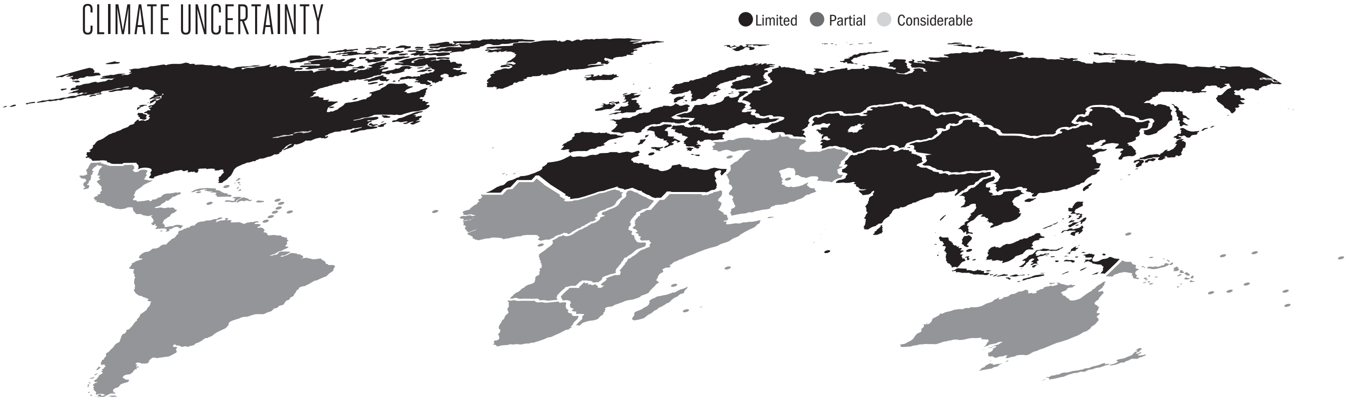
$ Additional economic costs due to climate change (million USD PPP) - yearly average

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY



COUNTRY	2010	2030
Iceland		
India		
Indonesia	-20	-150
Iran		
Iraq		
Ireland		
Italy	-1	-1
Jamaica		
Japan		
Jordan		
Kazakhstan		
Kenya		
Kiribati		
Kuwait		
Kyrgyzstan		
Laos		
Latvia		
Lesotho		
Liberia		
Libya		
Lithuania		
Luxembourg		
Macedonia		
Madagascar		
Malawi		
Malaysia	-0.25	-1
Maldives		
Mali		
Malta		
Marshall Islands		
Mauritania		
Mauritius		
Micronesia		
Moldova		
Morocco		
Myanmar		
Namibia		
Netherlands		
New Zealand		
Niger		
Nigeria		
North Korea		
Norway		
Oman		
Pakistan		
Palau		
Panama		
Papua New Guinea		
Peru		
Portugal	-0.25	-1
Qatar		
Romania		
Rwanda		
Saint Lucia		
Saint Vincent		
Samoa		
Sao Tome and Principe		
Saudi Arabia		
Senegal		
Seychelles		
Sierra Leone		
Singapore		
Slovenia		
Solomon Islands		
Somalia		
Spain	-0.25	-1
Sri Lanka		
Suriname		
Sweden		
Switzerland		
Syria		
Tajikistan		
Tanzania		
Thailand		
Timor-Leste		
Togo		
Tonga		
Trinidad and Tobago		
Tunisia		
Turkmenistan		
Tuvalu		
Uganda		
Ukraine		
United Arab Emirates		
United Kingdom		
United States	-5	-15
Uruguay		
Uzbekistan		
Vanuatu		
Venezuela		
Vietnam		
Yemen		
Zambia		
Zimbabwe		

HABITAT CHANGE

BIODIVERSITY

DESERTIFICATION

HEATING & COOLING

LABOUR PRODUCTIVITY

PERMAFROST

SEA-LEVEL RISE

WATER

80 BILLION LOSS	2010
400 BILLION LOSS	2030
5 BILLION LOSS	2010
20 BILLION LOSS	2030
35 BILLION GAIN	2010
75 BILLION GAIN	2030
300 BILLION LOSS	2010
2.5 TRILLION LOSS	2030
30 BILLION LOSS	2010
150 BILLION LOSS	2030
85 BILLION LOSS	2010
550 BILLION LOSS	2030
15 BILLION LOSS	2010
15 BILLION LOSS	2030

BIODIVERSITY

ESTIMATES GLOBAL CLIMATE IMPACT

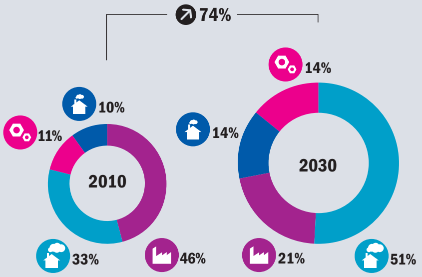
2010 EFFECT TODAY

$ USD **LOSS** PER YEAR **80** BILLION

2030 EFFECT TOMORROW

$ USD **LOSS** PER YEAR **400** BILLION

$ ECONOMIC IMPACT



CONFIDENCE
INDICATIVE

SEVERITY

AFFECTED

INJUSTICE

PRIORITY

MDG EFFECT

- Richness of life in the world's ecosystems is currently in full decline as human activities from toxic pollution to deforestation and destruction of natural habitats for agricultural land persist
- Climate change forces biological zones to face weather conditions that are unsuitable for their plant, animal, insect, and other species, hastening decline and extinction
- Biodiversity loss has significant market value and on a large scale will slow the world's economic growth
- Limiting non-climate dangers to biodiversity, such as deforestation, will be the basis of an effective response to the impact of climate change

RELATIVE IMPACT

$$$$$$ $ 2010
57 4

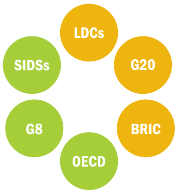
$$$$$$$$ $ 2030
75 7

HOTSPOTS

2010 $ 2030

25,000	**USA**	45,000
4,250	**CHINA**	45,000
3,500	**BRAZIL**	30,000
3,250	**IRAN**	25,000
3,250	**RUSSIA**	25,000

GEOPOLITICAL VULNERABILITY



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

$ = Losses per 10,000 USD of GDP

Change in relation to overall global population and/or GDP

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

The international definition of biodiversity is "variability among living organisms" (CBD, 1992). Biodiversity has both market and non-market value—such as aesthetic and other non-traded values—principally through the integral role of biodiversity in sustaining ecosystems (Boyd and Banzhaf, 2007). The agricultural sector is particularly dependent on ecosystem services, such as water, pollination, and pest control. If removed, they will incur predictable market-based costs, since compensating measures must be taken at market cost. Experts have estimated that a 30% species loss can generate some 10% of lost plant production affecting agricultural outputs (Hooper et al., 2012). Global biodiversity loss has become not only a conservation issue, but a large-scale and serious macroeconomic problem. UNEP estimates current global environmental damages at over 6 trillion dollars (Garfunkel ed., 2010). As one of the costliest impacts of climate change assessed here, losses can only worsen unless comprehensive solutions are found (IPCC, 2007; Bellard et al., 2012).

CLIMATE MECHANISM

The world's main biological zones, or biomes, from tropical woodlands, to grass steppes, and temperate deciduous forests, have taken thousands of years to establish rich habitats for an unimaginable variety of natural species. These zones are distinguished one from another by precise climate and geographical characteristics (Sala et al., 2000). The planet is warming at rates faster than in much of the Earth's recent past and the growing human presence in the environment limits the scope for biomes and their inhabitants to shift to new areas or adapt to changing climates (IPCC, 2007; Pereira et al., 2010).

Some species will become invasive, establishing themselves in new areas where others are in decline (Vilà et al. in Canadell et al. (eds.), 2007; Hellmann et al., 2008). As climates become unsuitable, endemic species of all kinds which have evolved to thrive in a specific habitat will be locked into declining biological zones with reduced geographic range. As that area shrinks, species decline at a predictable rate, reducing biodiversity (Thomas et al., 2004).

Climate change could conceivably also bring some biodiversity benefits in isolated cases, but on a global scale the impacts are clearly understood by experts to be negative (Bellard et al., 2012). Valuing the market worth of ecosystems and their so-called "services" is difficult, not least since it involves putting a price tag on ecological life (Farber et al., 2002). But in a surrogate market—in which consumers would be charged for the benefits many now enjoy without cost—around half of the losses estimated here might be considered to have value (Sutton and Constanza, 2002; Curtis, 2004).

IMPACTS

The scale of the estimated impact on biodiversity from climate change are substantial: around 80 billion dollars a year at present. By 2030, that estimate will nearly double as a share of global GDP, approaching 400 billion dollars a year in losses.

Although the impact is estimated to affect developing countries more severely, biodiversity loss will occur in virtually every region, since the world's entire climate is in rapid shift. However, lower-income countries are more dependent on ecosystem services, increasing the damage potential for populations lower on the socio-economic scale.

Large countries incur the most damages, especially the US, China, Brazil, Iran, and Russia. The US is estimated to incur one quarter of all losses today, at over 20 billion US dollars a year. Impacts are most severe as a share of GDP for countries in Africa and Central Asia, many of which could experience losses equivalent to more than 1% of GDP by 2030.

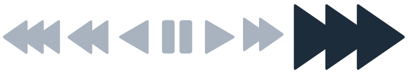
THE BROADER CONTEXT

The long-term decline of biodiversity is well established and continues as a clear trend. For example, since the 1970s, the fall in the abundance of vertebrate species has been almost one third. The World Conservation Union's (IUCN) "Red List" of endangered species reveals some 20,000 species of animals and plants at high risk for extinction. Decline of natural habitats due to human activities is also a continuing trend around the world, although destruction of tropical forests and mangroves has shown signs of slowing in some areas (SCBD, 2010). Deforestation is still a major global concern and threatens biodiversity (Busch et al., 2011). High demand for food and biofuels, driven by population and economic growth is an important driver of land change and degradation

BIGGER PICTURE

N/A

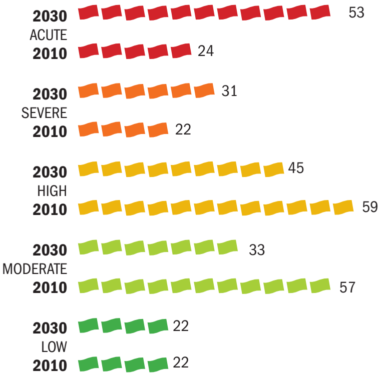
SURGE



OCCURRENCE

N/A

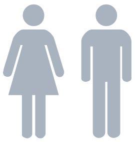
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: Baumgartner et al., 2012; Thomas et al., 2004

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: Costanza et al., 1997; Mace et al., 2003; US Forest Service (2010)

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

and deforestation (Gisladottir and Stocking, 2005).

VULNERABILITIES AND WIDER OUTCOMES

Assessments of the IUCN Red List show that the destruction of habitat by converting wild areas and forests into agricultural land are among the most significant contributors to biodiversity loss (Stuart et al., 2004; Brook et al., 2008). Unsustainable extraction of water resources further affects inland water-based ecosystems, especially those designed to meet the growing demand for water in the agricultural sector (Brinson and Malvarez, 2002). Agricultural and industrial pollutants are a further important source of stress (SCBD, 2010).

The biomes most at risk due to climate change include scrubland, temperate deciduous forest, warm mixed forest, temperate mixed forest, and savannah (Thomas et al., 2004). Countries with high concentrations of these biomes have high vulnerability to biodiversity loss from climate change, even if current environmental conservation is sound.

Lower-income countries, and those whose indigenous populations depend more heavily on ecosystems and wild areas, such as native forest, for their livelihood, are also highly vulnerable (Munasinghe, 1993; Salick and Byg, 2007).

Countries like Brazil that are already suffering large-scale biodiversity losses from forest destruction will increasingly experience double pressures from climate change (Miles et al., 2004). Biodiversity loss from climate change will slow the progress of human development in the worst-affected developing countries and will cause tangible economic losses worldwide by reducing ecosystem services (Roe and Elliot, 2004).

RESPONSES

Biodiversity loss due to climate change can be offset through measures that reduce other major biodiversity threats. Where those threats are already minimized, boosting conservation efforts, creating nature preserves, and reversing the fragmentation of habitats through the establishment of biodiversity corridors may help stem losses (Tabarelli et al., 2010). The principal response areas include promoting protection and sustainable management of forests, rationalizing and enhancing efficiencies in water usage, and managing toxic pollutants from industrial waste, agricultural fertilizers, and pesticides (Tilman et al., 2002). Interventions aimed at controlling invasive species, which can accelerate local biodiversity losses among endemic species, have shown to be effective and can complement other efforts (Veitch and Clout (eds.), 2004).

For many of the worst-affected communities in lower-income countries, capacity to implement such measures will be a major hurdle and international support will be vital. As with other systemic challenges, mainstreaming biodiversity considerations into decision making at different levels will be crucial to more effective solutions (Cowling et al., 2008). Social support should also be foreseen for indigenous groups and other communities which are heavily reliant on the fastest declining ecosystems (Salick and Byg, 2007).

Promising trends are visible in the global fight against biodiversity loss: protected and sustainable forest areas continue to grow incrementally and biodiversity aid has increased significantly in the past five years (SCBD, 2010). But the need is far greater than the response to date and most forms of biodiversity loss are irreversible (IPCC, 2002; Thomas et al., 2004). As climate change accelerates the decline, the urgency to respond effectively has never been greater.

THE INDICATOR

The indicator measures the proportion of species doomed to future extinction in different biomes around the world on account of the contraction of geographical climate-determined range size and future biome distribution due to climate change (Thomas et al., 2004). The exact time lag between threatened extinctions and their full realization varies and is not fully understood, although estimates exist (Brooks et al., 1999). Since the process of biodiversity loss due to climate change is continuous, in reality only a proportion of the estimated losses would be incurred at a date later than indicated. The indicator pairs biodiversity loss information and vegetation change with estimations of the lost economic value to determine a scale of economic losses in affected economies and the world (Mace et al. in Hassan et al. (eds.), 2005; US Forest Service, 2010; Costanza et al., 1997).

ESTIMATES COUNTRY-LEVEL IMPACT

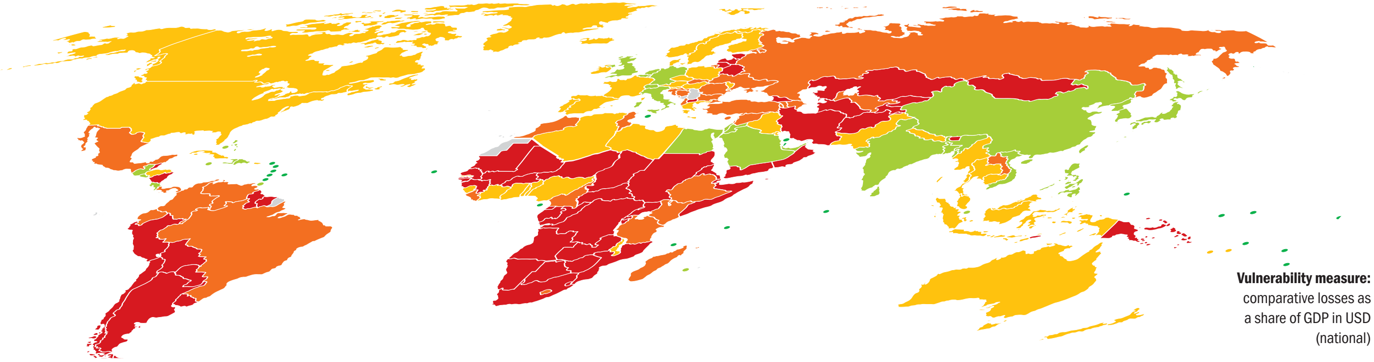
	$		🌳	
COUNTRY	2010	2030	2010	2030
ACUTE				
Afghanistan	80	650	-10,000	-20,000
Angola	400	2,500	-60,000	-100,000
Argentina	3,000	20,000	-35,000	-70,000
Belarus	700	4,250	-550	-1,250
Belize	15	100	-450	-850
Bhutan	45	350	-250	-450
Bolivia	500	4,000	-35,000	-65,000
Botswana	150	750	-1,500	-3,000
Burkina Faso	60	400	-4,500	-9,250
Central African Republic	35	200	-5,500	-10,000
Chad	200	1,250	-20,000	-40,000
Chile	800	6,250	-15,000	-30,000
Congo	80	500	-400	-750
Djibouti	10	75	-550	-1,250
DR Congo	55	350	-20,000	-45,000
Equatorial Guinea	60	400	-400	-850
Eritrea	20	100	-2,750	-5,750
Estonia	85	400	-150	-300
Gabon	100	650	-4,000	-8,000
Georgia	55	350	-2,750	-5,500
Guinea	30	200	-4,250	-8,500
Guinea-Bissau	5	40	-600	-1,250
Guyana	65	300	-3,500	-7,250
Iran	3,250	25,000	-10,000	-20,000
Kazakhstan	950	5,000	-5,750	-10,000
Kyrgyzstan	90	600	-1,250	-2,500
Latvia	150	700	-600	-1,250
Lithuania	200	1,250	-200	-400
Macedonia	65	450	-2,000	-4,000
Mali	100	750	-20,000	-40,000
Mauritania	70	450	-15,000	-35,000
Mongolia	150	1,500	-3,000	-6,250
Mozambique	80	550	-35,000	-70,000
Namibia	100	600	-2,250	-4,250
Nicaragua	40	300	-1,500	-2,750
Niger	55	350	-20,000	-40,000
Oman	200	1,750	-2,000	-3,750
Papua New Guinea	65	500	-1,250	-2,500
Paraguay	100	900	-10,000	-25,000
Peru	800	6,250	-4,000	-8,250
Senegal	75	500	-3,250	-6,500
Solomon Islands	10	80	-75	-150
Somalia	85	550	-15,000	-30,000
South Africa	1,750	10,000	-5,250	-10,000
Sudan/South Sudan	300	2,000	-45,000	-90,000
Suriname	30	150	-2,750	-5,500
Tajikistan	45	300	-450	-850
Timor-Leste	10	85	-1,500	-3,250
Turkmenistan	350	2,000	-8,000	-15,000
Uruguay	200	1,250	-400	-800
Yemen	150	1,250	-3,250	-6,500
Zambia	65	400	-85,000	-150,000
Zimbabwe	75	500	-9,500	-20,000
SEVERE				
Albania	40	250	-50	-100
Armenia	35	250	-700	-1,500
Azerbaijan	200	1,250	-2,000	-4,000
Bosnia and Herzegovina	70	500	-1,500	-3,000
Brazil	3,500	30,000	-200,000	-450,000
Bulgaria	250	1,500	-5,250	-10,000
Cameroon	85	550	-2,250	-4,250
Colombia	650	4,750	-5,500	-10,000
Croatia	150	1,250	-1	-5
Cyprus	35	100	-55	-100
Ecuador	150	1,250	-2,750	-5,250
Ethiopia	150	1,000	-25,000	-55,000
Kenya	100	700	-950	-2,000
Laos	30	300	-1,250	-2,500
Lesotho	5	40	-25	-50
Liberia	1	20	-1,750	-3,750
Madagascar	40	250	-1,000	-2,250
Mexico	2,500	20,000	-50,000	-100,000
Morocco	300	2,000	-10,000	-20,000
Panama	75	550	-1,750	-3,500
Romania	350	2,500	-200	-350
Russia	3,250	25,000	-70,000	-150,000
Slovakia	200	1,250	-450	-900
Swaziland	10	55	-45	-90
Syria	200	1,500	-1,250	-2,250
Tanzania	150	850	-10,000	-20,000
Tunisia	150	1,250	-4,000	-7,750
Turkey	1,500	4,750	-4,750	-9,750
Ukraine	700	4,750	-800	-1,500
Uzbekistan	100	850	-7,250	-15,000
Venezuela	550	4,000	-25,000	-55,000
HIGH				
Algeria				

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

🌳 Contraction of biological zones due to climate change (km^2) - yearly average

CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



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

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable

	$		🌳	
COUNTRY	2010	2030	2010	2030
MODERATE				
Bahamas	5	35	-500	-950
Bangladesh	20	150	-100	-250
Belgium	100	350	-350	-750
Burundi	1	5	-650	-1,250
China	4,250	45,000	-60,000	-100,000
Dominican Republic	30	250	-3,750	-7,250
Egypt	10	60	-25,000	-50,000
El Salvador	15	100	-450	-950
Germany	1,000	3,000	-1,250	-2,500
Guatemala	30	250	-1,250	-2,750
Haiti	1	20	-200	-400
India	1,500	10,000	-15,000	-30,000
Israel	30	200	-150	-250
Italy	700	2,000	-8,500	-15,000
Jamaica	5	40	-400	-750
Japan	900	2,500	-4,500	-9,250
Jordan	5	35	-550	-1,000
Lebanon	15	100	-65	-150
Luxembourg	15	40	-30	-60
Mauritius	5	20	-50	-100
Netherlands	150	400	-500	-1,000
North Korea	15	150	-1,750	-3,500
Philippines	95	750	-350	-650
Rwanda	1	10	-650	-1,250
Saudi Arabia	150	1,250	-15,000	-25,000
Singapore	10	70	-15	-30
South Korea	500	4,000	-550	-1,000
Sri Lanka	30	250	-1,250	-2,750
Switzerland	70	200	-300	-600
Trinidad and Tobago	5	45	-200	-350
United Arab Emirates	20	150	-500	-1,000
United Kingdom	1,000	3,000	-1,500	-3,000
Vietnam	70	750	-150	-300
LOW				
Antigua and Barbuda				
Bahrain				
Barbados				
Cape Verde				
Comoros				
Dominica				
Grenada				
Kiribati				
Kuwait				
Maldives				
Malta				
Marshall Islands				
Micronesia				
Palau				
Qatar				
Saint Lucia				
Saint Vincent				
Samoa				
Sao Tome and Principe				
Seychelles				
Tonga				
Tuvalu				

DESERTIFICATION

ESTIMATES GLOBAL CLIMATE IMPACT

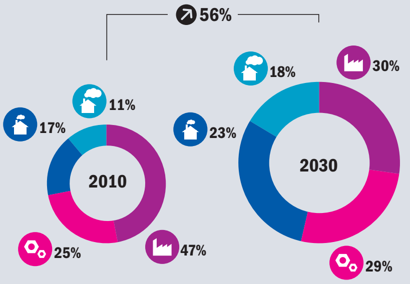
2010 EFFECT TODAY

$ USD **LOSS** PER YEAR **5 BILLION**

2030 EFFECT TOMORROW

$ USD **LOSS** PER YEAR **20 BILLION**

ECONOMIC IMPACT



CONFIDENCE
INDICATIVE

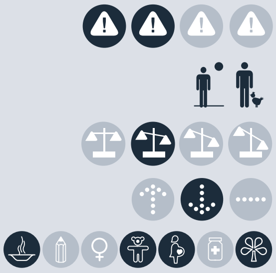
SEVERITY

AFFECTED

INJUSTICE

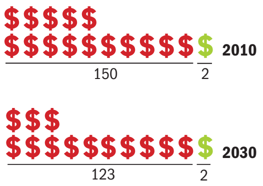
PRIORITY

MDG EFFECT



- Desertification will worsen already dry areas as heat rises and rainfall declines
- Although global climate change brings more rain, most of it will fall in the far north and south, while rainfall in the tropical zones, home to much of the world's drylands, is likely to decline as heat rises
- Millions of hectares of agricultural land in these areas are experiencing an increase in aridity, compounding other degradation taking place
- Climate change in the world's drylands will further impede human development progress for some of the world's poorest groups
- Sustainable land management strategies can help prevent desertification, but restoration of already degraded lands is difficult and costly

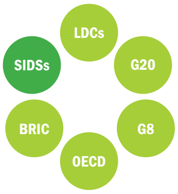
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
600	**MEXICO**	4,500
450	**UKRAINE**	2,750
500	**AUSTRALIA**	1,500
200	**RUSSIA**	1,250
450	**ITALY**	1,250

GEOPOLITICAL VULNERABILITY



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

$ = Losses per 100,000 USD of GDP

↗ Change in relation to overall global population and/or GDP

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

Desertification is degradation of drylands. The UN has defined "drylands" broadly as areas of land with an aridity index—a measure of rainfall versus evaporation—below a certain low-end threshold (UN, 2011). More than half the planet's productive land is considered drylands. Covering around 40% of the earth's land surface, drylands are home to some 2 billion people, nearly all in developing countries, and are responsible for more than 40% of global food production (UNCCD, 2011). As climate change intensifies heat and limits rainfall in drylands, already rampant land degradation in these areas will worsen (Evans and Geerken, 2004; Adeel et al., 2005; Zika and Erb, 2009). The UN and Christian Aid have estimated that anywhere between 25 and 700 million people could be displaced due to expected water stress and environmental degradation, including 50 million people affected by desertification over the next decade (Christian Aid, 2007; WWAP, 2009; UNCCD, 2010). Such groups have been campaigning for greater application of sustainable land and water resource management in order to combat this alarming development.

CLIMATE MECHANISM

A range of socio-economic and environmental processes are involved in land degradation in dry areas, including declining water availability, soil erosion and nutrient depletion, among others (Geist and Lambin, 2004). Climate observations and models indicate that many of the world's dry regions are becoming hotter and drier as global warming intensifies (Hansen et al, 2007; McCluney et al., 2011). A loss in net moisture or rainfall is a key factor in the degradation of dry land (Evans and Geerken, 2004). As a result, many non-arid lands will become arid, while affected arid lands will become even drier. On the other hand, where there are substantial increases in rainfall on existing drylands, such zones will improve and become more humid. Overall, the changes will be negative, since rainfall change is more likely to degrade the world's existing dryland, especially in Africa (IPCC, 2007 and 2007b; Helm et al., 2010). Where lands degrade, agricultural productivity and livelihoods will be severely affected (Fraser et al., 2011).

IMPACTS

The impact of climate change on desertification is expected to be widespread, affecting around 40 countries by 2030. The economic impact of land degradation is estimated at 5 billion dollars a year today, increasing to some 20 billion dollars annually and a larger share of global GDP by 2030.

Climate change-driven desertification is already estimated to affect some 5 million people worldwide, doubling to 10 million by 2030.

The range of worst affected countries is varied, with West Africa particularly hard hit. Countries such as Benin, Burkina Faso, Gambia, Guinea-Bissau, Mali, Niger, and Senegal top the list of those suffering the most extreme effects. A number of developed and industrialized countries are also affected from Australia to the Mediterranean, and Black Sea countries such as Bosnia and Herzegovina, Croatia, Russia and the Ukraine.

The bulk of global costs will occur in Organization for Economic Co-operation and Development (OECD) countries, including Italy, Spain and Turkey. However, Mexico is the country with the greatest total losses, reaching an estimated 5 billion dollars a year by 2030.

Countries acutely vulnerable to climate change include a large number of least developed and landlocked developing countries (LDCs and LLDCs), a particular cause for concern from a poverty/development perspective.

THE BROADER CONTEXT

Desertification itself is a serious global concern. The Secretariat of the UN Convention to Combat Desertification has been sounding the alarm on highly damaging changes underway in many of the world's drylands. They call attention, for instance, to 12 million hectares, including 75 billion tons of fertile soil, a principal global resource, lost each year as a result of desertification and drought (UNCCD, 2010). The extent to which climate change is rendering these regions hotter and drier (or wetter) will be its main, primarily negative, contribution to an already large-scale and multifaceted concern. Aside from climate change, the most widely cited causes of desertification include land-use issues such as deforestation, overcultivation, overgrazing, and unsustainable irrigation practices (Adeel et al, 2005). Natural variability in weather regimes can also result in

BIGGER PICTURE

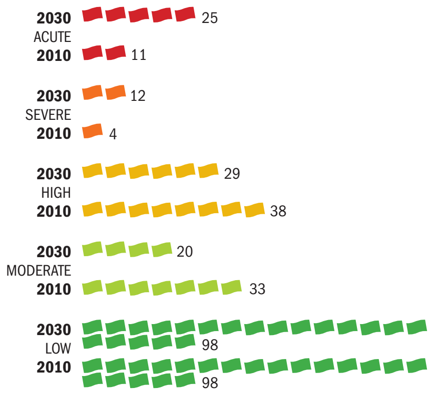
N/A

SURGE

OCCURRENCE

N/A

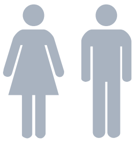
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: Hansen et al., 2007

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: FAOSTAT (land investments and gross crops production); Hoekstra et al., 2010; Kindermann et al., 2006; Portmann et al., 2010

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

large-scale short-term fluctuations in the primary productivity of drylands, both positive and negative (Hughes and Diaz, 2008).

Vulnerabilities and Wider Outcomes

Drylands exist around the world. Where they have been well managed, as in parts of southern Europe, they are fertile and productive. Where drylands are poorly managed, the opposite situation can develop as their susceptibility to degradation increases (Oygard et al., 1999). Given the overwhelming share of populated dryland areas within developing countries and LDCs or LLDCs, the capacity to promote and regulate sound policies can be an important factor in successful management (Esikuri ed., 1999).

Poverty can be viewed as a driver of desertification, when communities become locked in a vicious cycle that exacerbates deforestation for lack of alternative livelihoods. It can also be viewed as an outcome of desertification when, for example, households suffer losses of land, soil, or crop productivity due to desertification. As productive possibilities decline and populations in dryland areas continue to grow, these regions will likely expand as suppliers of seasonal and/or permanent migration (Johnson et al. (eds.), 2006). Poverty and health indicators for populations living in dryland areas are low, compared to other climatic zones (Adeel et al., 2005; Verstraete et al., 2009).

RESPONSES

Supporting dryland communities to adapt will require offsetting the additional heat and/or loss of rainfall brought about by climate change. Degradation prevention is preferable to costly restoration projects that seek to return vegetation and environmental integrity to degraded lands, often with limited results (Puigdefaabregas, 1998). Desertification control measures have had little success and have led experts to propose developmental approaches that foster technology uptake, investment, best practice land management replication, and boosting and diversifying incomes of dryland populations to better cope with change (Mortimore, 2003). Water capture, conservation and storage, increasing vegetation through reforestation, and the control of deforestation, and prevention of overgrazing and other soil-damaging processes can all contribute to enhanced resilience of drylands and their communities (Adeel et al., 2005). Improved monitoring of drylands would also facilitate better macro policy analysis and development (Reynolds et al., 2011).

THE INDICATOR

The indicator measures the value loss (or gain) in rapidly degraded (or improving) dryland agricultural zones resulting from an increase (or decrease) in aridity, due to temperature and rainfall changes brought about through global warming (Hansen et al., 2007). It is broadly indicative of how desertification is likely to unfold as a result of climate change. The amount of new agricultural lands accruing from deforestation is also accounted for. While projections of the key variable of rainfall are uncertain, there scientists are virtually unanimous about the direction of change (wet or dry) for a number of the world's key dryland regions, such as the Mediterranean basin.

ESTIMATES COUNTRY-LEVEL IMPACT

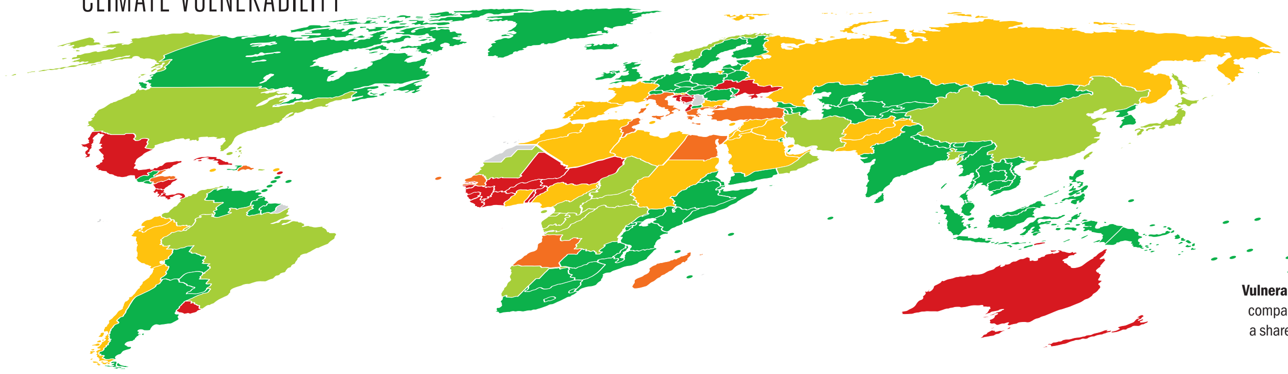
	$		▨		🧍	
COUNTRY	2010	2030	2010	2030	2010	2030
ACUTE						
Albania20	**100**	**300**	**600**	**35,000**	**80,000**	
Australia	**500**	**1,500**	**7,000**	**15,000**	**20,000**	**45,000**
Benin	**15**	**100**	**1,500**	**3,000**	**100,000**	**350,000**
Bosnia and Herzegovina	65	450	1,750	3,250	100,000	250,000
Burkina Faso	10	50				
Costa Rica	25	200	550	1,250	50,000	150,000
Cote d'Ivoire	15	95				
Croatia	100	800	2,000	3,750	150,000	300,000
Cuba	65	450	1,250	2,500	150,000	250,000
Dominica	1	10	20	35	1,750	3,750
Gambia	1	10				
Guinea	5	30				
Guinea-Bissau	1	5				
Liberia	1	5				
Mali	5	45				
Mexico	600	4,500	10,000	20,000	600,000	1,500,000
New Zealand	150	500	2,750	5,750	45,000	100,000
Nicaragua	15	100	550	1,000	25,000	65,000
Niger	5	30				
Panama	90	700	1,500	3,250	75,000	200,000
Sierra Leone	1	10				
Timor-Leste	25	200	650	1,250	50,000	100,000
Togo	10	45	1,250	2,500	150,000	400,000
Ukraine	450	2,750	9,000	20,000	700,000	1,000,000
Uruguay	20	150	400	800	7,750	15,000
SEVERE						
Angola						
HIGH						
Afghanistan	5	30	500	1,000	25,000	80,000
Algeria	45	350				
Antigua and Barbuda		1	5	5	750	1,750
Bahrain	5	25				
Bulgaria	10	80	150	350	10,000	20,000
Chile	40	300	700	1,500	15,000	40,000
Cyprus	5	10	40	85	5,000	10,000
Ecuador	20	150	400	850	25,000	60,000
France	400	1,250	5,250	10,000	600,000	1,500,000
Ghana	10	65	750	1,500	75,000	200,000
Iraq	15	100				
Israel	25	200				
Jamaica	1	20	65	150	15,000	40,000
Jordan	5	30				
Lebanon	5	50				
Libya	15	100				
Malta	1	5	15	30	20,000	45,000
Morocco	30	200	1,250	2,500	85,000	200,000
Nigeria	60	350	4,250	8,500	750,000	2,000,000
Pakistan	70	400	1,500	3,250	350,000	1,000,000
Peru	55	400	1,250	2,250	25,000	65,000
Portugal	30	90	450	900	55,000	100,000
Russia	200	1,250	3,250	6,250	25,000	50,000
Saudi Arabia	75	550				
Slovenia	10	75	100	250	10,000	25,000
Spain	200	600	2,750	5,500	250,000	450,000
Sudan/South Sudan	20	150				
Syria	15	95				
United Arab Emirates	30	200				
MODERATE						
Bahamas		1	1	5	70	150
Bangladesh	5	20	150	300	150,000	400,000
Brazil	70	550	2,250	4,500	50,000	100,000
Cameroon	1	10				
Central African Republic		1				
Chad	1	5				
China	75	750	2,000	4,000	300,000	600,000
Colombia	1	10	35	75	1,500	3,750
Congo	1	5				
DR Congo	1	5				
Equatorial Guinea	1	5				
Gabon	1	5				
Iran	1	20	35	70	1,500	4,000
Japan	40	100	500	950	150,000	300,000
Mauritania		1	25	50	85	250
Namibia		1	15	25	35	95
Norway	1	1	10	20	150	350
Oman						1
Sao Tome and Principe						
United States	200	700	1,750	3,500	55,000	150,000
LOW						
Argentina	-250	-2,000	-3,750	-7,500	-55,000	-150,000
Armenia						
Austria						
Azerbaijan		-1	-5	-10	-600	-1,500
Barbados						

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

▨ Additional land degraded due to climate change (km^2) - yearly average

CLIMATE VULNERABILITY

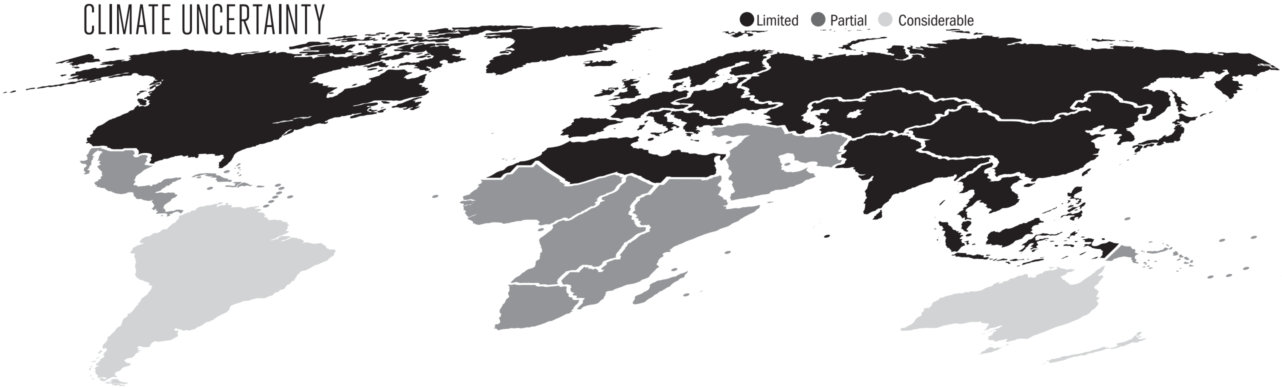
● Acute ● Severe ● High ● Moderate ● Low



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

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable



	$		◍		🚹	
COUNTRY	2010	2030	2010	2030	2010	2030
Belarus						
Belgium						
Bhutan						
Bolivia						
Botswana	-5	-25				
Brunei						
Burundi	-1	-1				
Cambodia						
Canada	-5	-10	-35	-70	-100	-250
Comoros		-1	-75	-150	-30,000	-90,000
Czech Republic						
Denmark						
Djibouti		-1				
El Salvador						
Eritrea	-1	-1				
Estonia						
Ethiopia	-10	-65				
Fiji						
Finland						
Georgia						
Germany						
Grenada						
Guatemala						
Guyana						
Haiti						
Hungary						
Iceland						
India	-40	-300	-1,750	-3,500	-650,000	-1,500,000
Indonesia	-5	-50	-400	-750	-50,000	-100,000
Ireland						
Kazakhstan	-5	-45	-150	-300	-950	-2,000
Kenya	-10	-50				
Kiribati						
Kuwait						
Kyrgyzstan						
Laos		-1	-15	-30	-400	-1,000
Latvia						
Lesotho		-1	-15	-30	-1,000	-2,000
Lithuania						
Luxembourg						
Macedonia						
Malawi	-1	-10				
Malaysia						
Maldives						
Marshall Islands						
Mauritius	-5	-40	-90	-200	-55,000	-150,000
Micronesia						
Moldova						
Mongolia						
Mozambique			-5	-10	-150	-350
Myanmar	-5	-35	-650	-1,250	-50,000	-100,000
Nepal						
Netherlands						
North Korea	-1	-10	-100	-200	-20,000	-45,000
Palau						
Papua New Guinea						
Paraguay						
Philippines						
Poland						
Qatar						
Romania						
Rwanda	-1	-10				
Saint Lucia						
Saint Vincent						
Samoa						
Seychelles		-1				
Singapore						
Slovakia						
Solomon Islands						
Somalia			-1	-5	-20	-75
South Africa	-5	-25	-90	-200	-3,750	-7,000
South Korea	-250	-1,750	-2,000	-4,000	-1,000,000	-2,000,000
Sri Lanka						
Suriname						
Swaziland	-5	-20	-150	-300	-10,000	-25,000
Sweden						
Switzerland						
Tajikistan						
Tanzania			-1	-5	-150	-400
Thailand	-80	-650	-2,000	-4,000	-250,000	-600,000
Tonga						
Trinidad and Tobago						
Turkmenistan				-1	-1	-10
Tuvalu						
Uganda	-5	-30				
United Kingdom						
Uzbekistan						
Vanuatu						
Venezuela						
Vietnam	-80	-850	-3,500	-7,250	-950,000	-2,000,000
Yemen	-1	-1	-30	-55	-1,250	-5,250
Zambia	-1	-15				
Zimbabwe	-1	-10				

🚹 Additional persons affected due to climate change - yearly average

HEATING & COOLING

ESTIMATES GLOBAL CLIMATE IMPACT

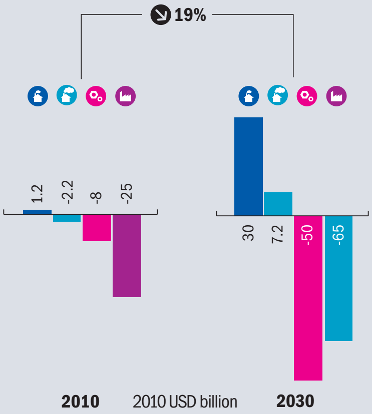
2010 EFFECT TODAY

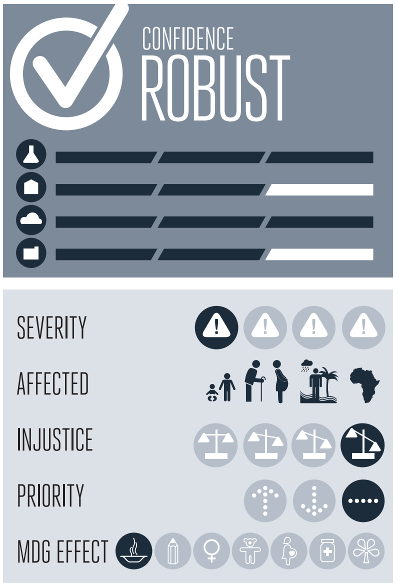
USD **GAIN** PER YEAR **35** **BILLION**

2030 EFFECT TOMORROW

USD **GAIN** PER YEAR **75** **BILLION**

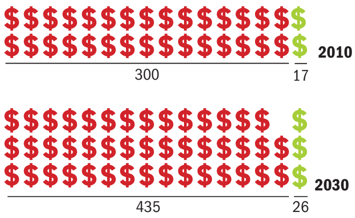
ECONOMIC IMPACT





- The most certain outcome of global warming is rising heat
- As heat goes up, heating costs decrease and air conditioning costs rise
- In the cooler north, heating especially is mandatory and widespread, but in tropical zones, artificial cooling is not always a necessity
- Currently, the impact of rising heat on indoor space conditioning is a positive effect of climate change globally, as cost reductions in cooler countries outweigh cost increases in hotter countries
- Tropical countries still incur serious losses, and in the longer term, if climate change is not controlled, high cooling costs will overtake reductions in heating costs

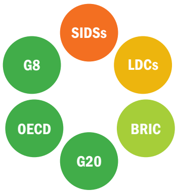
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
800	**INDIA**	10,000
600	**MEXICO**	10,000
250	**BRAZIL**	5,000
350	**SAUDI ARABIA**	4,250
150	**VIETNAM**	3,750

GEOPOLITICAL VULNERABILITY



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

$ = Losses per 100,000 USD of GDP

Change in relation to overall global population and/or GDP

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

The heating and cooling of residential and non-residential indoor spaces are among the largest energy consumers globally (WRI, 2009). Energy demand for heating is currently ten times higher than for cooling (Isaac and van Vuuren, 2008). As a result, temperature rise is presently generating a net economic benefit for the world economy, since the lowering of heating costs due to milder winters or fewer cold days is more significant than any increase in air conditioning costs (Hansen et al., 2012). However, if climate change continues to the end of the century, rising heat and increased air conditioning demand in developing countries would generate net losses for the world (Isaac and van Vuuren, 2009). Today, the increasing costs faced by middle and lower income countries in tropical regions can represent a significant negative economic impact at a national level. As a result, cooler countries are seeing declining emissions or less growth in emissions at national levels, enabling them to better meet GHG reduction targets. In hotter countries, however, GHG emissions will be artificially inflated, making it more difficult to reduce them. In fact, meeting the rapidly growing demand for air-conditioning as incomes expand in developing countries is a significant challenge without climate change. Not meeting the challenge, including with climate change, will curtail the economic development and welfare of many lower and middle-income countries, for example through reduced productivity and greater exposure to heat related health risks (Kjellstrom et al., 2009; Akpinar-Ferrand and Singh, 2010).

CLIMATE MECHANISM

The planet's warming is virtually certain, resulting in more hot and fewer cold days and nights (IPCC, 2007). On average, winters are becoming shorter and milder, summers longer and hotter. Areas that rely on heating indoor space to maintain comfortable temperature levels will increasingly need less energy in a year as the cold wanes. On the other hand, areas that can benefit from year-round or seasonal air-conditioning to bring down indoor temperatures to comfortable levels will increasingly need more energy to maintain these levels as temperatures climb. Many industrialized countries will see benefits from reduced winter heating needs, however many of those same countries will also experience increased cooling needs (Miller et al., 2008). In the sub-tropics and tropics where most of the world's population resides, greater cooling costs far outweigh any heating fluctuations (Isaac and van Vuuren, 2008).

IMPACTS

The global impact of climate change on heating and cooling is currently estimated to benefit the global economy by more than 30 billion dollars each year. By 2030, the costs of heating and cooling are estimated to decline slightly as a share of global GDP, but reach over 70 billion dollars. This is a signal of what lies ahead, as increased demand for cooling will gradually overtake any benefits from lower heating costs.

In 2010, national losses amounted to some 5 billion dollars a year in additional costs, whereas gains in countries benefitting from lower heating costs amounted to 40 billion dollars a year. By 2030, annual losses are estimated to be over 70 billion dollars and gains at 150 billion dollars. Countries with the largest losses in 2030 are India and Mexico, each with over 10 billion in annual costs. The largest gains are in the United Kingdom, Russia, China, and Germany, with benefits ranging from 10 to 20 billion dollars or more each year.

Least developed and lower-income countries in Africa, Central America, the Caribbean, and the Pacific are particularly negatively impacted, with losses reaching from 0.5–1% of GDP by 2030.

THE BROADER CONTEXT

Energy demand for both heating and cooling is growing almost everywhere. Global demand for heating is expected to peak around 2030, while demand for cooling will continue to expand throughout the 21st century as incomes grow in tropical and sub-tropical developing countries (Isaac and van Vuuren, 2008). These increases and decreases would occur without climate change, since energy efficiencies are being realized in cooler countries where markets for heating and cooling equipment are saturated and population growth is slow or declining (UNECE, 2012). In developing countries air conditioning demand is far from saturated and is expected to increase rapidly as incomes rise and

BIGGER PICTURE

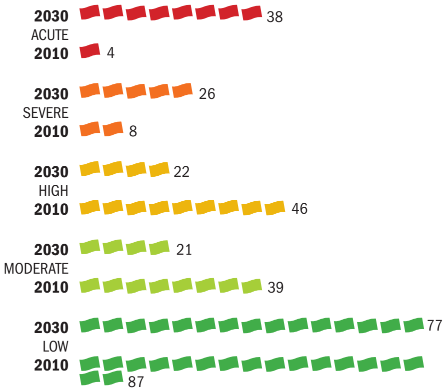
N/A

SURGE

OCCURRENCE

N/A

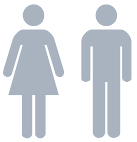
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: Isaac et al., 2008

EMISSION SCENARIO: TIMER/IMAGE reference scenario for the ADAM project (Isaac et al., 2008)

BASE DATA: Baumert et al., 2003; Electricity price EIA 2010; Perez-Lombard et al., 2007; UNECE (2012); Zmeureanu and Renaud, 2009

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

populations grow. Urban heat islands, growing in many places as a concern parallel to these other factors, are also exacerbating energy requirements (Kolokotroni et al., 2010; Memon et al., 2011).

VULNERABILITIES AND WIDER OUTCOMES

The world's hottest countries are most vulnerable to the impacts of climate change, since they already rely heavily on air-conditioning. Africa, Asia and the equatorial zones are particularly exposed since large populations and significant amounts of economic activity are located in warm zones.

If rising heat is not compensated by additional cooling that maintains at least the same level and progress in indoor climate control, economic productivity will fall more or less predictably (Kjellstrom et al., 2009a). Human welfare will be significantly affected through additional, serious impacts to human health from cardiovascular and chronic respiratory illnesses over and above what is already noted in the Health Impact section of this report (McMichael et al., 2006). As is highlighted in this report's Ghana country study, people in the lowest-income communities are more likely to sleep outdoors on the hottest nights, increasing exposure to mosquito bites during peak vector activity periods (dusk and dawn) and promoting higher transmission rates of malaria. Heat stress also affects cognitive performance, mental stress, and depression among other psychological effects (Hancock et al., 2003; Hansen et al., 2008).

RESPONSES

Increases in heat are often offset by increased energy consumption on the part of those who can afford it, but at an additional energy cost. For those who cannot, social and economic welfare will be compromised by productivity and health effects, although it is unclear how the economic costs of lost productivity might compare with extra cooling costs (Yardley et al., 2011; Kjellstrom et al., 2009b). Since solutions for indoor space cooling are technically possible in many cases, international responses could focus on ensuring adequate indoor cooling for lower-income communities unable to do so at will, particularly in areas with high risk for malaria and vector-borne disease. Improving building insulation and energy efficiency in the tropics (not only in cold countries) to protect against heat (not only cold) would be an important, lower-emission option for adapting to the growing heat (Akpinar-Ferrand and Singh, 2010).

Heating and cooling is a clear example of a dual-focus adaptation-mitigation response area. Any mitigation project that ensures provision of cooling-related technologies to affected communities would also constitute an adaptation action. In terms of practical steps, increasing local shade-tree cover can have a positive effect on cooling buildings (Donovan and Butry, 2009). Cities could take greater advantage of the geothermal energy created as a result of the heat island effect to supply energy for cooling, since cities also heat the ground below, not only the air above. The potential energy supply has been estimated to exceed cooling demand requirements in several major cities (Zhu et al., 2010).

THE INDICATOR

The indicator maps residential/non-residential heating demand changes. It is considered robust, given the certainty of the climate science community and model convergence on the main parameter of increasing heat, although humidity levels are also important (Wang et al., 2010). High quality energy consumption data gives a reasonable indication of the phenomenon's scale, but relies on the concept of heating and cooling degree-days, which are not fully accurate in terms of all demands, since wind, cloud cover, and humidity strongly influence heating and cooling behaviour (Baumert and Selman, 2003). While the same optimal temperature is assumed for different countries, it is argued that the optimal temperature varies by region, climate, and other conditions (Dear and Brager, 1998). Though the Indicator considers several dynamic variables, floor space size changes over time are not, though are understood to have a significant impact on future energy requirement estimates (Isaac et al., 2008; Clune et al., 2012).

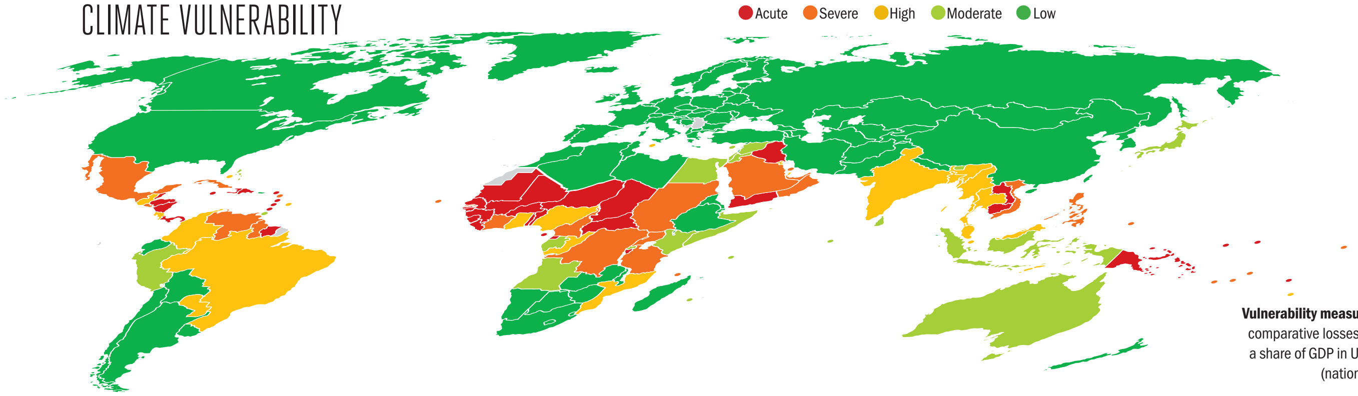
ESTIMATE COUNTRY-LEVEL IMPACT

	$		⚡		☁	
COUNTRY	2010	2030	2010	2030	2010	2030
ACUTE						
Antigua and Barbuda	1	25	15	65	15	55
Belize	1	30	15	55	1	10
Benin	15	150	100	300	85	200
Burkina Faso	45	400	250	600	150	350
Burundi	5	55	60	150	1	1
Cambodia	25	500	200	850	200	850
Central African Republic	5	55	40	100	5	15
Chad	45	350	150	350	150	350
Dominican Republic	65	950	450	1,750	350	1,250
Equatorial Guinea	25	200	150	400	95	250
Grenada	1	15	10	40	10	30
Guinea	15	100	95	250	25	60
Guinea-Bissau	1	20	15	45	15	35
Haiti	35	500	250	950	150	550
Honduras	25	400	200	750	65	250
Iraq	100	1,500	750	3,000	550	2,250
Jamaica	20	300	200	750	100	450
Laos	10	250	100	400	1	1
Liberia	5	50	40	100	25	65
Mali	30	250	200	550	65	150
Marshall Islands		5	1	10		
Mauritania	10	70	60	150	40	100
Micronesia	1	5	5	15		
Myanmar	75	1,250	650	2,750	100	450
Nicaragua	30	500	200	750	100	400
Niger	30	250	200	550	200	550
Panama	30	500	200	750	60	250
Papua New Guinea	20	350	200	900	85	350
Saint Lucia	1	25	15	65	15	50
Saint Vincent	1	15	10	35	5	20
Sao Tome and Principe		1	1	5	1	1
Senegal	30	250	200	550	150	400
Sierra Leone	10	75	65	150	30	80
Solomon Islands	1	25	15	65	15	55
Suriname	5	50	25	100	10	35
Togo	10	85	70	200	10	30
Tuvalu		1	1	1		
Yemen	200	2,250	1,500	4,750	1,000	3,250
SEVERE						
Bahrain	15	200	100	400	60	250
Cameroon	35	300	250	650	45	100
Cape Verde	1	10	5	15	5	10
Comoros	1	5	5	20	5	15
Cote d'Ivoire	35	300	300	750	150	350
Cuba	55	850	550	2,250	450	1,750
Dominica	1	10	5	25	5	15
DR Congo	15	150	400	1,000	1	5
El Salvador	20	300	150	600	50	200
Fiji	1	35	20	90	5	20
Gambia	5	25	20	60	15	40
Guyana	5	50	25	100	20	85
Kiribati		5	5	15	5	10
Mexico	600	10,000	6,250	30,000	3,000	15,000
Oman	45	550	350	1,250	250	800
Palau		1	1	5		
Philippines	200	3,000	1,500	6,500	800	3,250
Samoa	1	10	5	25	1	10
Saudi Arabia	350	4,250	2,500	9,000	2,000	7,250
Sudan/South Sudan	80	750	750	2,000	250	700
Tanzania	40	350	450	1,250	100	300
Uganda	40	300	150	450	25	70
United Arab Emirates	150	2,000	1,250	4,250	800	2,750
Vanuatu	1	10	5	25	5	20
Venezuela	200	3,000	1,500	6,250	400	1,500
Vietnam	150	3,750	1,500	6,000	550	2,500
HIGH						
Bahamas	1	30	20	80	15	60
Bangladesh	45	650	950	3,500	550	2,000
Barbados	1	30	20	80	20	70
Brazil	250	5,000	1,500	7,500	70	400
Brunei	5	50	25	100	20	85
Colombia	-40	1,250	-300	2,500	-55	450
Congo	5	60	50	100	10	25
Costa Rica	10	150	100	400	5	15
Ghana	30	250	350	900	60	150
Guatemala	5	150	30	300	10	100
India	800	10,000	15,000	65,000	15,000	55,000
Kuwait	55	650	400	1,500	450	1,500
Malaysia	65	1,000	550	2,250	350	1,500
Malta	1	10	15	30	10	25
Mozambique	10	90	150	400		
Nigeria	85	700	2,500	6,250	1,000	2,750
Paraguay	5	150	90	500		
Qatar	40	500	300	1,000	150	550
Singapore	60	1,000	300	1,250	200	900
Thailand	200	3,000	2,000	8,500	1,250	4,750
Timor-Leste	1	10	5	20		
Tonga		5	1	10	1	5
MODERATE						
Angola	15	150	95	350	20	75
Australia	150	550	1,750	4,000	1,500	3,750
Bhutan		1	-1	15		
Cyprus	1	15	5	65	5	50
Djibouti	-1	1	-5	1	-5	1
Egypt	-150	200	-1,250	550	-700	300

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

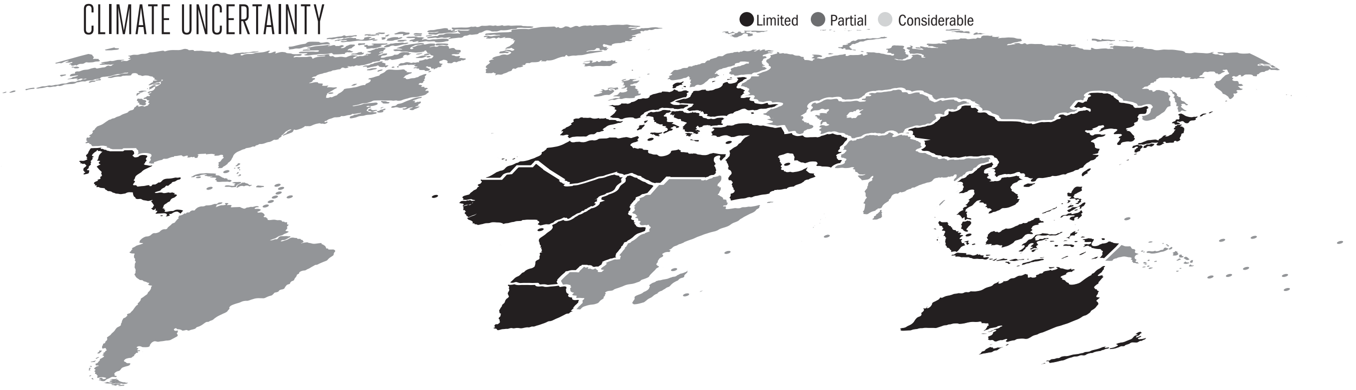
⚡ Additional/reduced energy load due to climate change (GWh) - yearly average

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY



	$		⚡		☁	
COUNTRY	2010	2030	2010	2030	2010	2030
Gabon	5	35	30	70	5	15
Indonesia	150	1,750	2,250	7,000	1,750	5,750
Israel	5	150	55	400	45	300
Japan	250	750	1,250	2,500	550	1,000
Jordan	-5	45	-50	95	-30	55
Kenya	-10	15	-60	35	-25	15
Maldives		5	-1	25	-1	20
Mauritius	1	20	20	45	10	30
Peru	5	450	35	900	10	200
Rwanda	-1	5	-15	10	-5	1
Seychelles		1	5	10	1	5
Somalia	-1	1	-10	5	-5	1
Sri Lanka	5	100	150	600	70	300
Syria	-25	55	-200	100	-100	70
Trinidad and Tobago	1	40	100	400	75	300
LOW						
Afghanistan	-30	-150	-650	-800	-150	-200
Albania	-20	-100	-95	-150	-1	-1
Algeria	-300	-1,750	-3,000	-4,500	-1,750	-2,750
Argentina	-65	-350	-3,000	-3,750	-1,000	-1,500
Armenia	-25	-150	-200	-300	-20	-40
Austria	-500	-1,500	-2,500	-4,750	-450	-850
Azerbaijan	-35	-200	-250	-400	-150	-250
Belarus	-350	-2,250	-1,750	-3,500	-1,500	-2,750
Belgium	-600	-1,750	-3,000	-5,250	-700	-1,250
Bolivia	-100	-800	-900	-1,750	-350	-650
Bosnia and Herzegovina	-85	-500	-450	-800	-350	-600
Botswana	-5	-30	-70	-100	-90	-150
Bulgaria	-250	-1,500	-1,250	-2,250	-800	-1,500
Canada	-550	-1,500	-6,750	-15,000	-1,250	-2,250
Chile	-400	-2,750	-2,000	-3,750	-850	-1,500
China	-2,750	-20,000	-60,000	-80,000	-50,000	-65,000
Croatia	-75	-450	-700	-1,250	-250	-400
Czech Republic	-700	-4,250	-3,500	-6,500	-2,500	-4,750
Denmark	-900	-2,500	-2,250	-4,000	-1,250	-2,500
Ecuador	-30	-10	-350	-20	-95	-5
Eritrea	-20	-100	-150	-300	-100	-200
Estonia	-40	-250	-150	-300	-150	-300
Ethiopia	-35	-200	-900	-1,500	-100	-150
Finland	-550	-1,500	-3,000	-5,500	-1,000	-1,750
France	-2,250	-6,250	-15,000	-25,000	-1,250	-2,000
Georgia	-1	-5	-5	-10	-1	-1
Germany	-8,000	-20,000	-30,000	-55,000	-15,000	-30,000
Greece	-25	-45	-250	-250	-200	-200
Hungary	-350	-2,250	-1,500	-2,750	-750	-1,250
Iceland	-40	-100	-150	-300		
Iran	-100	-350	-2,000	-2,000	-1,250	-1,250
Ireland	-300	-850	-1,250	-2,000	-500	-900
Italy	-2,000	-5,250	-6,500	-10,000	-3,250	-5,750
Kazakhstan	-150	-850	-2,500	-4,750	-2,500	-5,000
Kyrgyzstan	-10	-75	-250	-400	-20	-40
Latvia	-150	-950	-600	-1,000	-100	-200
Lebanon	-10	-15	-85	-30	-65	-20
Lesotho	-1	-10	-20	-35		
Libya	-55	-200	-500	-450	-500	-450
Lithuania	-300	-1,750	-1,250	-2,000	-950	-1,750
Luxembourg	-35	-100	-150	-300	-70	-150
Macedonia	-40	-250	-200	-350	-200	-300
Madagascar	-40	-150	-150	-200	-50	-60
Malawi	-1	-10	-80	-100	-10	-10
Moldova	-65	-450	-350	-650	-250	-500
Mongolia	-40	-450	-350	-750	-500	-1,000
Morocco	-200	-1,000	-1,750	-2,500	-1,250	-1,750
Namibia	-15	-70	-100	-200	-25	-40
Nepal	-15	-80	-250	-450	-1	-1
Netherlands	-1,250	-3,500	-5,250	-9,500	-2,500	-4,500
New Zealand	-65	-200	-400	-750	-65	-150
North Korea	-150	-1,250	-1,250	-2,250	-650	-1,250
Norway	-350	-1,000	-2,250	-4,250	-35	-65
Pakistan	-65	-75	-1,500	-400	-700	-200
Poland	-1,250	-8,250	-6,750	-10,000	-7,000	-15,000
Portugal	-150	-400	-700	-1,250	-300	-550
Romania	-200	-1,250	-1,750	-3,250	-1,000	-2,000
Russia	-2,250	-15,000	-20,000	-45,000	-15,000	-25,000
Slovakia	-300	-1,750	-1,250	-2,500	-400	-750
Slovenia	-100	-650	-550	-1,000	-200	-400
South Africa	-200	-1,000	-3,250	-5,500	-3,000	-5,250
South Korea	-150	-1,250	-1,750	-3,500	-950	-2,000
Spain	-500	-1,250	-2,500	-4,000	-800	-1,250
Swaziland	-1	-15	-30	-50	-1	-1
Sweden	-1,250	-3,250	-5,000	-9,000	-150	-300
Switzerland	-400	-1,250	-2,750	-5,000	-20	-30
Tajikistan	-5	-15	-95	-90	-1	-1
Tunisia	-100	-550	-1,000	-1,500	-600	-850
Turkey	-550	-1,250	-3,250	-5,250	-1,750	-2,750
Turkmenistan	-5	-25	-100	-150	-100	-100
Ukraine	-1,250	-8,000	-6,250	-15,000	-3,000	-5,750
United Kingdom	-4,250	-10,000	-20,000	-35,000	-9,000	-15,000
United States	-650	-1,000	-5,750	-5,750	-3,500	-3,500
Uruguay	-40	-200	-250	-300	-60	-85
Uzbekistan	-40	-150	-750	-850	-500	-550
Zambia	-1	-5	-55	-45		
Zimbabwe	-30	-150	-250	-400	-150	-250

☁ Additional CO$_2$ generated/reduced for heating and cooling due to climate change (Kt CO$_2$) - yearly average

LABOUR PRODUCTIVITY

ESTIMATES GLOBAL CLIMATE IMPACT

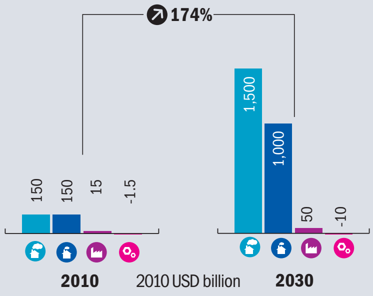
2010 EFFECT TODAY

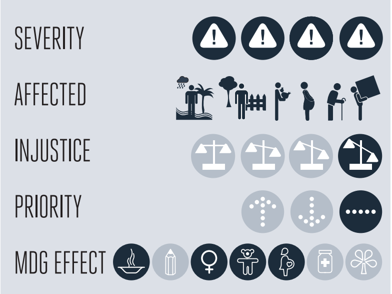
$ USD **LOSS** PER YEAR **300** BILLION

2030 EFFECT TOMORROW

$ USD **LOSS** PER YEAR **2.5** TRILLION

ECONOMIC IMPACT





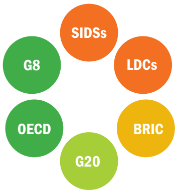
- People work less productively in hot conditions
- As the workplace warms, occupational heat exposure standards defined by the International Organization for Standardization (ISO) and other bodies are being breached
- Heat stress affects employees working outdoors or in non-cooled environments, except for the coldest and highest-altitude areas
- Effects are most serious for subsistence farmers in developing countries who cannot avoid daytime outdoor work
- Adapting to these changes can be cost-effective, such as through sun protection measures, but the full extent of adaptation is not well studied and could be extremely limited, especially for outdoor workers
- For indoor situations, air conditioning or insulation would need to be increased, but equally incur a cost

RELATIVE IMPACT

HOTSPOTS

2010	$	2030
55	**INDIA**	450
40	**CHINA**	450
35	**MEXICO**	250
30	**INDONESIA**	250
15	**THAILAND**	150

GEOPOLITICAL VULNERABILITY



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

$ = Losses per 10,000 USD of GDP

↗ Change in relation to overall global population and/or GDP

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

Labour productivity is one of the principal factors in contemporary economics, and a generalized loss of productivity results in economic loss (Samuelson and Nordhaus, 1948; Solow, 1956). Workers are less efficient and less productive when subjected to excess heat both outdoors and in inadequately climate-controlled working conditions (Ramsey, 1995; Pilcher et al., 2002; Niemelä et al., 2002; Hancock et al., 2007; Su et al., 2009). International ergonomic standards define highly specific thermal conditions for differing degrees of occupational exertion and stipulate clear threshold limits (ISO, 1989). Similar national standards are effective since the mid-1980s (NIOSH, 1986). Precise directives for personnel heat stress management are also imbedded in military operational guidelines, since it may affect combat outcomes (USDAAF, 2003). Science is more certain about the warming of the planet than any other aspect of climate change (IPCC, 2007). As the increase in hot days and hot nights continues, worker heat stress has the potential to become a significant drain on the world economy (Hansen et al., 2012; Kjellstrom et al., 2009a). Adapting to labour productivity impacts is costly, but not doing so will result in further costs through deteriorating health, cooling costs, or slower gains in competitiveness (Hanna et al., 2011a; CDC, 2008; Kjellstrom ed., 2009). Thus, incentives to adapt are high, but may be out of reach for three-quarters of the world's developing poor, who live in rural areas with few options (Kjellstrom et al., 2009b; Ravallion et al., 2007).

CLIMATE MECHANISM

As the planet warms, thresholds regulated in international and national occupational standards are increasingly surpassed. Unless measures are taken, more hours of work will be needed to accomplish the same tasks, or more workers to achieve the same output (Kjellstrom et al., 2009a-b). Thermally optimal working conditions increase productivity (Fisk, 2000). Incremental increases in temperature are well understood, with business-as-usual economic development set to raise the average temperature by 3°C (5°F) above today's levels in 50–60 years (Betts et al., 2009). An additional 4°C (7°F) above that level—not ruled out for this century—would make outdoor activities of any kind impossible in large tropical areas of human habitation (Sokolov et al., 2009; Sherwood and Huber, 2010).

IMPACTS

The global impact of climate change on labour productivity is already estimated to cost the world economy 300 billion dollars a year—around 0.5% of global GDP. It is overwhelmingly the single most significant negative impact included in this assessment.

Hot and humid tropical and sub-tropical countries of Africa, Asia, Latin America, and the Pacific are already severely affected. The greatest total losses affect the world's major emerging economies: China, India, Indonesia, and Mexico, whose development due to labour productivity set-backs alone could be impeded by more than 200 billion dollars a year by 2030, when China and India's annual losses could approach half a trillion dollars each.

Approximately 0.6°C (1°F) of heat absorbed by the world's oceans will be released back into the atmosphere in the coming decades, effectively committing the world to a labour productivity loss estimated to reach 2.5 trillion dollars a year by 2030, stunting global GDP by over 1% (Hansen et al., 2005). Parts of West and Central Africa may even have 6% lower levels of GDP by 2030.

Comparatively few people in colder zones of the planet, such as Australia and the United States, are expected to reap a modest gain in productivity: 3 billion dollars in 2010 and 18 billion dollars in 2030. The skewed workforce structure of developed economies, heavily reliant on low-exertion indoor work reduces vulnerability. However, numerous studies also indicate concern for exposed workers in developed countries (Graff Zivan and Neidell, 2011; Hanna et al., 2011a; Hübler et al., 2007).

THE BROADER CONTEXT

Labour productivity drives profitability and higher living standards (Ingene et al., 2010). Labour productivity is surging almost everywhere, even in the world's wealthiest and slowest growing economies (Jorgenson and Vu, 2011; OECD, 2012). Comparisons of labour productivity growth between the US (faster) and Europe (slower) have shown the importance of information technology (IT) as a positive driver (Ark

BIGGER PICTURE

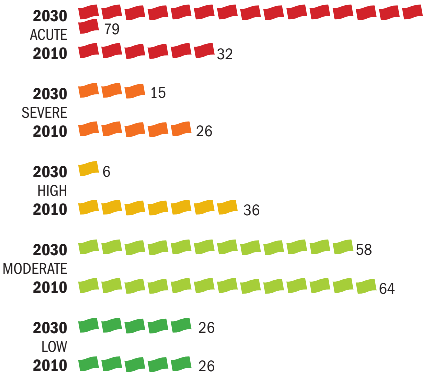
N/A

SURGE

OCCURRENCE

N/A

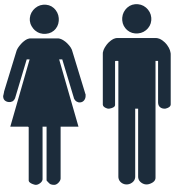
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: Euskirchen, 2006; Kjellstrom et al., 2009

EMISSION SCENARIO: SRES A2 (IPCC, 2000)

BASE DATA: Kjellstrom et al., 2009

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

et al., 2008; Holman et al., 2008). Above all, climate change is limiting the productivity potential otherwise achievable by developing countries, as they make structural shifts in workforce employment towards higher productivity economic sectors (Kjellstrom et al., 2009a; McMillan and Rodrik, 2012).

VULNERABILITIES AND WIDER OUTCOMES

Geographical and structural vulnerabilities are determined by levels of income or human development. Geography is important since only the coldest zones experience gains, while the hottest ones approach the limits of physiological habitability (Sherwood and Huber, 2010). Structurally, economies with mostly outdoor workers are particularly vulnerable, as are economies with slower industrialization rates and few climate controlled workspaces—middle and low-income countries (Kjellstrom et al., 2009d). Some evidence indicates that women are less resistant to heat stress, while men are more exposed, due to the proportion of men in heavy, outdoor work (Luecke, 2006; ILO, 2011). Subsistence farmers typically inhabit geographically vulnerable regions and would need to commit to higher levels of activity in order to deliver equal output; however, since they need to see the land, displacing their working shifts into the cooler night hours is impossible (Kjellstrom ed., 2009). This raises food security concerns. Nutrition can compound matters by contributing to, or detracting from, labour productivity (Maturu, 1979).

RESPONSES

Six key strategy and measurement areas for adapting to growing thermal stress on the workforce follow:

1. Education and awareness campaigns directed at behavioural change of employees and workers to drink water (hydrate) and minimize sun exposure; e.g., municipal initiatives to increase tree cover and shade, or movable screens (McKinnon and Utley, 2005);
2. Strengthened labour institutions, guidelines, protection, regulations, and labour market policies for workers (Crowe et al. 2010; ILO, 2011);
3. Climate control to increase use of air conditioning or building insulation systems, assisting some indoor workers; not all indoor workplaces can be adequately cooled;
4. Gaining productivity by expanding use of IT, improving capital equipment, or modernizing agricultural technology (Storm and Naastepad, 2009; Wacker et al., 2006; Restuccia et al., 2004);
5. Fiscal and regulatory intervention to stimulate a faster structural transition of the economy away from outdoor labour; e.g., coordinating industrial systems or transitioning from natural resource-intensive growth plans that detract from macroeconomic productivity gains (Storm and Naastepad, 2009; McMillan and Rodrik, 2012);
6. Promotion of individual health to improve body thermal responses (Chan et al., 2012).

THE INDICATOR

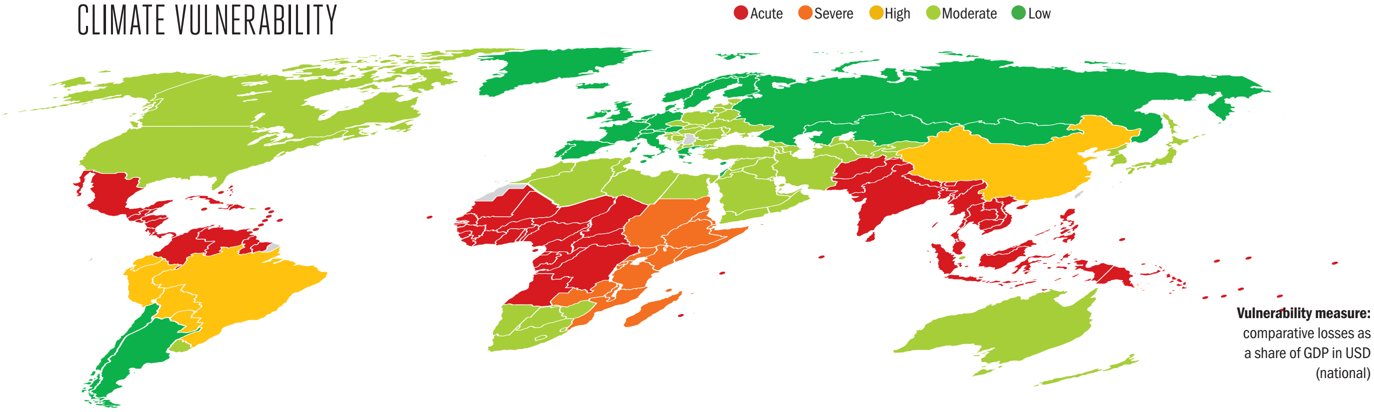
Certainty about increasing temperature, the main climate variable at play, contributes to the robustness of the indicator, although humidity levels are another important determiner of thermal stress and are less certain (Wang et al., 2010). The indicator relies on a global/sub-regional scale model for estimating the loss of labour productivity, based on international labour standards and estimates of wet bulb globe temperature (WBGT) change for populations assumed to be acclimatized (Kjellstrom et al., 2009a). It takes into account both the productivity of outdoor and indoor workers, although the heaviest forms of labour are not considered. The changing structure of the workforce over time, in particular, the industrial shift of developing countries away from outdoor agriculture is also factored in. Productivity gains to countries in high latitudes that will experience a reduction in extreme cold were also accounted for, over and above the base model (Euskirchen et al., 2006).

ESTIMATES COUNTRY-LEVEL IMPACT

	$		🚹	
COUNTRY	2010	2030	2010	2030
ACUTE				
Afghanistan	350	3,000	29%	23%
Angola	2,500	15,000	52%	43%
Antigua and Barbuda	25	200	49%	38%
Bahamas	150	1,250	44%	35%
Bangladesh	3,500	30,000	44%	34%
Barbados	90	700	45%	35%
Belize	40	300	41%	32%
Benin	400	2,750	59%	48%
Bhutan	55	400	44%	34%
Burkina Faso	600	4,000	67%	54%
Cambodia	900	9,250	52%	40%
Cameroon	1,250	8,750	55%	45%
Cape Verde	60	400	50%	41%
Central African Republic	75	500	59%	48%
Chad	550	3,750	55%	45%
Colombia	9,750	75,000	40%	31%
Congo	350	2,500	53%	43%
Costa Rica	1,250	9,000	40%	31%
Cote d,Ivoire	1,000	7,250	53%	43%
Cuba	1,750	15,000	38%	30%
Dominica	15	100	49%	38%
Dominican Republic	1,250	9,500	38%	30%
DR Congo	500	3,250	54%	44%
El Salvador	950	7,500	38%	30%
Equatorial Guinea	500	3,250	65%	53%
Fiji	75	600	27%	18%
Gabon	500	3,250	41%	33%
Gambia	100	700	59%	48%
Ghana	2,000	15,000	55%	45%
Grenada	20	150	49%	38%
Guatemala	1,500	10,000	44%	34%
Guinea	350	2,000	57%	47%
Guinea-Bissau	55	350	55%	45%
Guyana	80	600	37%	29%
Haiti	150	1,250	41%	32%
Honduras	750	5,750	40%	31%
India	55,000	450,000	35%	27%
Indonesia	30,000	250,000	40%	31%
Jamaica	350	2,500	39%	30%
Kiribati	10	90	33%	23%
Laos	450	4,750	49%	38%
Liberia	50	350	48%	39%
Malaysia	10,000	95,000	37%	29%
Maldives	75	550	37%	28%
Mali	500	3,250	40%	32%
Marshall Islands	5	45	33%	23%
Mauritania	200	1,250	30%	24%
Mauritius	550	3,500	35%	27%
Mexico	35,000	250,000	39%	30%
Micronesia	10	90	33%	23%
Myanmar	2,250	15,000	48%	37%
Nepal	500	3,750	53%	41%
Nicaragua	400	3,000	40%	31%
Niger	350	2,250	50%	41%
Nigeria	10,000	75,000	42%	34%
Pakistan	6,500	50,000	33%	25%
Palau	5	25	33%	23%
Panama	1,000	7,750	41%	32%
Papua New Guinea	300	2,250	33%	23%
Philippines	10,000	85,000	38%	29%
Saint Lucia	30	250	49%	38%
Saint Vincent	20	150	49%	38%
Samoa	20	150	33%	23%
Sao Tome and Principe	10	60	58%	47%
Senegal	700	4,750	57%	46%
Seychelles	60	400	45%	35%
Sierra Leone	150	900	54%	44%
Solomon Islands	30	250	30%	21%
Sri Lanka	3,000	25,000	33%	26%
Suriname	70	500	33%	25%
Thailand	15,000	150,000	45%	35%
Timor-Leste	90	750	35%	27%
Togo	200	1,250	61%	50%
Tonga	15	100	33%	23%
Trinidad and Tobago	400	3,000	43%	34%
Tuvalu	1	5	33%	23%
Vanuatu	20	150	33%	23%
Venezuela	8,000	60,000	41%	32%
Vietnam	8,000	85,000	48%	37%
SEVERE				
Burundi	35	250	61%	50%
Comoros	10	55	43%	35%
Djibouti	20	150	56%	46%
Eritrea	40	250	62%	51%
Ethiopia	950	6,000	64%	52%
Kenya	700	4,750	48%	39%
Madagascar	200	1,250	67%	55%
Malawi	150	900	61%	50%
Mozambique	250	1,500	63%	51%
Rwanda	150	850	68%	55%
Somalia	65	400	42%	34%
Sudan/South Sudan	1,000	7,500	39%	32%
Tanzania	650	4,000	63%	51%
Uganda	450	3,000	60%	48%
Zambia	200	1,500	54%	43%

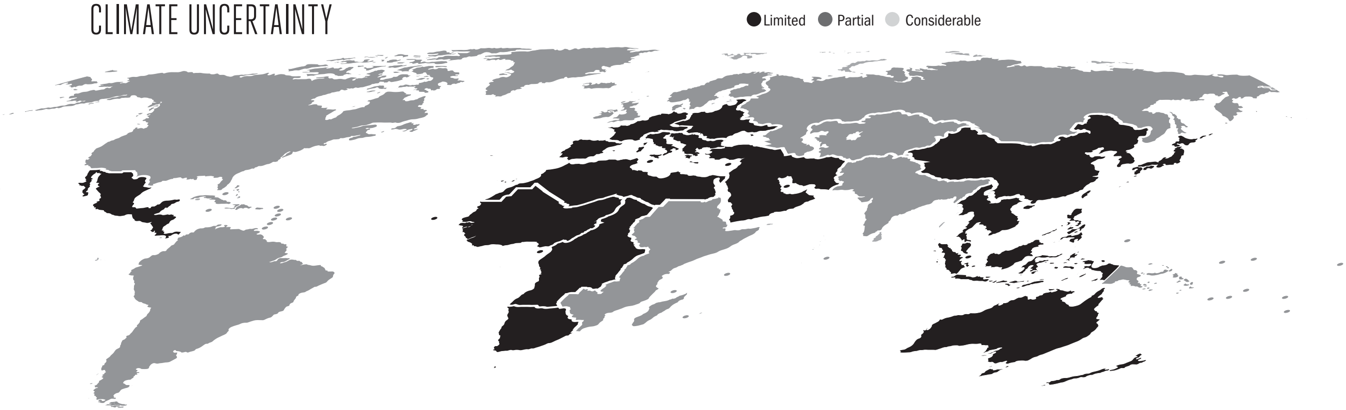
$ Additional economic costs due to climate change (million USD PPP) - yearly average

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY



	$		🧍	
COUNTRY	2010	2030	2010	2030
HIGH				
Bolivia	200	1,750	46%	36%
Brazil	6,000	45,000	43%	34%
China	40,000	450,000	36%	25%
Ecuador	500	4,000	43%	33%
Paraguay	90	700	46%	36%
Peru	1,250	9,500	48%	37%
MODERATE				
Albania	1	5	5%	5%
Algeria	100	750	18%	12%
Armenia	5	40	25%	19%
Australia	45	100	6%	6%
Azerbaijan	35	200	36%	27%
Bahrain	10	60	31%	21%
Belarus	15	95	5%	5%
Bosnia and Herzegovina	1	5	4%	4%
Botswana	60	400	53%	43%
Brunei	1	15	6%	6%
Bulgaria	1	15	5%	5%
Canada	300	950	7%	7%
Croatia	1	15	5%	5%
Czech Republic	5	40	5%	5%
Egypt	200	1,000	21%	14%
Estonia	5	20	5%	5%
Georgia	10	60	32%	24%
Hungary	5	30	5%	5%
Iran	400	2,750	19%	13%
Iraq	30	250	16%	11%
Japan	400	1,000	6%	6%
Jordan	10	70	17%	12%
Kuwait	55	350	31%	21%
Kyrgyzstan	5	25	36%	27%
Latvia	5	25	5%	5%
Lebanon	25	150	20%	13%
Lesotho	5	50	39%	32%
Libya	40	250	23%	16%
Lithuania	5	45	5%	5%
Macedonia	1	5	4%	4%
Moldova	1	10	4%	4%
Morocco	65	450	21%	14%
Namibia	30	200	33%	27%
New Zealand	5	15	6%	6%
North Korea	90	900	37%	26%
Oman	25	150	26%	18%
Poland	15	100	5%	5%
Qatar	65	450	40%	27%
Romania	5	40	5%	5%
Saudi Arabia	200	1,250	22%	15%
Singapore	25	200	6%	6%
Slovakia	1	20	5%	5%
Slovenia	1	10	5%	5%
South Africa	1,250	7,250	32%	27%
South Korea	150	1,000	6%	6%
Swaziland	15	85	36%	30%
Syria	35	200	18%	12%
Tajikistan	5	25	35%	26%
Tunisia	40	250	19%	13%
Turkey	400	1,250	20%	14%
Turkmenistan	15	90	32%	24%
Ukraine	30	200	5%	5%
United Arab Emirates	95	600	36%	24%
United States	15,000	50,000	6%	6%
Uruguay	10	75	41%	32%
Uzbekistan	25	150	32%	24%
Yemen	20	150	20%	13%
Zimbabwe	25	150	69%	56%
LOW				
Argentina				

🧍 Share of workforce particularly affected by climate change (%) - yearly average

PERMAFROST

ESTIMATES GLOBAL CLIMATE IMPACT

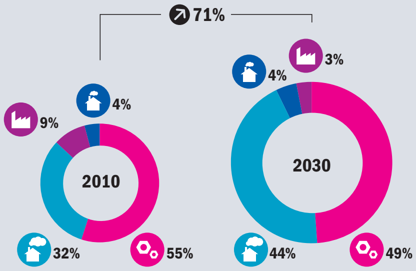
2010 EFFECT TODAY

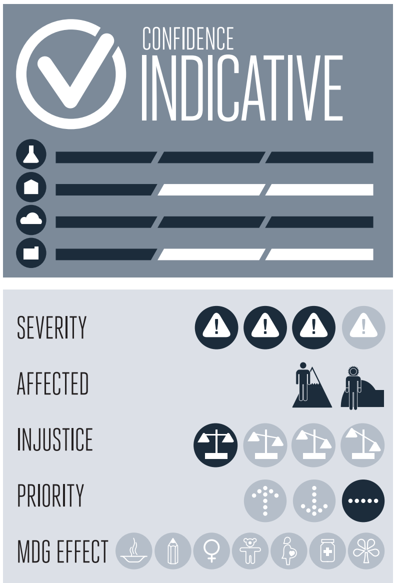
$ USD **LOSS** PER YEAR **30 BILLION**

2030 EFFECT TOMORROW

$ USD **LOSS** PER YEAR **150 BILLION**

$ ECONOMIC IMPACT





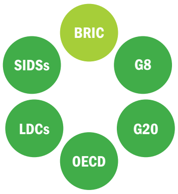
- One-quarter of the northern hemisphere's land is permanently frozen or frozen for extended periods
- The planet's warming has been most rapid in the far north, where rising heat simply melts permanently frozen land
- Infrastructure of every kind, from buildings, roads, and railways, to pipelines, airports, and power lines come under stress or are damaged when the rate of melting is accelerated
- The entire infrastructure of the far north and the world's coldest zones is affected
- Overall, the effect is estimated to accelerate by around 10–20% the rate of wear and tear on all exposed infrastructure in the near term

RELATIVE IMPACT

HOTSPOTS

2010	$	2030
15,000	**RUSSIA**	75,000
9,250	**CHINA**	65,000
600	**MONGOLIA**	4,000
1,750	**CANADA**	3,500
400	**PAKISTAN**	2,000

GEOPOLITICAL VULNERABILITY



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

$ = Losses per 10,000 USD of GDP

↗ Change in relation to overall global population and/or GDP

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

Permafrost thawing is one impact of climate change that does not spare some of the world's most advanced and industrialized countries. In some places rising heat is causing dry lands to degrade into desert. In the coldest parts of the world, the heat is instead causing land to melt and sink, damaging infrastructure as it subsides (Larsen and Goldsmith, 2007). Every conceivable type of infrastructure is at risk as permafrost melts, including buildings, roads, railways, and oil pipelines (Xu et al., 2010; Lin, 2011M; Feng and Liu, 2012). Preserving this infrastructure as growing heat adds to the stress is a major challenge for engineers and a serious cost for local communities (McGuire, 2009). In Alaska, for instance, two-thirds of the state roads budget is spent on permafrost repair alone (Stidger, 2001). In worst case scenarios, it is estimated that extreme permafrost thaw could force the relocation of entire communities (Romanovsky et al., 2010). Permafrost thawing through accelerated infrastructure replacement and repair will impose significant cost burdens on the world's coldest communities.

CLIMATE MECHANISM

As temperatures rise, regions nearer the poles are heating up the fastest (IPCC, 2007). Much of the land within the Arctic Circle is frozen on a permanent basis, or for more than 1–2 years. The permafrost region currently covers about one-quarter of earth's land area (Nelson et al., 2002); however, it is home to only a fraction of the world's population (Hoekstra et al., 2010). One-quarter of the land area of the northern hemisphere has a subterranean layer of ice built up under the soil which can melt when temperatures rise (Anisimov, 2009). The warming planet thaws otherwise permanently frozen land, destabilizes it, alters its ecosystem, and compromises the structural integrity of any buildings or infrastructure that have been constructed in these zones (Romanovsky et al., 2010). In this way, climate change is already accelerating the process by which key infrastructure in these areas requires repair or replacement (Larsen and Goldsmith, 2007).

IMPACTS

The impact of climate change on infrastructure in affected permafrost zones is estimated globally at 30 billion dollars a year in 2010. With the expected increase in temperatures through to 2030, losses associated with permafrost thawing are estimated to grow as a share of global GDP, amounting to approximately 150 billion dollars a year.

Countries worst affected include the US (because of Alaska), Canada, China (because of Tibet), Mongolia, Russia, and a number of Central Asian states (because of the Himalayas). As climate change intensifies, the same group of countries continues to be affected.

The largest total losses are incurred in Russia, China, Mongolia, and Canada. Losses for Russia and China are currently estimated at around 20 and 10 billion dollars respectively, and should grow to over 60 billion dollars each year by 2030.

Mongolia, Kyrgyzstan, and Bhutan are estimated to suffer the most severe effects as a share of GDP, with Mongolia and Kyrgystan's losses at over 4% of GDP by 2030, and Bhutan's in excess of 1% of GDP.

Some 10 million people are estimated to be affected by the impact of climate change on permafrost globally, a number that will more than double to nearly 25 million by 2030.

THE BROADER CONTEXT

Dealing with some degree of oscillation in permanently frozen land in the coldest zones of the planet is normal (Wei et al., 2009). It is the acceleration in these processes that incurs additional costs as temperatures rise. While the northernmost or coldest regions of the planet are sparsely inhabited, oil and gas exploitation has grown in permafrost regions in and around the Arctic Circle. Planned or constructed high value infrastructure in these regions will face growing risks (Pavlenko and Glukhareva, 2010). The same is true for the multi-billion dollar China–Tibet railway, built over partially unstable land across the Tibetan ranges and plateaux (Yang and Zhu, 2011).

VULNERABILITIES AND WIDER OUTCOMES

Communities and governments maintaining expensive public infrastructure in lower-middle income countries, such as Kyrgyzstan in Central Asia, will face a major development challenge in tackling accelerated infrastructure erosion. There is a lack of clarity on the extent to which insurance

BIGGER PICTURE

N/A

SURGE

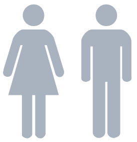
OCCURRENCE

N/A

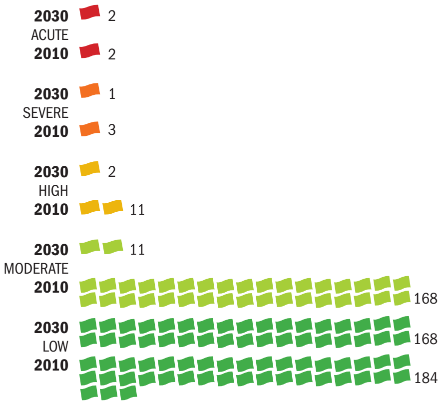
PEAK IMPACT

N/A

GENDER BIAS



VULNERABILITY SHIFT



INDICATOR INFORMATION

MODEL: Hoekstra et al., 2010; Nelson et al., 2001

EMISSION SCENARIO: UKTR GCM-based scenario (Nelson et al., 2001)

BASE DATA: Larsen and Goldsmith, 2007; UN CHS, 2010; US CB website, 2000

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

policies are valid for permafrost erosion damage (Mills, 2005; Williams, 2011). Insurance coverage is growing, as incomes of developing countries expand, suggesting that for many of the worst affected areas, including Tibet, Mongolia, and Kyrgyzstan, a lack of insurance will heighten the impact of these changes (Kharas, 2010). Permanently frozen land also stores around half of the potential soil-derived emissions of greenhouse gases (GHGs), mostly in the form of methane, a highly potent GHG. As such, there is mounting concern that, as they thaw, the permafrost regions could become a major unmanageable driver of global climate change (Tarnocai et al., 2009).

RESPONSES

Adaptation to the thawing of permafrost is a challenge. Future planning might make non-essential infrastructure projects in transition zones less of a priority. For all existing infrastructure, there is a predictable accelerated depreciation and replacement cost that must be faced (Larsen and Goldsmith, 2007). Unlike sea-level rise, changes are likely to come faster, and no wall can prevent the retreat of frozen land which, as it thaws, will decimate any built infrastructure in affected areas. However, for certain types of infrastructure, such as pipelines or railways, measures can be taken to mitigate the extent of destabilising effects, especially when designing new infrastructure (Xu et al., 2010; Wei et al., 2009).

Public resources may be considered, for instance, to subsidise or back insurance schemes which allow risk to be managed in a more long-term framework, buffering communities from abrupt losses and enhancing the resilience of highly exposed groups (Verheyen, 2005). In worst cases, community relocation may be necessary (Romanovsky, 2010).

THE INDICATOR

The indicator is understood to be moderately robust. This is because clarity on the climate signal in one of the fastest warming regions of the world is pronounced, and the IPCC's stance on the possibility of extensive damage stemming from permafrost erosion is firm (IPCC, 2007). However, permafrost damage is for now a niche research area at best, and the indicator's robustness is compromised by being based on only one study and model from Alaska (Larsen and Goldsmith, 2007). Further uncertainties relate to the extrapolation of the damage estimations through income (GDP) metrics and population-weighted adjustments in order to simulate the damage effects in the other countries. Assumptions were also made by proxy for non-public infrastructure based on capital values of private infrastructure at risk, which could be an area for further improvement. Given the potential scale of the damage, the topic remains a clear research priority for additional enquiry in all respects.

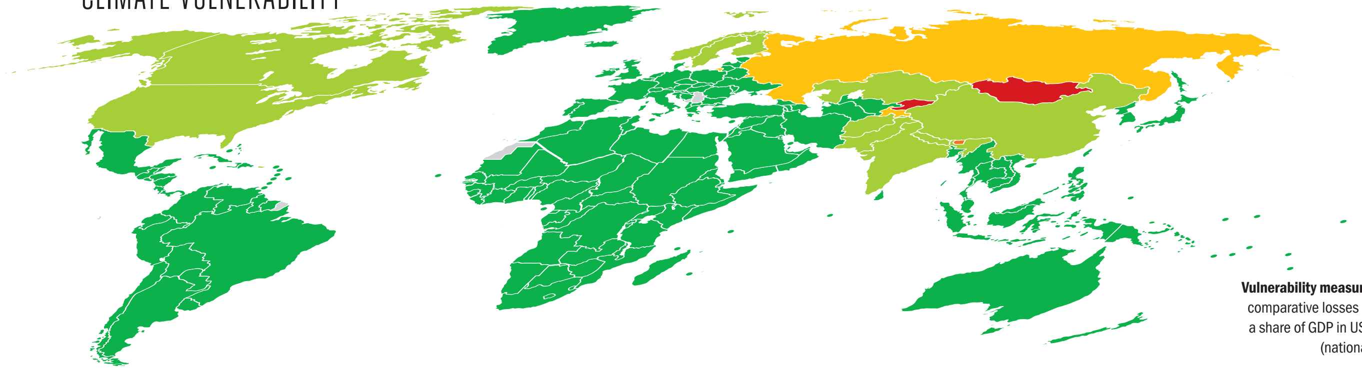
ESTIMATES COUNTRY-LEVEL IMPACT

	$		👤	
COUNTRY	2010	2030	2010	2030
ACUTE				
Kyrgyzstan	**400**	**1,750**	**450,000**	**850,000**
Mongolia	**600**	**4,000**	**550,000**	**1,000,000**
SEVERE				
Bhutan	45	250	20,000	40,000
HIGH				
Russia	15,000	75,000	4,500,000	9,500,000
Tajikistan	100	500	150,000	250,000
MODERATE				
Afghanistan	20	100	90,000	200,000
Canada	1,750	3,500	350,000	700,000
China	9,250	65,000	4,500,000	9,500,000
Finland	15	30	3,750	7,750
India	100	550	85,000	150,000
Kazakhstan	200	800	75,000	150,000
Nepal	65	300	150,000	300,000
Norway	100	200	20,000	40,000
Pakistan	400	2,000	350,000	750,000
Sweden	85	150	20,000	40,000
United States	650	1,250	90,000	200,000
LOW				
Albania				
Algeria				
Angola				
Antigua and Barbuda				
Argentina				
Armenia				
Australia				
Austria				
Azerbaijan				
Bahamas				
Bahrain				
Bangladesh				
Barbados				
Belarus				
Belgium				
Belize				
Benin				
Bolivia				
Bosnia and Herzegovina				
Botswana				
Brazil				
Brunei				
Bulgaria				
Burkina Faso				
Burundi				
Cambodia				
Cameroon				
Cape Verde				
Central African Republic				
Chad				
Chile				
Colombia				
Comoros				
Congo				
Costa Rica				
Cote d'Ivoire				
Croatia				
Cuba				
Cyprus				
Czech Republic				
Denmark				
Djibouti				
Dominica				
Dominican Republic				
DR Congo				
Ecuador				
Egypt				
El Salvador				
Equatorial Guinea				
Eritrea				
Estonia				
Ethiopia				
Fiji				
France				
Gabon				
Gambia				
Georgia				
Germany				
Ghana				
Greece				
Grenada				
Guatemala				
Guinea				
Guinea-Bissau				
Guyana				
Haiti				
Honduras				
Hungary				
Iceland				
Indonesia				
Iran				
Iraq				
Ireland				
Israel				
Italy				

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

CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



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

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable

	$		👤	
COUNTRY	2010	2030	2010	2030
Jamaica				
Japan				
Jordan				
Kenya				
Kiribati				
Kuwait				
Laos				
Latvia				
Lebanon				
Lesotho				
Liberia				
Libya				
Lithuania				
Luxembourg				
Macedonia				
Madagascar				
Malawi				
Malaysia				
Maldives				
Mali				
Malta				
Marshall Islands				
Mauritania				
Mauritius				
Mexico				
Micronesia				
Moldova				
Morocco				
Mozambique				
Myanmar				
Namibia				
Netherlands				
New Zealand				
Nicaragua				
Niger				
Nigeria				
North Korea				
Oman				
Palau				
Panama				
Papua New Guinea				
Paraguay				
Peru				
Philippines				
Poland				
Portugal				
Qatar				
Romania				
Rwanda				
Saint Lucia				
Saint Vincent				
Samoa				
Sao Tome and Principe				
Saudi Arabia				
Senegal				
Seychelles				
Sierra Leone				
Singapore				
Slovakia				
Slovenia				
Solomon Islands				
Somalia				
South Africa				
South Korea				
Spain				
Sri Lanka				
Sudan/South Sudan				
Suriname				
Swaziland				
Switzerland				
Syria				
Tanzania				
Thailand				
Timor-Leste				
Togo				
Tonga				
Trinidad and Tobago				
Tunisia				
Turkey				
Turkmenistan				
Tuvalu				
Uganda				
Ukraine				
United Arab Emirates				
United Kingdom				
Uruguay				
Uzbekistan				
Vanuatu				
Venezuela				
Vietnam				
Yemen				
Zambia				
Zimbabwe				

👤 Additional persons affected due to climate change - yearly average

SEA-LEVEL RISE

ESTIMATES GLOBAL CLIMATE IMPACT

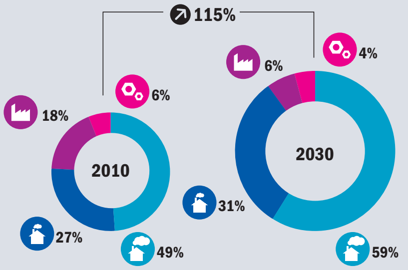
2010 EFFECT TODAY

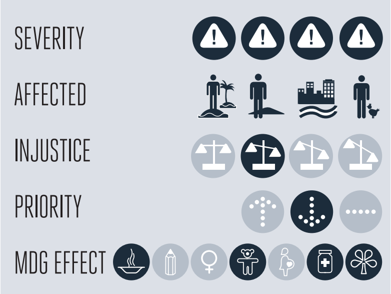
$ USD **LOSS** PER YEAR **85 BILLION**

2030 EFFECT TOMORROW

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

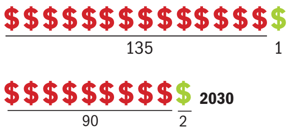
ECONOMIC IMPACT





- ➡ 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

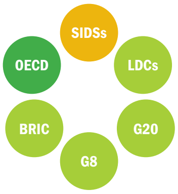
RELATIVE IMPACT



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



$ 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

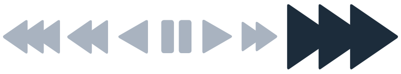
Coastal erosion and geological subsidence, or the sinking of land due to earth plate tectonics and associated factors, are completely natural phenomena which are part of the basic geological processes sustaining the planet. When land surfaces are lowered near the sea, the result is indistinguishable 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

N/A

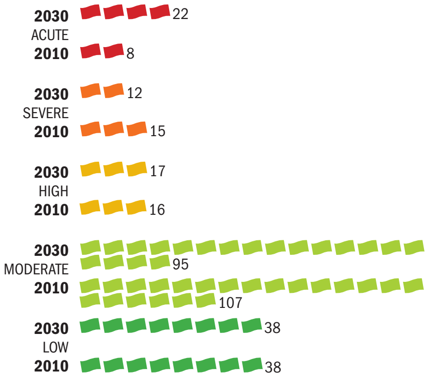
SURGE



OCCURRENCE

N/A

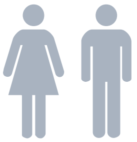
VULNERABILITY SHIFT



PEAK IMPACT

N/A

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 related 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.

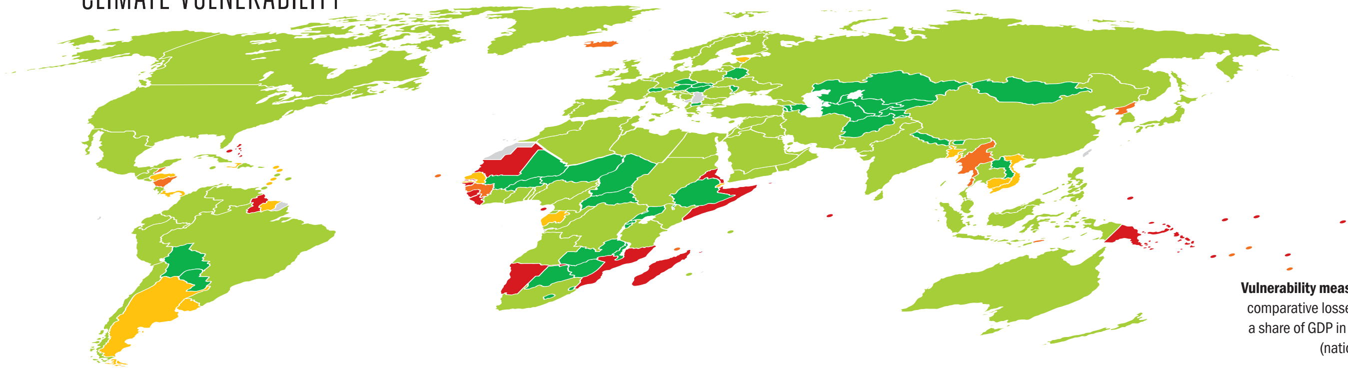
ESTIMATES COUNTRY-LEVEL IMPACT

	$		🧍		⊕	
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						
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 (km^3) - yearly average

WATER

ESTIMATES GLOBAL CLIMATE IMPACT

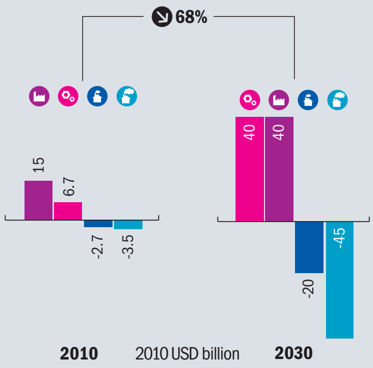
2010 EFFECT TODAY

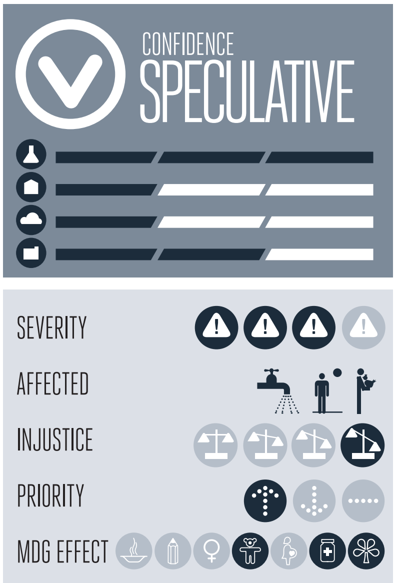
USD **LOSS** PER YEAR **15 BILLION**

2030 EFFECT TOMORROW

USD **LOSS** PER YEAR **15 BILLION**

ECONOMIC IMPACT





- Climate change brings extra rain as warmer oceans evaporate more moisture
- Water resources will not increase everywhere: in places more rain may not keep pace with strong heat
- Longer, hotter summers deplete water resources but melting glaciers can cause short-term surges
- Where less or more water is made available to countries already facing chronic water scarcity, losses or gains match heightened marginal water supply costs
- Adapting to impacts of climate change on water is feasible in most cases, but in highly arid regions, solutions may prove too costly

RELATIVE IMPACT

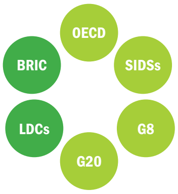
$$$$$$ **2010**
49 3

$$$$$$$$$ **2030**
72 3

HOTSPOTS

2010	$	**2030**
4,000	**MEXICO**	30,000
9,000	**FRANCE**	25,000
5,000	**GERMANY**	15,000
4,750	**SPAIN**	15,000
1,250	**CZECH REPUBLIC**	9,000

GEOPOLITICAL VULNERABILITY



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

$ = Losses per 10,000 USD of GDP

Change in relation to overall global population and/or GDP

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

Water is an important input to the full range of economic activities and is therefore a crucial natural resource with market value (Morrison et al., 2009). Rainfall is highly uncertain (Blöschl and Montanari, 2010). Two global climate change projections could show mirror opposites for a region like Brazil: one dry and the other wet (Murray et al., 2012). A full ensemble of IPCC models was used to predict water supply change presented here (Nohara et al., 2006). But selecting only some models as opposed to others would likely have produced a different set of results. For some regions it is more certain whether they will be dry (such as Southern and Eastern Europe and North Africa) or wet (North America, East Asia). Others are completely unsure about what the future holds (Australasia, South America). In this assessment, roughly half of all countries are expected to either gain or have a no impact. The other half will suffer losses.

Water is supplied according to specific local conditions at the market price (McKinsey & Company, 2009). However, the price of water varies widely around the world, from more than 8 dollars per m3 in Denmark to less than 8 cents/m3 in parts of India (GWI, 2008). Generally speaking, water costs a larger share of income in most developed than in developing countries. As a result, climate change is contributing to a worsening of water availability in the Mediterranean basin, and generating a large share of estimated global losses.

CLIMATE MECHANISM

Climate change increases rainfall globally, since the planet's water cycle accelerates as it warms (Huntington, 2006). As temperature increases, so does the overall moisture content of the air and rain falls back to ground levels (Allen and Ingram, 2002). More moisture in the air from the world's oceans is the main contributor to the water cycle's acceleration (Syed et al., 2010). However, much of the additional rain falls in the far north or south (Nohara et al., 2006).

Recent evidence shows that rainfall has already declined in the tropics and increased significantly in the far north and south (Helm et al., 2010). Even where more rainfall occurs, if evaporation rates are high due to greatly increased temperature, a loss of water availability can result (Chu et al., 2009). Long-term decline in the world's glaciers and longer drier summers also aggravate water scarcity in certain areas and lead to near-term surges in flows elsewhere before declining again (NSIDC, 2008; Immerzeel et al., 2012; Marengo et al., 2011; Olefs et al., 2009). Economic impacts will cause the greatest challenges where water scarcity and the cost of water are already high (Morrison et al., 2009).

IMPACTS

The effect of climate change on water scarcity is already estimated to cost affected countries 45 million dollars a year. However, 30 billion dollars in yearly gains in water resources in countries experiencing increasing water availability mean a net global loss of 15 billion dollars a year. This net global loss is stable at 15 billion dollars a year to 2030 and declines by three times as a share of global GDP. By 2030, affected countries will incur 200 billion dollars in yearly losses, which are almost entirely offset by similar levels of gains in other countries.

The bulk of losses is estimated to affect wealthy European countries, such as France, Germany, Spain, and Italy. Mexico and Turkey are also expected to experience high losses in absolute terms. Canada, China, Japan, India, and Russia are estimated here to recoup the largest gains.

Southern and Eastern European countries are estimated to be worst affected relative to GDP, along with a number of Central American countries, such as Belize and Panama.

The impacts represent a possible outcome of highly unpredictable rainfall and should be treated with caution, especially for countries in sub-regions with considerable uncertainty about the direction of change (wet or dry).

On a global level, the results could be considered more robust since different hydrological regimes will invariably favour some and disfavour others in terms of water availability.

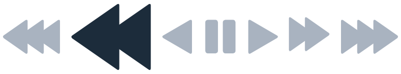
THE BROADER CONTEXT

The world is experiencing a growing water crisis. Between 2010 and 2030, global water demand is expected to increase by around 40%, requiring an additional 3 trillion m^3 of water, as compared with a total global demand of only 4.5 trillion m^3 today, without accounting for the possible impacts of climate change (McKinsey & Company, 2009). This increase is driven largely by population growth and economic

BIGGER PICTURE

N/A

SURGE



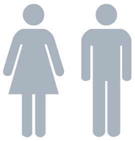
OCCURRENCE

N/A

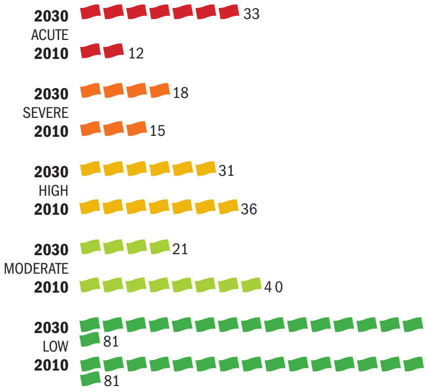
PEAK IMPACT

N/A

GENDER BIAS



VULNERABILITY SHIFT



INDICATOR INFORMATION

MODEL: Hoekstra et al., 2010; McKinsey and Company, 2009; Nohara, 2006; Portmann et al., 2010; Rosengrant et al., 2002

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: Nohara, 2006

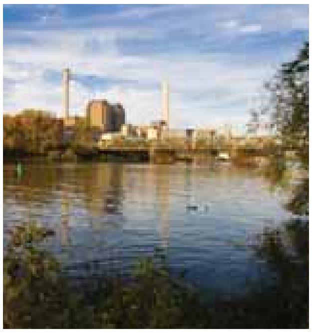
▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

growth, which brings greater industry demand for water. Over half of the water gap is expected to be met through infrastructure and other changes which deviate from business-as-usual approaches to water. Unless countries develop more sophisticated responses to dealing with the water supply, the expense of closing this gap, while technically possible, will become increasingly cost-prohibitive, because of the steep cost of generating water to compensate for the water scarcity in an economy.

VULNERABILITIES AND WIDER OUTCOMES

Pollution, over-grazing, deforestation, and other environmentally unsustainable practices can all exacerbate water scarcity (Economy, 2010). Farmers who must rely on rainfall alone and who cannot afford or get access to irrigation are highly vulnerable to falling water availability. Water insecurity can lead to food insecurity in marginalized communities and to a lack of water for sanitation and drinking, leading to further negative health consequences, or even violence and conflict (Ludi, 2009; Raleigh, 2010).



Economies heavily reliant on agriculture, responsible for about 70% of global water demand, are also more vulnerable to water stress (FAO AQUASTAT, 2012).

RESPONSES

Managing water often requires large-scale investment that can have an important impact on longer-term development prospects (Aerts and Droogers in Kabat et al. (eds.), 2009). Planning for the wrong outcome is costly. Where uncertainty is high, it is therefore vital that responses are appropriate for a wide range of possible outcomes, i.e., a wet or a dry future (Dessai et al., 2009). However, planning for different outcomes can add significantly to the costs of adaptation. Five broad response areas are central to effective water management: 1) Enhancing catchment capacity or access to supplies, through reservoirs or wells for instance; 2) There is wide scope for improving water efficiency in many contexts (Wallace, 2000), from micro-irrigation, to improved drainage and re-use of water, lining canals and limiting water leakage, as well as the cultivation of more water-efficient crops (Rodríguez Díaz et al., 2007; Wilby and Dessai, 2010; Elliot et al., 2011); 3) Supporting improved institutional environments to enable communities to make and implement effective decisions is critical (Rogers and Hall, 2003); 4) The vulnerability of communities to water stress can also be reduced, whether for socio-economic reasons (e.g., subsistence farmers), pollution, land degradation, or deforestation (Sullivan, 2011; Kiparsky et al., 2012; Epule et al., 2012; Postel and Thompson, 2005); 5) GHG emission reductions do not instantaneously slow or accelerate the hydrological cycle, but will limit the extent of changes in water availability due to climate change in the long term (Wu et al., 2010; Arnell et al., 2011).

THE INDICATOR

The indicator measures costs of changes in the re-supply of water resources due to temperature and precipitation changes caused by climate change (Nohara et al., 2006). It considers agricultural, domestic/municipal and industrial demand and country or region-specific marginal water costs (Rosengrant at al., 2002; McKinsey & Company, 2009). A key limitation not controlled for is that while climate change may increase water availability over a year, if it does not fall when water demand peaks in the absence of adequate catchment, reservoir and irrigation facilities, water scarcity may still increase. It has been estimated that around 20% of areas experiencing increased water could also experience an increase in water scarcity, including India, Northern China, and Europe (Yamamoto et al., 2012). Since the indicator is aggregating the country-level picture of change, it is possible that increases in water availability for some parts of a country are not compensating fully for decreases in water availability elsewhere.

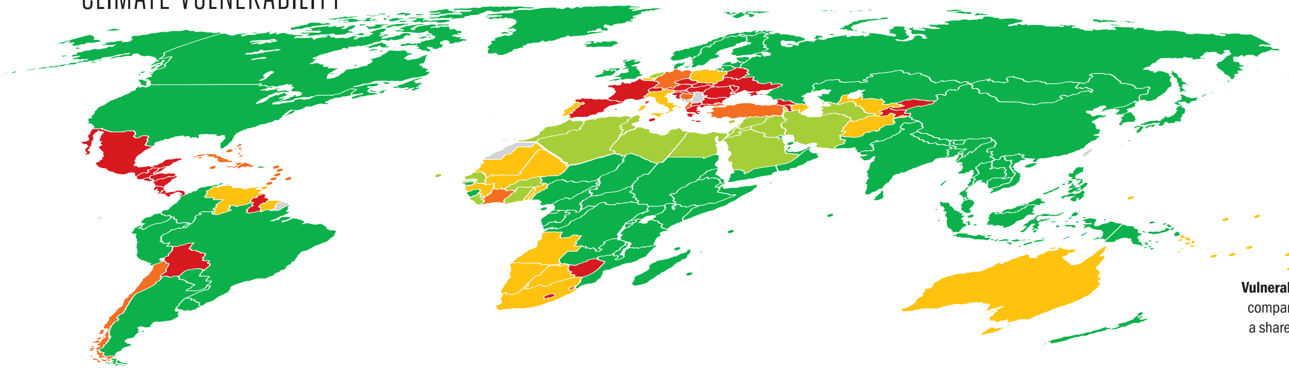
ESTIMATES COUNTRY-LEVEL IMPACT

	$		💧	
COUNTRY	2010	2030	2010	2030
ACUTE				
Armenia	70	500	0.25	0.50
Austria	2,000	6,000	1	1
Belarus	400	2,500	0.50	1
Belize	35	250		0.25
Bolivia	350	2,500	1	1
Bulgaria	600	4,000	1	1
Costa Rica	150	1,000	0.50	0.75
Croatia	700	4,750	0.50	1
Czech Republic	1,250	9,000	0.75	1
El Salvador	150	1,000	0.00	
France	9,000	25,000	5	10
Georgia	200	1,250	0.75	1
Greece	900	2,750	0.50	1
Guatemala	150	1,250	0.75	1
Guyana	15	100		
Honduras	80	650	0.75	1
Hungary	500	3,500	0.75	1
Kyrgyzstan	40	300	0.75	1
Lesotho	10	65	0.50	0.75
Macedonia	100	850	0.25	0.50
Malta	40	100		
Mexico	4,000	30,000	20	35
Moldova	30	200	0.25	0.50
Nicaragua	75	600	1	1
Panama	200	1,250	0.75	1
Romania	1,000	6,750	1	5
Slovakia	700	5,000	0.50	1
Slovenia	400	2,750	0.25	0.50
Spain	4,750	15,000	5	5
Switzerland	800	2,250	0.50	1
Tajikistan	45	300	0.75	1
Ukraine	1,000	7,000	1	5
Zimbabwe	30	200	1	5
SEVERE				
Albania	35	250	0.25	0.50
Antigua and Barbuda	1	20		
Bahamas	15	100		
Barbados	10	70		
Bosnia and Herzegovina	40	300		0.25
Chile	400	3,250	1	5
Cote d,Ivoire	45	300	1	5
Cuba	150	1,250		
Dominica	1	10		
Dominican Republic	100	950		
Germany	5,000	15,000	1	5
Grenada	1	15		
Haiti	15	100		
Jamaica	35	250		
Saint Lucia	1	20		
Saint Vincent	1	15		
Swaziland	10	70		0.25
Turkey	1,750	5,500	10	20
HIGH				
Afghanistan	35	250	1	5
Angola	70	450	1	1
Australia	750	2,000	0.50	1
Azerbaijan	100	800	0.25	0.50
Belgium	350	1,000	0.25	0.50
Benin	10	75	0.25	0.75
Botswana	20	100		0.25
Fiji	1	20		
Guinea	10	60	0.25	0.75
Italy	2,250	6,750	1	5
Kiribati		1		
Luxembourg	50	150		
Mali	15	95	0.75	1
Marshall Islands		1		
Mauritania	5	40	0.25	0.25
Micronesia		1		
Namibia	10	55		0.25
Palau		1		
Poland	900	6,250	1	1
Portugal	250	700	0.25	0.25
Samoa	1	5		
Solomon Islands	1	5		
South Africa	550	3,500	5	5
Suriname	1	15		
Togo	5	30	0.25	0.50
Tonga	1	5		
Trinidad and Tobago	15	150		0.25
Tuvalu				
Uzbekistan	40	300	0.50	1
Vanuatu	1	5		
Venezuela	350	2,750	1	5
MODERATE				
Algeria	15	95		0.25
Burkina Faso	1	15		0.25
Cape Verde	1	5		
Cyprus	5	15		
Egypt	1	15		
Gambia	1	5		
Ghana	10	55	0.25	0.25
Iran	300	2,250	1	1
Iraq	5	55	0.25	0.25
Israel	10	65		

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

CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



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

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable

	$		💧	
COUNTRY	2010	2030	2010	2030
Jordan	1	10		
Lebanon	1	10		
Liberia	1	1		
Libya	1	5		
Morocco	10	70		0.25
Netherlands	150	500		0.25
Saudi Arabia	20	150		0.25
Senegal	1	5		
Syria	10	65		0.25
Tunisia	1	15		
Turkmenistan	10	75		0.25
LOW				
Argentina	-150	-1,250	-0.25	-0.50
Bahrain	-1	-5		
Bangladesh	-25	-200	-0.50	-1
Bhutan	-85	-700	-0.50	-1
Brazil	-1,250	-10,000	-5	-10
Brunei	-55	-450		-0.25
Burundi	-1	-10	-0.25	-0.25
Cambodia	-15	-150	-0.25	-0.50
Cameroon	-35	-250	-0.75	-1
Canada	-2,500	-7,250	-1	-1
Central African Republic	-5	-25	-0.25	-0.50
Chad	-25	-150	-0.50	-1
China	-5,750	-60,000	-30	-55
Colombia	-250	-2,000	-1	-5
Comoros	-1	-1		
Congo	-5	-50		-0.25
Denmark	-65	-200		
Djibouti	-1	-5		
DR Congo	-20	-100	-1	-5
Ecuador	-750	-5,500	-1	-5

	$		💧	
COUNTRY	2010	2030	2010	2030
Equatorial Guinea	-5	-35		
Eritrea				
Estonia	-100	-800	-0.25	-0.50
Ethiopia	-100	-650	-5	-5
Finland	-1,000	-3,000	-0.75	-1
Gabon	-1	-10		
Guinea-Bissau		-1		
Iceland	-25	-70		
India	-2,000	-15,000	-15	-35
Indonesia	-950	-7,500	-10	-20
Ireland	-250	-700	-0.25	-0.25
Japan	-4,250	-10,000	-1	-5
Kazakhstan	-50	-350	-0.25	-0.25
Kenya	-65	-400	-1	-5
Kuwait		-1		
Laos	-70	-750	-1	-1
Latvia	-55	-350		-0.25
Lithuania	-20	-150		
Madagascar	-1	-5		
Malawi	-1	-15		-0.25
Malaysia	-800	-6,000	-1	-5
Maldives	-10	-60		
Mauritius	-10	-65		
Mongolia	-1	-10		
Mozambique	-1	-5		
Myanmar	-75	-600	-1	-5
Nepal	-25	-200	-1	-1
New Zealand	-90	-250		-0.25
Niger	-10	-55	-0.50	-1
Nigeria	-65	-400	-1	-1
North Korea	-20	-200	-0.50	-1
Norway	-1,250	-4,000	-0.75	-1

	$		💧	
COUNTRY	2010	2030	2010	2030
Oman	-25	-200		-0.25
Pakistan	-10	-60		-0.25
Papua New Guinea	-100	-850	-5	-5
Paraguay	-25	-200	-0.25	-0.50
Peru	-200	-1,500	-1	-1
Philippines	-45	-350	-0.50	-1
Qatar	-10	-55		
Russia	-2,500	-15,000	-5	-10
Rwanda	-5	-40	-0.25	-0.50
Sao Tome and Principe		-1		
Seychelles	-1	-5		
Sierra Leone		-1		
Singapore	-250	-2,000		
Somalia	-5	-40	-0.50	-1
South Korea	-85	-650	-0.25	-0.50
Sri Lanka	-1	-20		
Sudan/South Sudan	-40	-300	-1	-1
Sweden	-1,500	-4,500	-1	-1
Tanzania	-200	-1,250	-5	-10
Thailand	-300	-2,250	-1	-5
Timor-Leste	-5	-35		
Uganda	-70	-450	-1	-5
United Arab Emirates	-15	-150		
United Kingdom	-1,250	-4,000	-0.75	-1
United States	-1,250	-4,000	-1	-1
Uruguay	-10	-70		
Vietnam	-100	-1,000	-1	-1
Yemen	-10	-60	-0.25	-0.25
Zambia	-1	-5		

💧 Additional water losses/gains due to climate change (km^3) - yearly average

HEALTH IMPACT

COSTS

2010
23 BILLION

2030
106 BILLION

- DIARRHEAL INFECTIONS
- HEAT & COLD ILLNESSES
- HUNGER
- MALARIA & VECTOR-BORNE
- MENINGITIS

⬇	☠	85,000 15,000	2010 2030	⚠⚠⚠△	▶
⬇	☠	35,000 35,000	2010 2030	⚠⚠△△	◀
⬇	☠	225,000 380,000	2010 2030	⚠⚠⚠⚠	▶
⬇	☠	20,000 20,000	2010 2030	⚠⚠△△	❚❚
⬇	☠	30,000 40,000	2010 2030	⚠⚠△△	▶

DIARRHEAL INFECTIONS

ESTIMATES GLOBAL CLIMATE IMPACT

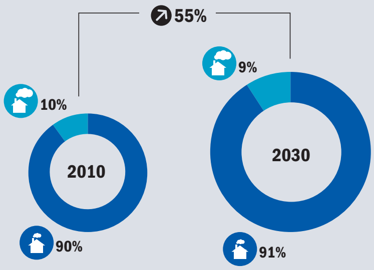
2010 EFFECT TODAY

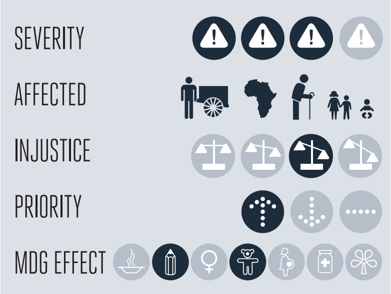
DEATHS PER YEAR **85,000**

2030 EFFECT TOMORROW

DEATHS PER YEAR **150,000**

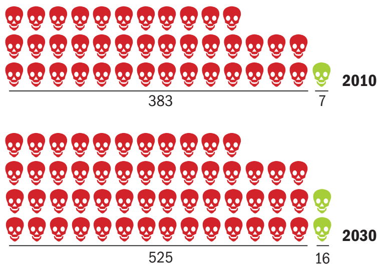
MORTALITY IMPACT





- ➔ Diarrheal disease is one of the leading causes of preventable death in developing countries, especially among children and infants
- ➔ Today, diarrheal diseases kill 2.5 million people per year globally
- ➔ Germs causing these infections favour warmer environments; as the planet heats, the risks of diarrheal diseases will worsen unless counteracting measures are taken

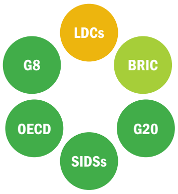
RELATIVE IMPACT



HOTSPOTS

2010		2030
40,000	**INDIA**	85,000
6,750	**NIGERIA**	9,250
3,250	**PAKISTAN**	9,250
3,500	**ETHIOPIA**	6,500
3,500	**DR CONGO**	6,500

GEOPOLITICAL VULNERABILITY



Deaths
Developing Country Low Emitters
Developing Country High Emitters
Developed
Other Industrialized

= Deaths per 10 million

Change in relation to overall global population and/or GDP

Diarrheal infections are one of the world's top communicable disease groups globally by overall death toll (WHO, 1999; WHO BDD, 2011). Food spoils more quickly and water contamination accelerates at higher temperatures, with the result that diarrheal infection rates may be 3–4 times higher in the summer than in the winter. Too much water, from flooding and contamination, or too little water, causing difficulties in treating/rehydrating the ill, are also problematic (WHO, 2009). Diarrheal disease influenced by climate change is a major concern for developing countries because risks are simply higher: inadequate refrigeration, difficult access to plumbed water in homes, or sanitation, such as basic toilet facilities (Bilenko et al, 1999; WHO, 2004; Ashbolt, 2004). In order to save lives and steadily reduce the prevalence of these diseases, simple interventions from vaccines to breastfeeding can prevent death. Systemic improvements in water, sanitation and hygiene are necessary for a more comprehensive reduction in risks (Jamison et al. (eds.), 2006).

CLIMATE MECHANISM

Several climate parameters affect diarrheal diseases from the level of infectious agents (bacteria, pathogen and viruses) through to population level practices. Direct observation of the effects of rising temperatures on infectious agents shows increases in disease replication rates and survival duration (WHO, 2004). Temperature changes also affect hospitalizations rates, with noticeable percentage increases in patient admissions as temperatures rise above normal levels (Checkley et al., 2000). Diarrheal diseases are transmitted via the fecal-oral route through food, water, human contact, or contact with objects such as cups (Dennehy, 2000). Key types of infectious diarrhea include cholera and rotavirus. Other factors such as humidity and rainfall also influence diarrhea. For instance, extremely low rainfall can force people in developing countries to make more use of polluted waters, while too much rain can contaminate unpolluted waters (Hunter, 2003; Ashbolt, 2004). Diarrheal diseases are also affected by malnutrition rates, which are influenced by climate change. This relationship is studied under "Hunger" (WHO, 2004).

IMPACTS

Owing to general temperature increase, the current impact of climate change on diarrheal diseases is estimated to lead to over 80,000 additional deaths per year in developing countries. Each year, over 100 million people are estimated to be affected by diarrheal diseases resulting from climate change.

By 2030, these impacts will increase to over 150,000 deaths proportionate to the future global population, taking into account expected evolutions in the disease in relation to socio-economic development, unless measures are taken to counteract them. Over 200 million people could be affected by 2030.

Africa is by far the region worst affected by diarrheal disease as result of the effects of climate change, with more than a dozen countries estimated to be experiencing similarly extreme levels of impact. Some parts of Asia, particularly, Afghanistan, Pakistan, and India are also particularly vulnerable.

In general, low-income and least developed countries are significantly worse off than middle income countries. No significant impact is expected for developed countries, but primarily because of a higher level of public awareness, and not because people in those countries are invulnerable (WHO, 2004; Bentham, 1997).

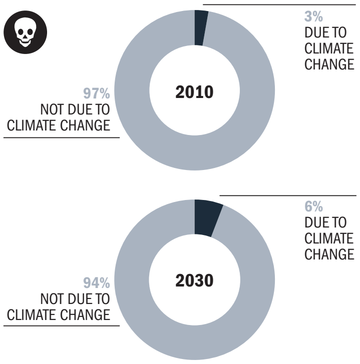
THE BROADER CONTEXT

While many preventable diseases in developing countries are seeing reductions in prevalence or declines in growth rates, diarrheal diseases have expanded rapidly since the year 2000, with nearly three quarters of a million additional deaths worldwide by 2010 (Mathers and Loncar, 2006; WHO BDD, 2011). However, different regions have evolved in different ways. In the last 10 years, Africa has worsened considerably, while East Asia has markedly diminished its burden of suffering from diarrheal disease.

VULNERABILITIES AND WIDER OUTCOMES

Less than 1% of diarrheal disease deaths occur in developed countries. Lower-income countries with already significant burdens of diarrheal infections will face serious challenges in combating the disease as temperatures continue to rise, since the same preconditions prevail. Prevalence of diarrhea is closely linked

BIGGER PICTURE

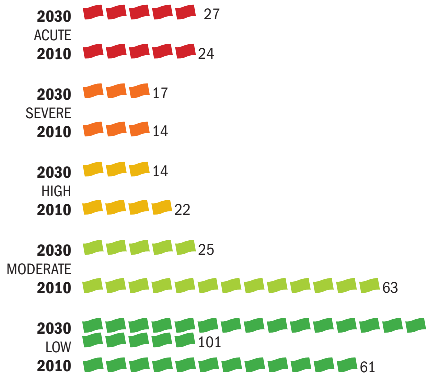


SURGE

OCCURRENCE

N/A

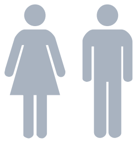
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: McMichael et al., 2004

EMISSION SCENARIO: S750 (IPCC, 2007)

BASE DATA: WHO BDD, 2011

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

to income levels for two reasons: 1) the main vulnerabilities relate to sanitation and by association, hygiene, whereby certain minimum standards in higher-income countries are enough to greatly reduce infection rates; and 2) deaths from diarrhea are easily preventable, especially among infants and toddlers, but only when either medical treatment or clean water are accessible and awareness about treatments is widespread; this is, unfortunately, not the case in many least developed contexts (Ashbolt, 2004; Jamison et al. (eds.), 2006).

While children make up more than half of the death toll, the millions who do survive what may often be repeated illnesses can, in many cases, be left with long-term cognitive impairments (Niehaus et al., 2002). Combined economic and social costs constitute a serious impediment to development progress for the world's poorest communities. With respect to the Millennium Development Goals, 2 (universal education) and 4 (child health) are particularly affected.

RESPONSES

Reponses are needed at the treatment and prevention level. In terms of treatment, simple water and salt, called "oral rehydration" solutions (ORS) cost next to nothing and can prevent death from extreme dehydration, the most common trigger of diarrheal mortality. In terms of prevention, access to clean water and basic sanitation are the central concerns (WHO, 2009). In this context, four sets of strategies are commonplace: 1) vaccination, especially against rotavirus and to a lesser extent cholera, has the potential to save up to half a million lives each year; 2) child breastfeeding programmes which limit the transmission of infections through food and water to infants; 3) sanitation improvements, in the form of improved water sources for houses or small communities, construction of wells, and improved waste and latrine systems; and 4) education programmes, which target awareness about the other three areas and which promote personal hygiene through the use of soap and other simple measures (Jamison et al. (eds.), 2006).

THE INDICATOR

The indicator is deemed robust, particularly because of its reliance on temperature—among the most certain of climate effects—as the parameter for estimating a climate effect and because of the quality of the global health database compiled by the WHO on which the estimates are based (WHO BDD, 2011). Nevertheless, a number of improvements could be envisioned: for example, the WHO modelled the global effect on the basis of two detailed studies, which could benefit from further expansion into different areas, particularly detailed analysis of climate change effects on diarrhea in Africa (WHO, 2004). Moreover, the model does not take into account factors other than temperature, such as humidity and rainfall, nor does it take into account effects for developed countries which, while potentially low in terms of mortality, could be high in terms of the number of illnesses; one study identified a 9% increase in food poisoning causing diarrhea in the UK for every one degree increase in temperature (Bentham, 1997).

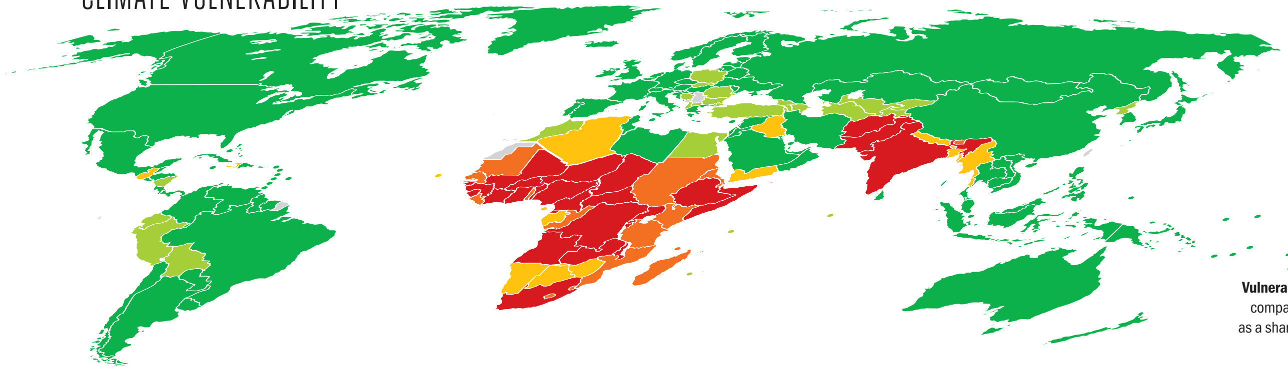
ESTIMATES COUNTRY-LEVEL IMPACT

	☠		👤	
COUNTRY	2010	2030	2010	2030
ACUTE				
Afghanistan	2,000	4,000	2,500	5,000
Angola	1,250	1,750	7,750	10,000
Benin	350	450	400	550
Burkina Faso	900	1,250	1,000	1,500
Burundi	400	750	500	900
Cameroon	900	1,250	1,250	1,500
Central African Republic	150	250	200	350
Chad	900	1,250	1,000	1,500
Cote d'Ivoire	550	950	650	1,250
DR Congo	3,500	6,500	4,500	8,000
Equatorial Guinea	25	35	200	300
Ethiopia	3,500	6,500	4,500	8,250
Ghana	900	1,250	1,250	1,500
Guinea	400	550	500	700
Guinea-Bissau	100	150	150	200
India	40,000	85,000	50,000	100,000
Malawi	450	800	550	1,000
Mali	950	1,250	1,250	1,750
Niger	1,000	1,500	1,250	1,750
Nigeria	6,750	9,250	8,250	10,000
Pakistan	3,250	9,250	4,000	10,000
Rwanda	350	650	450	850
Sierra Leone	350	450	400	550
Somalia	550	1,000	700	1,250
South Africa	1,000	2,000	9,000	15,000
Uganda	1,000	2,000	1,250	2,500
Zambia	400	750	500	950
SEVERE				
Bhutan	10	20	10	25
Comoros	20	30	25	35
Congo	80	150	100	200
Djibouti	15	25	85	150
Eritrea	85	150	100	200
Gambia	45	65	60	80
Kenya	800	1,500	1,000	1,750
Lesotho	25	45	30	55
Liberia	150	200	200	250
Madagascar	500	700	600	850
Mauritania	100	150	150	200
Mozambique	550	950	650	1,250
Senegal	300	400	400	500
Sudan/South Sudan	850	1,500	1,000	2,000
Swaziland	15	30	100	200
Tanzania	1,000	2,000	1,250	2,250
Togo	150	250	200	300
HIGH				
Algeria	350	500	2,250	3,000
Bangladesh	1,250	2,250	1,500	2,750
Botswana	15	25	100	200
Cape Verde	5	5	25	35
Gabon	20	30	200	250
Guatemala	150	150	850	800
Haiti	150	100	200	150
Iraq	300	850	1,750	5,000
Myanmar	550	1,000	650	1,250
Namibia	15	25	85	150
Nepal	300	550	350	650
Sao Tome and Principe	1	5	1	5
Yemen	400	850	500	1,000
Zimbabwe	150	250	150	300
MODERATE				
Albania	1	1	5	1
Armenia	1	1	5	5
Azerbaijan	15	10	95	55
Bolivia	80	70	450	450
Bosnia and Herzegovina			1	
Bulgaria	1		1	1
Ecuador	15	15	100	80
Egypt	95	150	550	1,000
Georgia	1	1	15	5
Kyrgyzstan	15	5	15	10
Macedonia			1	1
Maldives		1	1	5
Mauritius	1	1	5	10
Morocco	150	250	850	1,500
Nicaragua	15	15	15	15
North Korea	60	100	75	150
Peru	45	35	250	200
Poland	1	1	10	5
Romania	1	1	5	1
Seychelles			1	1
Slovakia			1	1
Tajikistan	45	25	60	30
Turkey	25	15	250	150
Turkmenistan	20	15	100	85
Uzbekistan	55	35	70	45
LOW				
Antigua and Barbuda				
Argentina				
Australia				
Austria				
Bahamas				
Bahrain			1	
Barbados				
Belarus				

☠ Additional mortality due to climate change - yearly average

CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure:
comparative mortality
as a share of population
(national)

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable

	☠		🚹	
COUNTRY	2010	2030	2010	2030
Belgium				
Belize				
Brazil				
Brunei				
Cambodia	100		150	
Canada				
Chile				
China	550		3,000	
Colombia				
Costa Rica				
Croatia				
Cuba				
Cyprus			1	
Czech Republic				
Denmark				
Dominica				
Dominican Republic				
El Salvador				
Estonia				
Fiji	1		10	
Finland				
France				
Germany				
Greece				
Grenada				
Guyana				
Honduras				
Hungary			1	
Iceland				
Indonesia				
Iran	100		600	
Ireland				

	☠		🚹	
COUNTRY	2010	2030	2010	2030
Israel				
Italy				
Jamaica				
Japan				
Jordan	5		25	
Kazakhstan	1		15	
Kiribati	1		5	
Kuwait			1	
Laos	35		45	
Latvia				
Lebanon	1		10	
Libya	5		30	
Lithuania				
Luxembourg				
Malaysia	5		55	
Malta				
Marshall Islands			1	
Mexico				
Micronesia			1	
Moldova				
Mongolia	5		5	
Netherlands				
New Zealand				
Norway				
Oman	1		10	
Palau				
Panama				
Papua New Guinea	30		35	
Paraguay				
Philippines	200		1,250	
Portugal				
Qatar			1	

	☠		🚹	
COUNTRY	2010	2030	2010	2030
Russia	5		45	
Saint Lucia				
Saint Vincent				
Samoa			1	
Saudi Arabia	15		250	
Singapore				
Slovenia				
Solomon Islands	1		1	
South Korea	5		55	
Spain				
Sri Lanka				
Suriname				
Sweden				
Switzerland				
Syria	15		85	
Thailand				
Timor-Leste				
Tonga			1	
Trinidad and Tobago				
Tunisia	10		55	
Tuvalu				
Ukraine	1		5	
United Arab Emirates			1	
United Kingdom				
United States				
Uruguay				
Vanuatu			1	
Venezuela				
Vietnam	90		100	

🚹 Additional persons affected due to climate change (thousands) - yearly average change

HEAT & COLD ILLNESSES

ESTIMATES GLOBAL CLIMATE IMPACT

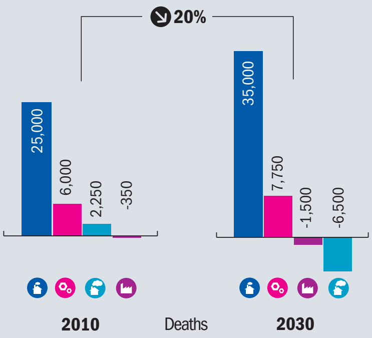
2010 EFFECT TODAY

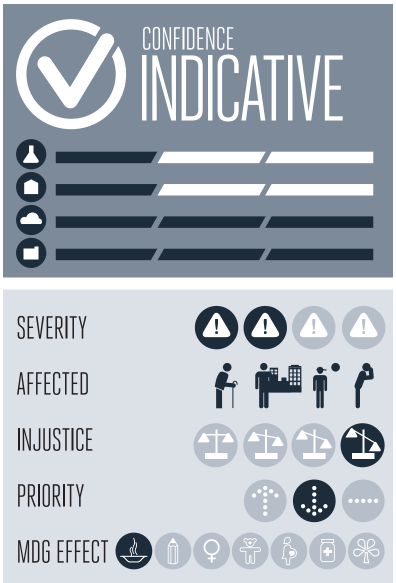
DEATHS PER YEAR **35,000**

2030 EFFECT TOMORROW

DEATHS PER YEAR **35,000**

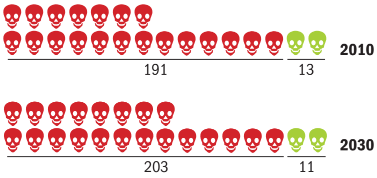
MORTALITY IMPACT





- Extreme heat is dangerous, entails high risks for the elderly, sufferers of chronic cardiovascular and respiratory diseases, and may increase skin cancer rates
- Shorter and less harsh winters alleviate dangers for the same risk groups and reduce the incidence of flu-like illnesses
- Some developed countries are estimated to experience modest health gains, as winters become less severe on average
- Effective responses to heat and cold illnesses benefit from a restricted high-risk group, concentrated on the elderly and chronic disease sufferers, while skin cancer risk is more diffuse in the population

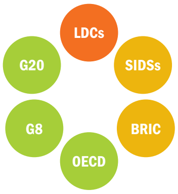
RELATIVE IMPACT



HOTSPOTS

2010		2030
10,000	**INDIA**	10,000
3,000	**NIGERIA**	4,250
2,250	**RUSSIA**	3,000
2,000	**UKRAINE**	2,250
1,750	**BANGLADESH**	2,000

GEOPOLITICAL VULNERABILITY



Deaths
Developing Country Low Emitters
Developing Country High Emitters
Developed
Other Industrialized

= Deaths per 10 million

Change in relation to overall global population and/or GDP

= Millions of USD (2010 PPP non-discounted)

Changes in the average levels and the extremities of heat and cold affect health. Increases in hospitalization and mortality rates are particularly evident for those suffering from chronic disease during heat waves (Michelozzi et al., 2009). Vulnerabilities to extreme hot and cold exist both in developed and developing countries and involve cardiovascular and respiratory diseases, skin cancer, and influenza-like illnesses, with both positive and negative effects. In tropical developing countries, exposure to heat is higher, especially since air conditioning, being linked to income, is less prevalent (Isaac and van Vuuren, 2009). Nor do tropical countries reap any of the potential benefits of shorter, warmer winters. While cooler, wealthy countries are likely to see improved health outcomes, experts have argued that even in developed countries, heat-related deaths may be greater than any gains from milder winters (McMichael et al., 2006). In Europe for example, 2003 was the hottest summer in some 500 years and left an estimated death toll of approximately 35,000–70,000 additional deaths (Patz et al., 2005; Robine et al., 2008). Scientists have argued the extent to which such extreme heat waves would be unlikely without climate change (Hansen et al., 2012). Reponses to the challenge benefit from clearly delineated groups among chronic disease sufferers. Skin cancer risk is much more generalized and presents a growing challenging for the promotion of safe behavioural adjustments for communities at risk (Bharath and Turner, 2009).

CLIMATE MECHANISM

Warm spells and heat waves have become more common and extreme, cold spells less so (IPCC, 2007). Because heat causes sweating, which removes water from the blood, high temperatures "thicken" blood, causing heart attacks or strokes (Solonin and Katsyuba, 2003). Sufferers of chronic respiratory illnesses, such as chronic obstructive pulmonary disease are also under additional stress during periods of high heat, but reduced stress in cold extremes. The elderly are another major risk group, due in part to impaired body temperature regulation (Lin et al., 2009; Gosling et al., 2009). Populations are thought to gradually acclimatize to increasing heat up to a point, a process for which the elderly are poorly equipped to handle; however, the speed of heat increase is outstripping the capacity to acclimatize (Kennedy and Munce, 2003; Kjellstrom, 2009b).

Skin cancer rates are expected to be affected by behavioural change—as people in colder climates spend more time outdoors as the planet warms, increasing the carcinogenicity of UV radiation—and by the delay or speed of recovery of the ozone layer, due to temperature effects in the upper atmosphere (Bharath and Turner, 2009; Gilchrest et al., 1999; Waugh et al., 2009). In some regions, ozone recovery is speeded up through climate change; in others, the recovery is slowed. Finally, influenza-like illnesses, in particular pneumonia, respond in complex ways to weather, but are generally more prevalent at lower temperatures, i.e., during winter, with climate change reducing the risks (van Noort et al., 2012).

IMPACTS

The global impact of climate change on heat and cold-related illnesses is estimated at 35,000 additional deaths a year in 2010, with one million more people affected than would have been the case without climate change. The net figure includes approximately 45,000 deaths, mainly in developing countries, and close to 10,000 deaths avoided in developed countries, which are expected to see a net positive effect.

The worst affected countries are mainly developing countries of Africa and Asia, but include Russia and several Commonwealth of Independent States countries where chronic disease burdens are very high. The largest total effects occur in India, with over 10,000 deaths per year. Very high total impacts are also seen in countries such as Nigeria, Russia, the Ukraine, Bangladesh, and DR Congo.

The death toll is expected to remain relatively stable through to 2030, with mortality increasing to 55,000 people, but with avoided deaths also doubling from 10,000 to 20,000 over the same time period.

THE BROADER CONTEXT

The types of illnesses, particularly non-communicable illnesses, that are most affected by extreme heat and cold fluctuations are widely prevalent in both developed and developing countries. The incidence of cardiovascular and chronic respiratory diseases as well as skin cancer have increased in the last decade, while respiratory, including influenza-like diseases have declined (WHO BDD, 2000 and 2011).

BIGGER PICTURE

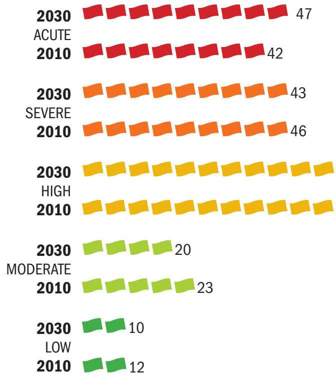
N/A

SURGE

OCCURRENCE

N/A

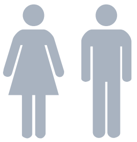
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: Curriero et al., 2002; Knutti et al., 2008; Toulemon and Barbieri, 2006; Van Noort et al., 2012

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: CIA World Factbook, 2012; WHO BDD, 2011

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

VULNERABILITIES AND WIDER OUTCOMES

Elderly populations are at the greatest risk by far, with two-thirds of all mortality in persons of 70 years of age, and over 80% of all mortality in persons over 60.

Countries with higher relative burdens of cardiovascular risk and chronic respiratory diseases have higher levels of vulnerability. Those same sufferers are less at risk of disease aggravation during milder winters; so geography is key: those in cold countries will benefit, while those in warmer countries will suffer more. Heat stress effects are deemed also to be stronger in tropical regions where temperatures are already elevated, air conditioning and insulation less prevalent, and outdoor work more common (Kovats and Hajat, 2008; Kjellstrom, 2009b). Since most developing countries fall in this category, there are negative implications for poverty reduction and development. Cities are more vulnerable, because they exaggerate extreme heat through the well-known heat island effect (Campbell-Lendrum and Corvalán, 2007).

More frequent and severe hot periods with sudden impacts will contribute to temporary capacity overloads on the health systems of affected areas, which may lead to further degradations in health services, with still additional negative health outcomes (Frumkin et al., 2007; Gosling et al., 2009).

The well-being and health of outdoor workers especially in hot countries is also seriously jeopardized (Kjellstrom et al., 2009b).

RESPONSES

Responses include a variety of measures from preventative (pre-summer) health assessments, early-warning procedures for heat spells, and behaviour adjustments, such as increasing fluid intake, adjusting medication, and avoiding midday heat, as well as increasing climate-controlled indoor cooling or heightened vigilance of high risk patients. Longer-term measures might include changes to building design and housing, improved institutional care for the elderly, and stricter controls on urban air pollution, which seriously exacerbates the heat effects of the summer hot spells (Kovats and Hajat, 2008; Ayres et al., 2009).

THE INDICATOR

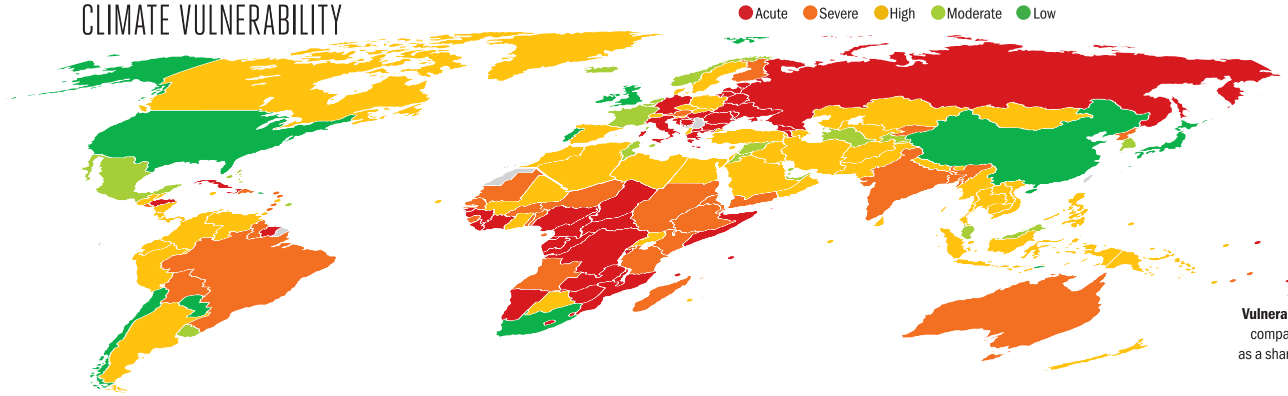
The indicator measures the impact of new heat or cold patterns on cardiovascular and respiratory diseases, skin cancer, and influenza-like illnesses (Curriero et al., 2002; Bharath and Turner, 2009; Hill et al., 2010; van Noort et al., 2012). Baseline mortality is drawn from World Health Organization disease data (WHO BDD, 2011). The indicator has corrected for the so-called "harvesting effect"— i.e., climate change merely shifts the timing of mortality, as opposed to triggering it, given the high share of morality in already high-risk groups. Baseline research from a wider set of countries studies would help improve the analysis, although the basic mechanisms of heat stress are understood to be broadly similar from country to country (Suchday et al., 2006). While the temperature effect is highly certain, other weather effects, such as humidity, which plays a key role, are more unpredictable. The complex interplay of disease and climate parameters for influenza-like illnesses is particularly difficult to map.

ESTIMATES COUNTRY-LEVEL IMPACT

	☠		🧍	
COUNTRY	2010	2030	2010	2030
ACUTE				
Armenia	75	85	400	-1,250
Belarus	250	300	6,000	6,750
Bosnia and Herzegovina	50	85	1,000	1,500
Bulgaria	200	200	2,000	-250
Burundi	150	200	6,250	9,250
Cameroon	350	450	15,000	20,000
Central African Republic	95	150	4,000	5,500
Chad	250	400	10,000	15,000
Comoros	10	15	450	700
Congo	70	100	3,000	5,000
Cote d'Ivoire	350	450	15,000	20,000
Croatia	55	75	650	-300
Cuba	150	150	5,000	4,750
DR Congo	1,250	2,000	50,000	85,000
Equatorial Guinea	15	20	550	850
Estonia	20	25	700	750
Gabon	25	40	1,250	1,750
Georgia	65	100	1,750	3,000
Germany	700	1,250	80,000	150,000
Greece	150	200	15,000	20,000
Guinea	150	250	6,750	10,000
Guinea-Bissau	25	40	1,250	1,750
Haiti	200	250	8,750	10,000
Honduras	150	150	3,750	4,750
Hungary	100	200	4,000	5,250
Italy	600	850	60,000	95,000
Latvia	45	60	1,500	1,750
Lesotho	40	35	1,750	1,500
Liberia	75	150	3,250	5,750
Lithuania	10	55	-600	300
Macedonia	45	60	950	1,250
Malawi	250	400	10,000	15,000
Marshall Islands	1	1	40	50
Moldova	55	75	1,500	950
Mozambique	400	550	15,000	20,000
Namibia	40	55	1,250	1,500
Nigeria	3,000	4,250	100,000	150,000
Romania	300	400	150	-6,000
Russia	2,250	3,000	75,000	90,000
Seychelles	1	1	65	95
Somalia	150	250	5,750	10,000
Suriname	10	10	350	350
Swaziland	25	30	800	900
Tuvalu			5	5
Ukraine	2,000	2,250	55,000	60,000
Zambia	250	400	10,000	15,000
Zimbabwe	200	250	8,250	10,000
SEVERE				
Angola	200	300	5,250	9,000
Antigua and Barbuda	1	1	40	40
Australia	100	250	8,000	20,000
Austria	30	85	3,000	8,750
Bangladesh	1,750	2,000	70,000	85,000
Barbados	5	1	150	100
Benin	90	150	3,750	5,750
Bolivia	100	150	3,250	4,250
Brazil	1,750	2,000	50,000	55,000
Burkina Faso	150	250	6,000	10,000
Djibouti	10	10	300	350
Dominica	1	1	35	35
Dominican Republic	150	150	4,000	4,250
El Salvador	55	65	1,500	2,000
Eritrea	45	65	1,750	2,750
Ethiopia	750	1,250	30,000	50,000
Fiji	10	10	250	250
Finland	30	70	3,000	6,750
Gambia	20	25	750	1,000
Grenada	1	1	50	50
Guyana	10	5	250	200
India	10,000	10,000	500,000	500,000
Kenya	350	450	15,000	20,000
Kyrgyzstan	60	75	1,000	-600
Madagascar	200	350	9,000	15,000
Mauritania	30	45	1,250	2,000
Myanmar	600	650	25,000	30,000
New Zealand	20	50	1,500	3,750
Niger	150	250	5,500	9,750
North Korea	150	300	7,250	10,000
Poland	250	350	-3,000	-15,000
Rwanda	100	150	5,250	7,250
Saint Vincent	1	1	55	55
Samoa	1	1	55	65
Sao Tome and Principe	1	5	85	150
Senegal	100	150	4,500	6,500
Sierra Leone	75	100	3,000	4,750
Sudan/South Sudan	600	850	25,000	35,000
Sweden	45	90	5,500	10,000
Tanzania	350	550	15,000	20,000
Togo	55	80	2,250	3,250
Tonga	1	1	30	35
Yemen	200	450	8,250	20,000
HIGH				
Afghanistan	250	400	10,000	15,000
Albania	5	20	-1,500	-3,250
Algeria	150	200	4,750	5,750

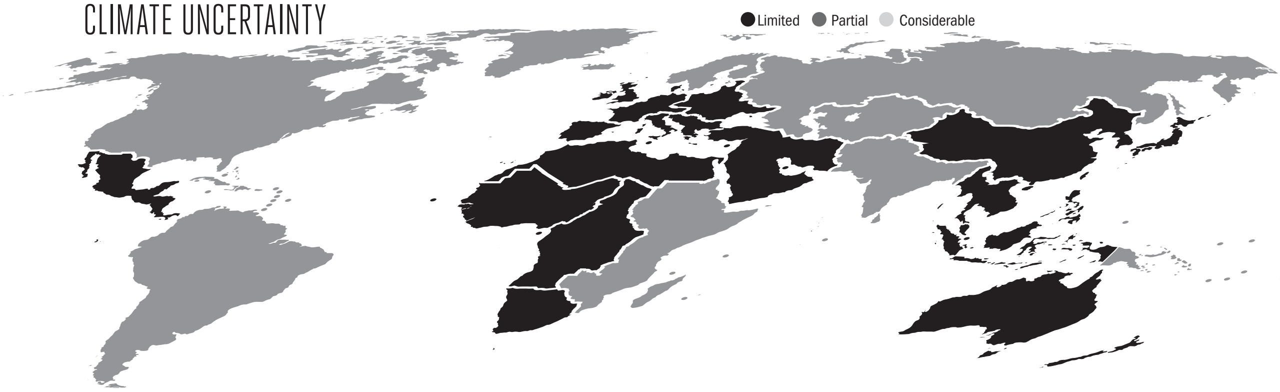
☠ Additional mortality due to climate change - yearly average

CLIMATE VULNERABILITY



Vulnerability measure:
comparative mortality
as a share of population
(national)

CLIMATE UNCERTAINTY



	☠		👤	
COUNTRY	2010	2030	2010	2030
Argentina	300	250	-9,750	-45,000
Azerbaijan	25	65	-2,250	-5,000
Belize	1	1	85	100
Bhutan	5	10	250	400
Botswana	15	15	650	700
Brunei	1	1	100	150
Cambodia	100	150	5,000	5,500
Canada	75	200	10,000	25,000
Cape Verde	5	5	95	100
Colombia	300	350	8,750	10,000
Costa Rica	20	25	850	1,000
Cyprus	5	10	600	900
Czech Republic	30	70	-3,000	-5,250
Denmark	15	30	2,500	5,250
Ecuador	60	70	1,750	2,000
Egypt	450	500	10,000	15,000
Ghana	200	250	8,250	10,000
Guatemala	90	100	2,500	3,500
Indonesia	1,250	1,250	35,000	35,000
Iran	250	300	7,250	8,750
Iraq	100	150	3,500	4,750
Israel	30	35	2,750	3,000
Jamaica	15	15	400	400
Kazakhstan	15	85	-8,000	-15,000
Kiribati	1	1	20	25
Laos	45	50	2,000	2,000
Lebanon	35	40	1,500	1,750
Libya	20	30	1,000	1,250
Luxembourg	1	1	100	400
Maldives	1	1	25	40
Mali	80	150	3,500	5,500
Mauritius	5	5	200	300
Micronesia	1	1	30	35
Mongolia	15	10	100	-700
Morocco	100	150	3,500	4,000
Nepal	250	300	9,500	15,000
Nicaragua	40	55	1,750	2,250
Oman	10	15	350	650
Pakistan	1,250	1,750	55,000	75,000
Palau			10	10
Panama	15	20	750	800
Papua New Guinea	60	80	2,500	3,500
Peru	100	150	3,500	4,000
Philippines	700	800	20,000	25,000
Saint Lucia	1	1	70	65
Saudi Arabia	75	150	7,250	10,000
Singapore	25	25	2,250	2,500
Slovakia	40	40	-1,000	-3,500
Slovenia	5	10	900	1,500
Solomon Islands	5	5	150	200
Spain	250	300	30,000	45,000
Sri Lanka	90	150	2,750	3,750
Switzerland	15	40	2,000	5,250
Thailand	200	350	5,250	9,750
Trinidad and Tobago	5	5	300	250
Turkey	250	500	10,000	20,000
Uganda	250	500	10,000	20,000
Uzbekistan	200	300	2,500	-1,500
Vanuatu	1	1	50	70
Venezuela	150	150	6,250	7,250
Vietnam	450	350	20,000	15,000
MODERATE				
Bahamas	1	1	40	70
Bahrain	1	1	150	150
Belgium	20	20	5,500	9,250
France	20	150	10,000	30,000
Iceland		1	50	150
Jordan	10	10	200	300
Kuwait	5	5	350	450
Malaysia	1	65	40	3,000
Malta			200	350
Mexico	150	95	5,500	4,250
Netherlands	-10	1	3,000	8,500
Norway	5	10	1,250	2,750
Qatar	1	1	70	70
South Korea	-1	30	5,000	15,000
Syria	10	10	300	300
Tajikistan	45	20	-1,000	-7,250
Tunisia	1	30	75	900
Turkmenistan	25	5	-4,500	-15,000
United Arab Emirates	5	1	300	250
Uruguay	20	10	-1,750	-5,000
LOW				
Chile	-20	-70	-9,250	-25,000
China	-5,500	-15,000	-500,000	-1,000,000
Ireland	-15	-15	-250	900
Japan	-850	-1,750	20,000	50,000
Paraguay	-5	-25	-3,000	-9,000
Portugal	-15	-60	5,250	7,750
South Africa	-300	-1,250	-100,000	-200,000
Timor-Leste				
United Kingdom	-55	-200	25,000	40,000
United States	-1,500	-3,250	-100,000	-250,000

👤 Additional persons affected due to climate change - yearly average

HUNGER

ESTIMATES GLOBAL CLIMATE IMPACT

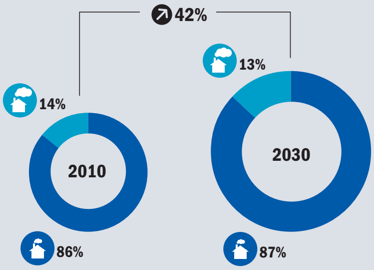
2010 EFFECT TODAY

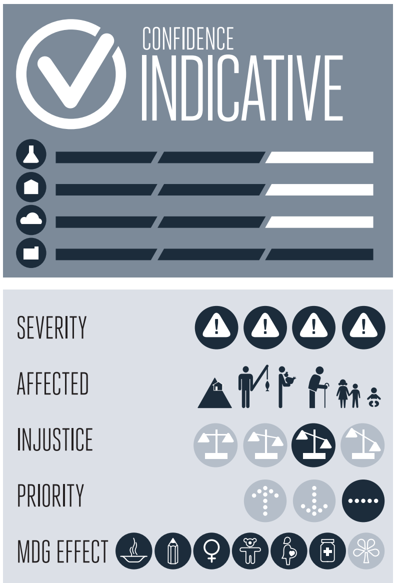
DEATHS PER YEAR **225,000**

2030 EFFECT TOMORROW

DEATHS PER YEAR **380,000**

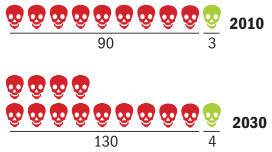
MORTALITY IMPACT





- 200 million people are estimated to suffer from food insecurity as a result of climate change in lower-income countries
- Half of all such deaths are among children and infants in the world's poorest communities, the group least responsible for climate change
- Although hunger is among the most preventable causes of human death, there are no quick fixes to the 850 million people facing hunger today
- There are major ongoing food emergencies and famine facing populations in the Horn of Africa and the Sahel

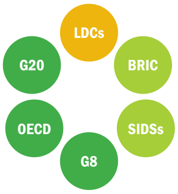
RELATIVE IMPACT



HOTSPOTS

2010		2030
100,000	**INDIA**	250,000
10,000	**PAKISTAN**	25,000
9,750	**BANGLADESH**	15,000
10,000	**NIGERIA**	10,000
7,500	**INDONESIA**	10,000

GEOPOLITICAL VULNERABILITY



- Deaths
- Developing Country Low Emitters
- Developing Country High Emitters
- Developed
- Other Industrialized
- = Deaths per million
- Change in relation to overall global population and/or GDP

Fifteen percent of all human beings are undernourished and 850 million people are prevented from leading active lives as a result of hunger (FAO, 2011). The Millennium Development Goal (MDG) target for reducing hunger has remained static since the early 1990s in all the world's developing regions. Despite enormous increases in wealth over the last two decades, the world has made almost no progress on hunger and its roots in the most extreme forms of poverty. A humanitarian food emergency continues in the Sahel and the Horn of Africa (HPN, 2012; Oxfam, 2012; CARE, 2012). It has long been understood that drought is a key trigger of famine and extreme drought has also been closely linked to climate change. (Glanz (ed.), 1987; Hansen et al., 2012). The combined effects of climate change on agricultural production on land, rivers, coastal zones, and oceans reduces disposable incomes and food availability for the world's poorest, especially in those communities with the least resources to adjust and diversify activities in the face of warmer and more extreme weather (Nelson et al., 2009; Allison et al., 2009). When people are hungry for prolonged periods, they not only suffer illness and potentially death as a result of acute nutritional imbalances, but may also become seriously predisposed to illness and death from other diseases, such as pneumonia, diarrheal infections, malaria, and measles, dramatically expanding the death toll that is attributable to hunger (WHO, 2004).

CLIMATE MECHANISM

The effects of climate change on agriculture and fisheries are well covered in other sections of this report and extensively examined in the scientific, development, and humanitarian literature (IPCC, 2007; UNDP, 2007; World Bank, 2010). Rising heat, increasing variability, overabundance, or absence of rainfall, flooding, drought, disease and insect infestations are real threats to agricultural communities around the world (Parry et al., 2004; Gregory et al., 2009). Coastal areas are endangered by the rise in sea levels and the depletion of fish populations (Dasgupta et al., 2009; Allison et al., 2009). Increasing temperatures are making it difficult for subsistence farmers to accomplish the same amount of work in a given day and leave them few options other than to go hungry when food availability and/or incomes fall below critical levels (Kjellstrom et al., 2009b). Communities outside of the subsistence spectrum are much better able to adjust to the effects of climate change and minimize losses.

IMPACTS

The global impact of climate change on rates of hunger causes more than 200,000 deaths each year, half of which are among children in low-income countries. This implies that over 200 million people each year are affected by hunger as a result of climate change. Anticipated increases in socio-economic development should continue to reduce the global burden of malnutrition deaths into the future (Mathers and Loncar, 2005). However, unless actions are taken by 2030, nearly 400,000 lives could be lost each year, and the number of people affected could exceed 400 million. Lower-income developing countries of Africa and Asia are worst affected, with Sub-Saharan Africa, least developed, and land-locked developing countries dominating the list of those hit hardest. However, even as the scale of the problem expands, researchers project a decrease in the number of countries suffering the most acute effects, resulting from expected socio-economic development over the next 20 years. India suffers more than half of all the hunger effects of climate change, with an estimated climate change-aggravated death toll in excess of 100,000 people yearly. Bangladesh, Indonesia, Nigeria, and Pakistan are also heavily affected.

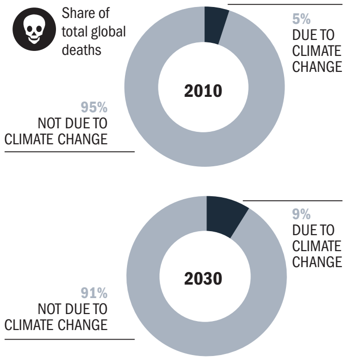
THE BROADER CONTEXT

Poverty is declining. Although serious progress has been made on the MDGs, despite the array of challenges faced, the important goal for hunger is not among the success stories (UN, 2012). More than 2 million children die each year solely as a result of undernutrition (WHO, 2009). The number of people living with hunger has been stable for decades and remains undiminished by the opposing forces of rapidly expanding income and population growth. Food prices adjusted to inflation were at their highest in the 1960s and 1970s, declining until around 2000, at which point they have continued to rise, culminating in current new highs (FAO, 2011).

VULNERABILITIES AND WIDER OUTCOMES

The world's poorest groups spend virtually all their income on food,

BIGGER PICTURE

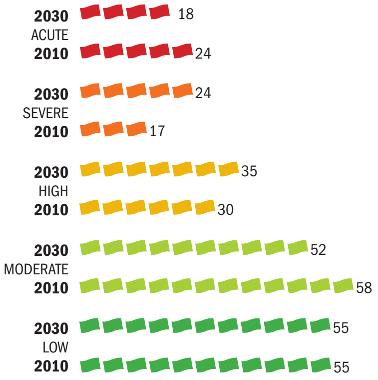


SURGE

OCCURRENCE

N/A

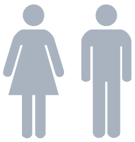
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: McMichael et al., 2004

EMISSION SCENARIO: S750 (IPCC, 2007)

BASE DATA: WHO BDD, 2011

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

making them more vulnerable to shifts in food prices. Issues affecting food prices include fuel oil, food preferences, population and income growth, trade regulations, extreme weather, and macroeconomic sensitivities in commodity markets, to name a few (FAO, 2011). Welfare is most compromised when affected communities are less able to take autonomous action in response to additional pressures from climate change. By far the worst off are subsistence, small-scale farmers, and fishermen in developing countries (Morton, 2007; Nelson et al., 2009). Hunger stalls development progress. This can be understood through analysis of the effects that sickness and death from hunger have across the full spectrum of the MDGs. First, Goal 1, aimed at eradicating hunger itself. Goal 2, aimed at universalizing primary education is affected, since school attendance rates are lowest in communities with the highest levels of malnutrition; this, in turn, affects Goal 3 (gender equality), since it prevents girls from beginning school (Glewwe and Jacoby, 1993; UN, 2012). Goal 4, which aims to reduce child mortality is affected, since hunger is a vicious killer of children and infants under 5—around 50% of all mortality). The close interlinkages between malnutrition, child and maternal health also imply serious effects for maternal health (Goal 5) (Black et al., 2008). Finally, progress towards MDG Goal 6, aiming to significantly reduce HIV/AIDS, malaria and other diseases is also threatened, since a majority of deaths from hunger occur as a result of diseases for which low weight is a key risk factor, especially malaria, pneumonia, diarrheal diseases, and measles (WHO, 2004).

RESPONSES

First and foremost is the humanitarian imperative to intervene and avert highly preventable deaths as a result of hunger aggravated by climate change (Parry et al., 2009). The inability of the international community to defuse the simultaneous and ongoing Horn of Africa and Sahelean food crises is a testament to the lack of preparedness and the inadequacy of contemporary responses to food security emergencies (Oxfam, 2012; CARE, 2012).

There is no vaccine for hunger. Decades of development commitments and foreign aid have not eradicated global hunger. Trade conditions continue to disfavour equitable food availability for many of the world's poor, and the World Trade Organization negotiations offer faint hope for the world's most vulnerable groups despite the solutions proposed (FAO, 2011; Moser and Rose, 2012; Priyadarshi, 2009).

Development programmes, it is hoped, will become more effective (Brown and Funk, 2009). The Ghana country study in this report emphasizes what steps must be taken to counteract the pressure on the disposable income of food-stressed families and communities. Without these sensible steps, it will be challenging to adopt and sustain the wide range of sensible technical or social protection measures which could limit risks, through insurance policies, new seed and fertilizer purchases, or investments in irrigation infrastructure, capital, and financial resources (Parry et al., 2009). Possibilities for expanding the purchasing power of the most vulnerable communities could be created through the promotion of small-scale agricultural industries that increase options for farmers to access and sell their goods in global supply chains. It is possible to enable rural communities currently locked out of global markets to benefit from higher food prices, rather than, as net importers of food, to suffer from them (Swinnen and Squicciarinim, 2012).

THE INDICATOR

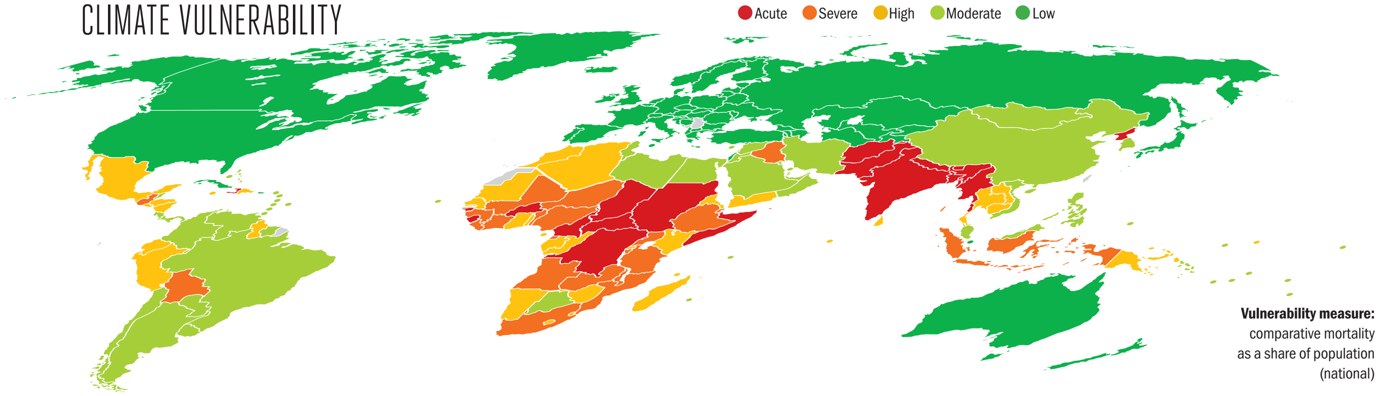
The indicator measures the risk for malnutrition and disease for which low-weight is a principal risk factor as a result of global climate change (WHO, 2004). It relies on the latest global health data updated by the World Health Organization (WHO BDD, 2011). Scientists and the IPCC have recognized the challenges of hunger in the context of climate change. In addition to socio-economic considerations, which add layers of complexity and potential error, the many uncertainties related to impacts on agriculture apply to hunger. Nevertheless, the scientific community is virtually unanimous that lower-income groups are profoundly affected by the impacts of climate change on agriculture (Loetze-Campen et al. in Edenhofer et al., 2012). The indicator could have benefitted from the use of updated emission scenarios than those upon which the base model is built. The base model includes carbon fertilization, which is otherwise considered a "carbon" issue in this report.

ESTIMATES COUNTRY-LEVEL IMPACT

	☠		🧍	
COUNTRY	2010	2030	2010	2030
ACUTE				
Afghanistan	5,750	7,500	5,000	6,500
Bangladesh	9,750	15,000	10,000	15,000
Bhutan	60	150	65	150
Burkina Faso	1,750	1,750	800	850
Cameroon	1,500	1,750	750	800
Central African Republic	250	400	150	250
Chad	1,250	1,500	650	700
DR Congo	4,750	7,500	3,000	4,750
Guinea-Bissau	200	200	85	90
Haiti	600	800	750	1,000
India	100,000	250,000	150,000	250,000
Myanmar	5,250	7,750	5,750	8,500
Nepal	2,000	2,500	2,000	2,750
North Korea	1,750	2,500	2,000	2,750
Pakistan	10,000	25,000	9,750	20,000
Sierra Leone	650	700	300	350
Somalia	1,750	2,000	1,500	1,750
Sudan/South Sudan	3,250	4,000	2,750	3,500
SEVERE				
Angola	1,750	2,000	850	900
Benin	600	650	300	300
Bolivia	300	650	400	850
Burundi	400	600	250	400
Cote d'Ivoire	850	1,250	550	850
Djibouti	40	50	35	45
Equatorial Guinea	50	50	25	25
Ethiopia	3,250	5,250	2,000	3,250
Gambia	85	90	40	45
Guatemala	500	1,000	650	1,500
Guinea	800	850	400	400
Indonesia	7,500	10,000	9,500	15,000
Iraq	850	2,000	750	1,750
Liberia	250	250	100	150
Malawi	650	1,000	400	650
Mali	1,250	1,500	650	700
Mozambique	1,000	1,750	650	1,000
Niger	1,500	1,750	750	800
Nigeria	10,000	10,000	5,250	5,500
South Africa	1,250	1,750	700	1,250
Tanzania	1,500	2,500	950	1,500
Timor-Leste	35	50	35	55
Uganda	1,500	2,250	850	1,250
Zambia	600	900	350	550
HIGH				
Algeria	550	600	250	300
Cambodia	200	300	900	1,250
Comoros	35	35	15	20
Congo	150	200	80	150
Dominican Republic	100	200	250	450
Ecuador	200	350	250	450
El Salvador	75	150	150	350
Eritrea	85	150	50	80
Gabon	40	45	20	20
Ghana	900	950	450	450
Guyana	10	15	25	30
Honduras	80	150	200	350
Jamaica	35	65	85	150
Kenya	800	1,250	500	750
Laos	85	100	350	500
Lesotho	30	50	20	30
Madagascar	600	650	300	300
Maldives	5	10	5	10
Marshall Islands	1	1	1	5
Mauritania	150	150	75	75
Mexico	1,000	1,750	2,250	4,000
Morocco	500	600	450	500
Namibia	30	45	20	30
Nicaragua	70	150	90	200
Papua New Guinea	95	200	450	900
Peru	650	1,250	800	1,500
Rwanda	350	550	200	350
Sao Tome and Principe	5	5	1	1
Senegal	550	550	250	250
Sri Lanka	200	350	250	450
Swaziland	20	35	15	20
Thailand	1,000	1,500	1,250	2,000
Togo	250	300	150	150
Yemen	1,250	1,500	1,000	1,500
Zimbabwe	250	400	150	250
MODERATE				
Antigua and Barbuda	1	1	1	1
Argentina	300	500	650	1,250
Bahamas	1	1	1	5
Bahrain	1	1	5	5
Barbados	1	1	5	5
Belize	1	5	5	10
Botswana	15	25	10	15
Brazil	1,250	2,500	3,000	5,500
Cape Verde	5	5	5	5
Chile	85	150	200	350
China	1,750	2,750	7,500	10,000
Colombia	250	450	500	950
Costa Rica	5	10	15	25
Cyprus	1	1	5	10
Dominica	1	1	1	1

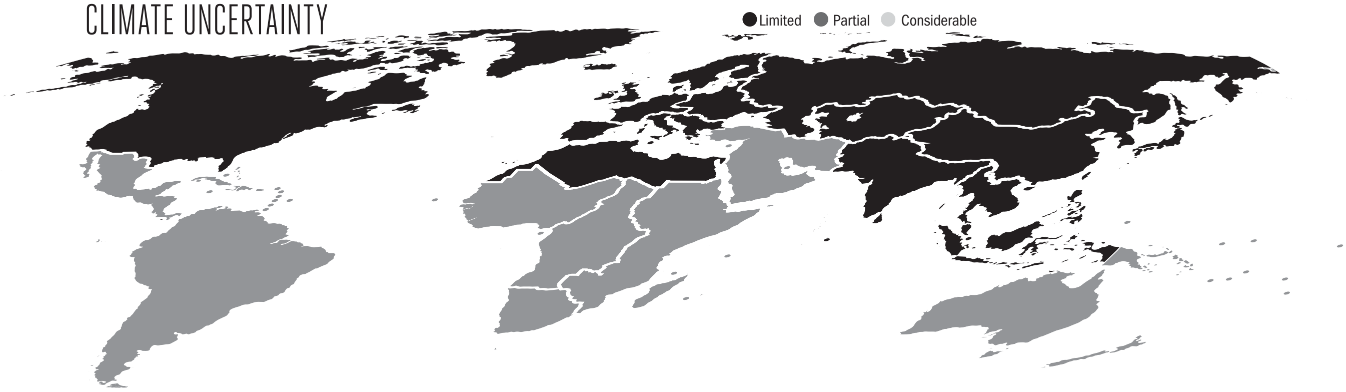
☠ Additional mortality due to climate change - yearly average

CLIMATE VULNERABILITY



Vulnerability measure:
comparative mortality
as a share of population
(national)

CLIMATE UNCERTAINTY



	☠		👤	
COUNTRY	2010	2030	2010	2030
Egypt	600	750	550	650
Fiji	5	5	15	25
Grenada	1	1	1	1
Iran	200	400	900	1,750
Jordan	20	45	85	200
Kiribati	1	1	5	5
Kuwait	1	5	10	15
Lebanon	5	15	30	55
Libya	15	20	70	80
Malaysia	75	100	350	450
Mauritius	5	5	1	1
Micronesia	1	1	5	5
Mongolia	5	15	35	60
Oman	1	5	5	20
Palau				1
Panama	20	35	50	85
Paraguay	40	90	95	200
Philippines	550	700	2,250	3,250
Qatar		1	1	1
Saint Lucia	1	1	1	1
Saint Vincent	1	1	1	5
Samoa	1	1	5	10
Saudi Arabia	55	150	250	550
Seychelles	1	1	1	1
Solomon Islands	5	5	15	20
South Korea	55	90	250	400
Suriname	1	5	5	10
Syria	50	100	200	450
Tonga	1	1	1	5
Trinidad and Tobago	5	10	15	25
Tunisia	75	85	300	350
Tuvalu				1
United Arab Emirates	5	10	20	35
Uruguay	25	40	55	90
Vanuatu	1	1	5	10
Venezuela	90	150	200	400
Vietnam	200	250	850	1,250
LOW				
Albania				
Armenia				
Australia				
Austria				
Azerbaijan				
Belarus				
Belgium				
Bosnia and Herzegovina				
Brunei				
Bulgaria				
Canada				
Croatia				
Cuba				
Czech Republic				
Denmark				
Estonia				
Finland				
France				
Georgia				
Germany				
Greece				
Hungary				
Iceland				
Ireland				
Israel				
Italy				
Japan				
Kazakhstan				
Kyrgyzstan				
Latvia				
Lithuania				
Luxembourg				
Macedonia				
Malta				
Moldova				
Netherlands				
New Zealand				
Norway				
Poland				
Portugal				
Romania				
Russia				
Singapore				
Slovakia				
Slovenia				
Spain				
Sweden				
Switzerland				
Tajikistan				
Turkey				
Turkmenistan				
Ukraine				
United Kingdom				
United States				
Uzbekistan				

👤 Additional persons affected due to climate change (thousands) - yearly average

MALARIA & VECTOR-BORNE

ESTIMATES GLOBAL CLIMATE IMPACT

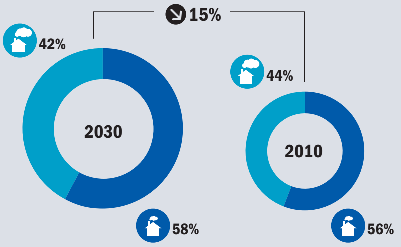
2010 EFFECT TODAY

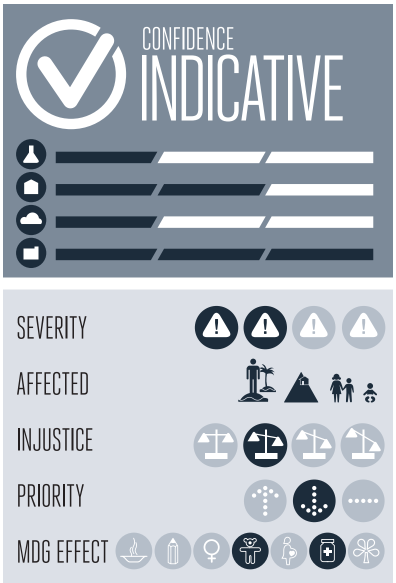
DEATHS PER YEAR **20,000**

2030 EFFECT TOMORROW

DEATHS PER YEAR **20,000**

MORTALITY IMPACT





CONFIDENCE

INDICATIVE

SEVERITY

AFFECTED

INJUSTICE

PRIORITY

MDG EFFECT

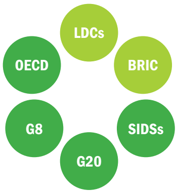
- Malaria is a large-scale cause of illness, with over 90% of deaths occurring among children in tropical regions, in particular in Africa and the Pacific
- Malaria and other vector-borne diseases have declined over the last decade, as a result of poverty reduction and anti-malaria programmes
- Vector-borne diseases are sensitive to climate; as climate becomes warmer and wetter, changes to their prevalence will slow and complicate efforts aimed at eradication
- Fighting vector-borne diseases is highly cost effective; minimizing vulnerability requires action to reduce or eradicate prevalence and increase the resilience of populations affected

RELATIVE IMPACT

HOTSPOTS

2010		2030
6,000	**DR CONGO**	5,750
1,750	**MOZAMBIQUE**	1,750
1,750	**TANZANIA**	1,750
1,500	**UGANDA**	1,500
2,250	**NIGERIA**	1,250

GEOPOLITICAL VULNERABILITY



Deaths

Developing Country Low Emitters

Developing Country High Emitters

Developed

Other Industrialized

= Deaths per 10 million

Change in relation to overall global population and/or GDP

A major cause of illness in developing countries, climate change will worsen the burden of vector-borne diseases, although it is difficult to predict with any precision the areas that will be worst affected (IPCC, 2007). Countries that already have serious malaria burdens should expect to see an aggravation of these diseases, due to increasing temperatures and other climate-related phenomena. Such aggravations will be offset to some degree through anticipated socio-economic development in the predominantly lower-income countries in which these diseases are most prevalent (Mathers and Loncar, 2005). But vector-borne outbreaks are also re-occurring in places where they have long been absent: a yellow fever epidemic in Uganda in 2010 was the first in 20 years (Rosenberg and Beard, 2011). As climate change brings warmer weather to colder places, the range of vector-borne disease is also shifting from the tropics, and to higher altitudes, as insects and other vectors roam further afield. In the US for instance, Leishmaniasis, a vector-borne disease originating in Mexico and Texas has begun to shift further north (González et al., 2010). Communities now linked by globalization are also becoming exposed to higher risks, as illustrated for instance by a colony of yellow fever mosquitoes recently found in Holland (Enserink, 2010). Successful international programmes fighting these diseases should be reinforced in areas of particular risk, in order to safeguard against set-backs due to climate change in the fight to eradicate malaria and control other deadly vector-borne diseases (WHO and RBMP, 2010).

CLIMATE MECHANISM

Climate change is understood to enable the shift in vector-borne diseases like malaria, dengue, and yellow fever in several ways. As mountainous areas warm up for instance, vectors, such as mosquitos, would reach higher altitudes and increase exposure to disease in zones adjacent to affected areas; the same can be said of higher latitudes at the boundaries of current areas of infection. Transmission conditions and seasons are likely to expand in warm areas where rainfall used to be too low to support vectors, but now will increase. Temperature changes affect incubation rates and, together with range changes, increase the amount of time people are exposed to insect bites (Jetten and Focks, 1997). However, transmission could also decline, due to a drop in rainfall and temperature peaks—beyond which diseases like malaria cannot thrive—or due to very high rainfall that washes away insect larvae (WHO, 2004 and 2011). At a smaller scale, temperatures also influence the survival rates of mosquitoes (Martens et al., 1999). As was pointed out in the Ghana country study in this report, climate change also affects human behaviour, as, for instance, when people sleep outside on the hottest nights without mosquito net protection, significantly increasing their risk of contracting vector-borne diseases.

IMPACTS

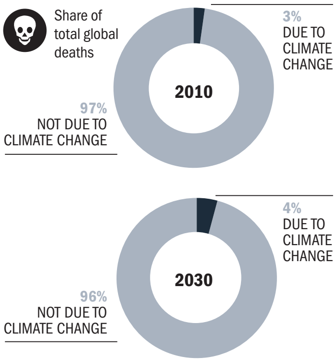
The impact of climate change on the key vector-borne diseases of malaria, dengue fever and yellow fever is estimated to be over 20,000 deaths a year today, with 6 million people affected.

Fourteen African and Pacific island countries are estimated to suffer Acute and Severe levels of vulnerability to the effects of climate change on vector-borne disease; most of these countries are land-locked developing countries, such as the Central African Republic or Zambia, or small island developing states, such as the Solomon Islands. The greatest total effects are estimated to occur in the DR Congo, with nearly 6,000 additional deaths due to vector-borne diseases in 2010. Five other countries also suffer large scale effects in the thousands: Nigeria, Mozambique, Tanzania, Uganda, and Côte d'Ivoire. By 2030, the effect of climate change on malaria is expected not to change since it is expected that there will be continued large-scale reductions in the prevalence of malaria, due mainly to economic growth over this 20-year period. In fact, as a proportion of population, malaria is estimated to decrease as a concern under these assumptions.

THE BROADER CONTEXT

According to the World Health Organization, malaria has undergone a major reduction in its overall prevalence in the last decade, falling from 1.2 million deaths in 2000 to 0.8 million deaths in 2008. However, most of the reduction occurred in the first years of the decade: over the four-year period between 2004 and 2008, there was a reduction of only 60,000 deaths (WHO BDD, 2000 and 2011). However, even at lowered rates of death, malaria

BIGGER PICTURE

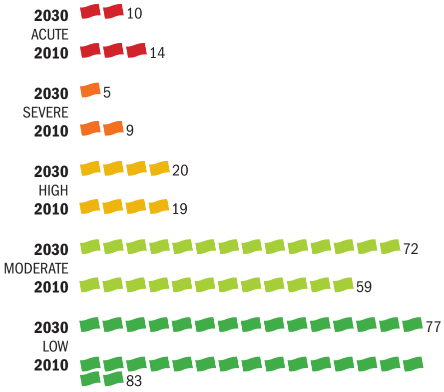


SURGE

OCCURRENCE

N/A

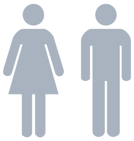
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: McMichael et al., 2004

EMISSION SCENARIO: S750 (IPCC, 2007)

BASE DATA: WHO BDD, 2011

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

is considered one of the largest global contributors to sickness. Interpretations of the scale of the disease also vary dramatically, with some estimating more than 5 billion clinical episodes that resemble, and could be characterized as, malaria occurring in endemic areas annually (DCPP, 2006). Other factors, such as economic growth, will likely compensate for increased risks due to climate change, but they will also slow efforts to eradicate these diseases (Reiter, 2001).

Given that climate-aggravated malaria is highly prevalent in impoverished rural communities, delaying efforts to eradicate the disease will also delay development progress. As people in the affected communities also have a high propensity to migrate, malaria could also be carried to new areas, generating epidemics (Haleset al., 2000).

VULNERABILITIES AND WIDER OUTCOMES

Experts have identified various determinants of malaria and vector-borne diseases. Environmental conditions play an important role, such as high temperatures, high rainfall, and humidity, together with pools of still, sun-drenched water (WHO, 2009). Social vulnerabilities include the level of education enabling people to take preventative measures, such as draining mosquito ponds, or address environmental predispositions to disease (Garg et al., 2009). Finally, poverty seriously inhibits access to medicine, vaccines, and preventative measures, such as insecticides and bed nets (Breman, 2001).

Given that some 6 million people are affected, the economic productivity of those worst hit communities is jeopardized. For example, when members of rural, subsistence families lose working hours because of illness, their already minimal disposable income will be threatened further. The Ghana country study in this report illustrated how in malaria-infested areas, people were often ill several times in a given year. One study has showed how a 10% reduction in malaria is associated with a 0.3% increase in economic growth (Gallup and Sachs, 2001). With over 90% of the death toll assessed here affecting children under 15, a greater challenge faces those making efforts to improve child health, such as through attainment of Millennium Development Goal 4 for reducing child mortality.

RESPONSES

Responses are numerous and comprise preventative and treatment-type actions. Drugs and vaccines through national or region-specific immunization programmes (for dengue and yellow fever, not malaria), insecticide-treated bed nets, use of pesticides outdoors, insecticide for personal use and indoors, and civil engineering projects to drain malaria breeding sites are all key components of the anti-malaria and vector-borne response toolkit. Access to affordable health services, including through low-cost health insurance, is also critical for the speedy diagnosis and treatment of disease. Education and awareness can also help to raise the level of preventative responses and encourage health services to be sought soon after the onset of symptoms. Aside from civil infrastructure projects, vector-borne disease control is considered to be highly cost effective (DCPP, 2006).

THE INDICATOR

The indicator measures the effect of climate change on malaria, dengue fever, and yellow fever, based on World Health Organization research and data (WHO, 2004; WHO BDD, 2011). The climate change effect on malaria is used as a proxy for dengue and yellow fever, since research suggests similar mechanics apply (Epstein, 2001; Hales et al., 2002). Uncertainties in climate parameters, particularly rainfall, environmental, and socio-economic factors call into question the reliability of all estimations. The indicator is also conservative from the perspective that it does not take into account a variety of other vector-borne diseases, whose prevalence may also be significantly influenced by climate change, such as viral encephalitis, schistosomiasis, leishmaniasis, Lyme disease, and onchocerciasis (WHO, 2003).

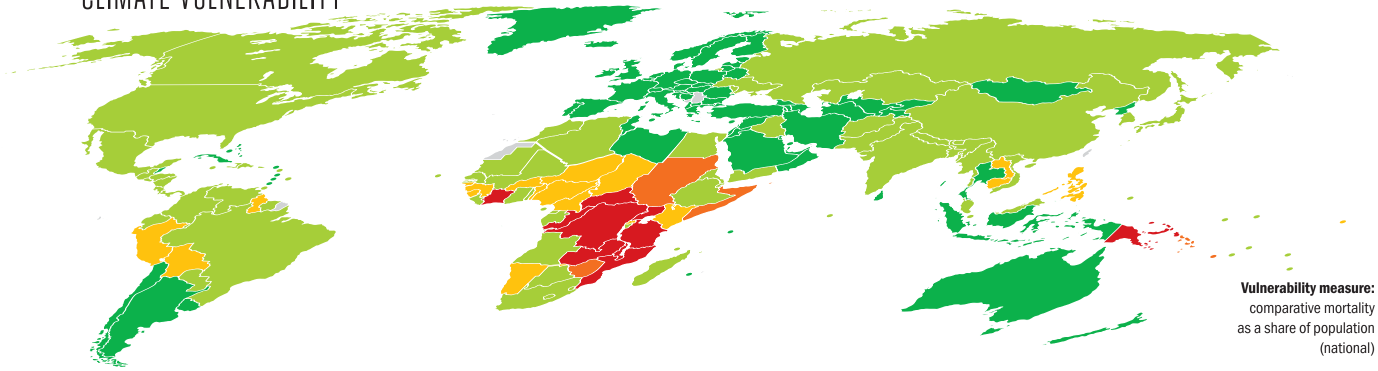
ESTIMATES COUNTRY-LEVEL IMPACT

	☠		🚹	
COUNTRY	2010	2030	2010	2030
ACUTE				
Central African Republic	400	400	100,000	100,000
Congo	200	200	55,000	55,000
Cote d'Ivoire	1,250	1,250	300,000	300,000
DR Congo	6,000	5,750	1,500,000	1,500,000
Malawi	600	600	150,000	150,000
Mozambique	1,750	1,750	500,000	450,000
Papua New Guinea	400	850	100,000	250,000
Tanzania	1,750	1,750	450,000	450,000
Uganda	1,500	1,500	400,000	400,000
Zambia	600	600	150,000	150,000
SEVERE				
Solomon Islands	20	15	5,250	4,500
Somalia	200	200	50,000	60,000
Sudan/South Sudan	750	950	200,000	300,000
Vanuatu	1	5	1,250	2,500
Zimbabwe	250	250	65,000	60,000
HIGH				
Benin	95	60	25,000	20,000
Bolivia	60	150	35,000	70,000
Burkina Faso	350	200	90,000	50,000
Burundi	150	150	40,000	40,000
Cambodia	90	90	25,000	30,000
Cameroon	250	150	65,000	40,000
Chad	250	150	65,000	35,000
Guinea	200	100	50,000	35,000
Guinea-Bissau	30	20	8,500	4,750
Guyana	1	5	800	1,250
Kenya	250	250	65,000	70,000
Kiribati	1	1	150	350
Laos	40	50	15,000	20,000
Namibia	30	30	10,000	10,000
Niger	250	150	70,000	40,000
Nigeria	2,250	1,250	600,000	400,000
Peru	100	200	60,000	100,000
Philippines	450	900	250,000	500,000
Rwanda	70	65	20,000	20,000
Sierra Leone	150	75	35,000	20,000
MODERATE				
Afghanistan	10	15	2,750	6,000
Algeria			5	5
Angola	150	90	65,000	35,000
Bangladesh		45		15,000
Barbados			5	15
Bhutan				100
Botswana	1	1	400	400
Brazil	100	250	55,000	100,000
Canada			100	150
Cape Verde			5	1
China	50	80	25,000	45,000
Colombia	45	100	25,000	55,000
Comoros	5	1	1,000	550
Costa Rica			20	55
Djibouti	1	1	350	400
Dominica			10	15
Dominican Republic	10	20	5,250	10,000
Ecuador	10	20	5,500	10,000
Egypt	10	10	4,250	5,000
El Salvador	1	5	900	2,000
Equatorial Guinea	5	5	2,750	1,500
Eritrea	1	1	450	450
Ethiopia	400	400	100,000	100,000
Fiji	1	1	350	550
Gabon	5	5	2,250	1,500
Gambia	15	10	4,000	2,250
Ghana	100	65	30,000	20,000
Guatemala	1	5	800	1,750
Haiti	35	45	10,000	20,000
Honduras	5	10	2,500	6,000
India		300		95,000
Iraq			5	15
Jamaica			5	5
Japan			100	150
Kazakhstan			80	150
Lesotho			25	35
Liberia	40	25	10,000	6,750
Madagascar	15	10	4,250	2,250
Malaysia	30	50	10,000	20,000
Maldives				75
Mali	150	90	45,000	25,000
Marshall Islands			65	150
Mauritania	10	5	3,000	1,750
Mexico	1	5	700	1,500
Micronesia			45	95
Moldova			35	65
Morocco			1	5
Myanmar		85		25,000
Nepal		1		450
Nicaragua	1	5	800	1,750
Pakistan	100	400	40,000	100,000
Palau			5	10
Panama			1	1
Paraguay			1	5
Russia	1	1	300	450
Samoa		1	150	300
Sao Tome and Principe			40	20

☠ Additional mortality due to climate change - yearly average

CLIMATE VULNERABILITY

● Acute ● Severe ● High ● Moderate ● Low



Vulnerability measure: comparative mortality as a share of population (national)

CLIMATE UNCERTAINTY

● Limited ● Partial ● Considerable

	☠		👤	
COUNTRY	2010	2030	2010	2030
Senegal	100	65	30,000	20,000
Singapore	1	1	250	300
South Africa	5	5	2,000	2,000
South Korea	1	1	350	600
Suriname	1	1	500	1,000
Swaziland			75	75
Togo	40	25	10,000	6,250
Tonga		1	85	200
Trinidad and Tobago			20	40
Tuvalu			5	5
Ukraine	1	1	200	300
United States	1	1	600	1,000
Venezuela	15	30	5,250	15,000
Vietnam	40	55	15,000	25,000
Yemen	80	95	20,000	25,000
LOW				
Albania				
Antigua and Barbuda				
Argentina				
Armenia				
Australia				
Austria				
Azerbaijan				
Bahamas				
Bahrain				
Belarus				
Belgium				
Belize				
Bosnia and Herzegovina				
Brunei				
Bulgaria				
Chile				
Croatia				
Cuba				
Cyprus				
Czech Republic				
Denmark				
Estonia				
Finland				
France				
Georgia				
Germany				
Greece				
Grenada				
Hungary				
Iceland				
Indonesia				
Iran				
Ireland				
Israel				
Italy				
Jordan				
Kuwait				
Kyrgyzstan				
Latvia				
Lebanon				
Libya				
Lithuania				
Luxembourg				
Macedonia				
Malta				
Mauritius				
Mongolia				
Netherlands				
New Zealand				
North Korea				
Norway				
Oman				
Poland				
Portugal				
Qatar				
Romania				
Saint Lucia				
Saint Vincent				
Saudi Arabia				
Seychelles				
Slovakia				
Slovenia				
Spain				
Sri Lanka				
Sweden				
Switzerland				
Syria				
Tajikistan				
Thailand				
Timor-Leste				
Tunisia				
Turkey				
Turkmenistan				
United Arab Emirates				
United Kingdom				
Uruguay				
Uzbekistan				

👤 Additional persons affected due to climate change - yearly average

MENINGITIS

ESTIMATES GLOBAL CLIMATE IMPACT

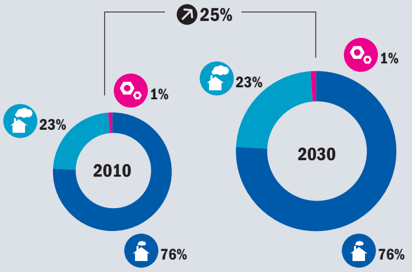
2010 EFFECT TODAY

DEATHS PER YEAR **30,000**

2030 EFFECT TOMORROW

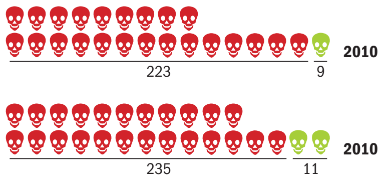
DEATHS PER YEAR **40,000**

MORTALITY IMPACT



- Meningitis is growing worldwide and claims around 350,000 lives a year
- Humidity levels, wind, and dust are linked to outbreaks of the disease, factors actively influenced by climate change
- A "meningitis belt" stretches across northern Sub-Saharan Africa from Senegal to Ethiopia, sharing dusty and dry conditions, favouring meningitis
- Vaccines exist, but hundreds of millions of people living in risk areas around the world create a serious challenge for mass immunization
- Broader vulnerability measures, such as health education campaigns and improved sanitation will also be crucial

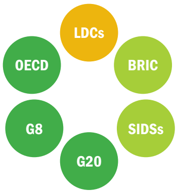
RELATIVE IMPACT



HOTSPOTS

2010		2030
6,500	**INDIA**	8,000
3,500	**NIGERIA**	5,250
2,000	**DR CONGO**	3,750
2,000	**ETHIOPIA**	3,000
800	**TANZANIA**	1,250

GEOPOLITICAL VULNERABILITY



Deaths
Developing Country Low Emitters
Developing Country High Emitters
Developed
Other Industrialized

= Deaths per 10 million

Change in relation to overall global population and/or GDP

Meningitis is a lethal and greatly feared disease in affected areas, because of the rapid onset of symptoms and serious risk of mortality, as well as high rates of infection—as many as 1 per 1,000 in parts of the African Sahel (Adamo et al., 2011). With mortality having more than doubled since the year 2000 and risks escalating as a result of climate change, mass inoculation is an attractive and life-saving component of any response to this growing challenge. However, beyond tackling the disease itself, it is also critical to address underlying vulnerabilities, such as over-grazing, soil degradation, deforestation, and the lack of adequate sanitation.

CLIMATE MECHANISM

The fact that meningococcal meningitis is largely a seasonal disease indicates the extent to which its prevalence is determined by weather-related parameters directly affected by climate change. Models that attempt to recreate meningitis epidemics show a high degree of success when calibrated with climate and environmental parameters. Meningitis epidemics are more likely to occur during the hottest, driest periods which are accompanied by high dust content in the air, and thus most likely to abate with the onset of the rainy season (Molesworth et al., 2006). The bacteria which causes meningitis is spread from person to person through coughing and sneezing, much like influenza or the common cold, and can be spread through poor sanitation (WHO, 2011; Schonning and Stenström, 2004). Bacteria can be present in a significant proportion of a population in areas affected by meningitis, but still remain benign.

Dust is a key trigger, because it damages the tissues of the nose and throat, facilitating the passage of pathogenic meningitis bacteria into the bloodstream (Thomson et al., 2009). Climate change affects both weather (heat, humidity, wind) and the environment (extent of vegetation or desertification) and can increase heat, dust, and wind, resulting in exposure and creating peaks of meningitis (Patz et al., 1996; Sultan et al., 2005). Climate change intensifies those factors that most determine meningitis outbreaks, particularly humidity (drought) and dust levels for areas that will become more arid (Sheffield and Wood, 2008; Prospero and Lamb, 2003).

IMPACTS

The global impact of climate change on meningitis is estimated to cause around 20,000 deaths a year in 2010, with 50,000 people affected. Some 30 countries are acutely vulnerable to the impact of climate change on meningitis exclusively in Africa, both inside and beyond the meningitis belt.

Least developed and landlocked countries of Africa are significantly more vulnerable than countries with even marginally higher levels of development. The largest impacts are estimated to occur in India, with nearly 7,000 deaths, and in Nigeria, the DR Congo, and Ethiopia, each of which is estimated to have an annual death toll in the thousands.

As incidence of the disease is rapidly increasing, it is expected to moderately expand through to 2030 and increase proportionate to population growth, claiming over 40,000 a year by 2030 with 80,000 people affected each year.

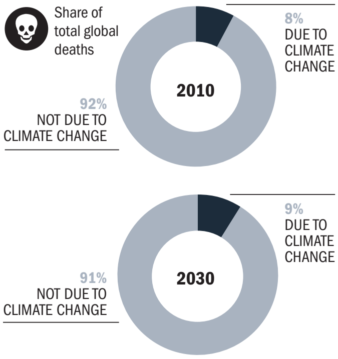
THE BROADER CONTEXT

Meningitis underwent explosive growth in the first decade of the 21st century, doubling from just over 150,000 deaths in 2000, to well over 350,000 deaths a year by 2008—this in spite of a dramatic increase in economic development during that period. Meningitis is one of the few communicable diseases to have rapidly expanded in the past decade (WHO BDD, 2011).

VULNERABILITIES AND WIDER OUTCOMES

Pockets of environmental vulnerability to meningitis exist around the world, but outside of Africa, India makes up a large share of the remainder of the global burden of the disease. Environmental predispositions to meningitis are exacerbated through land degradation, such as deforestation, over-irrigation, and over-grazing—effects that also generate the dry and dusty conditions that are most favourable to meningitis (Nicholson et al., 1998). The incidence of meningitis is also closely related to cramped living conditions and poor sanitation, inadequate hygiene and access to water, since infection is carried through human contact, coughing, and sneezing (WHO, 2011). Levels of awareness and education can affect understanding of the disease and largely determine the measures taken by individuals to prevent contracting the

BIGGER PICTURE

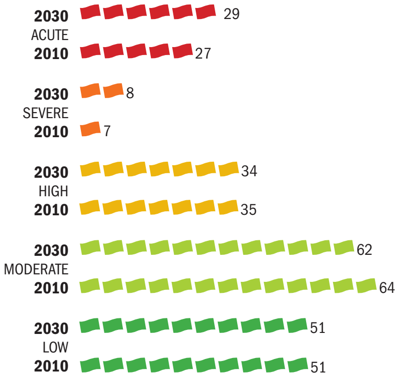


SURGE

OCCURRENCE

N/A

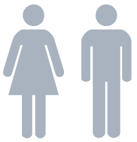
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: Adamo et al., 2011; Sheffield and Wood, 2008

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

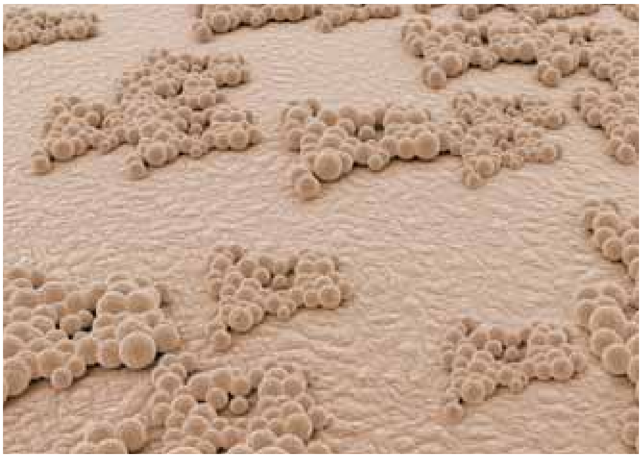
BASE DATA: WHO BDD, 2011

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

disease (Nutbeam, 2000).

Given the high prevalence of meningitis among some of the world's poorest communities, the impact of climate change on the disease is a serious concern for human development progress (Arora, 2001). More tangibly, the increasing prevalence of meningitis with its high death rate among children—around two-thirds of all mortality—limits progress in lag regions towards the achievement of Millennium Development Goal 4, which aims to tangibly reduce child mortality (WHO BDD, 2011).



RESPONSES

Meningitis is one of the few major deadly infectious diseases affecting developing countries for which several effective vaccines already exist. Immunization is a particularly cost effective response.

There are now several success stories in the fight against meningitis, where programmes have managed to significantly reduce the burden of the disease (Kshirsagar et al., 2007; LaForce and Okwo-Bele, 2011).

Given the large scale of the populations at risk—in Africa alone comparable to the entire population of the US—full breadth vaccination becomes prohibitively expensive, even using the lowest-cost solutions available. For this reason, response strategies to meningitis outbreaks have favoured early warning monitoring and vaccine interventions at the community level, when outbreaks of meningitis exceed a certain threshold (LaForce et al., 2007). Although newer, more effective meningitis vaccines are currently being disseminated in affected zones of the Sahel which promise to dramatically reduce the incidence of meningitis, it could take a full decade to provide them for the required numbers (Thomson et al., 2009).

Improving sanitation and living conditions, promoting education and awareness, and tackling environmental issues, including overgrazing, deforestation and land degradation will address the underlying causes of meningitis, in addition to ensuring the other well known benefits of such actions (DCPP, 2006; Nutbeam, 2000; Donohoe, 2003).

THE INDICATOR

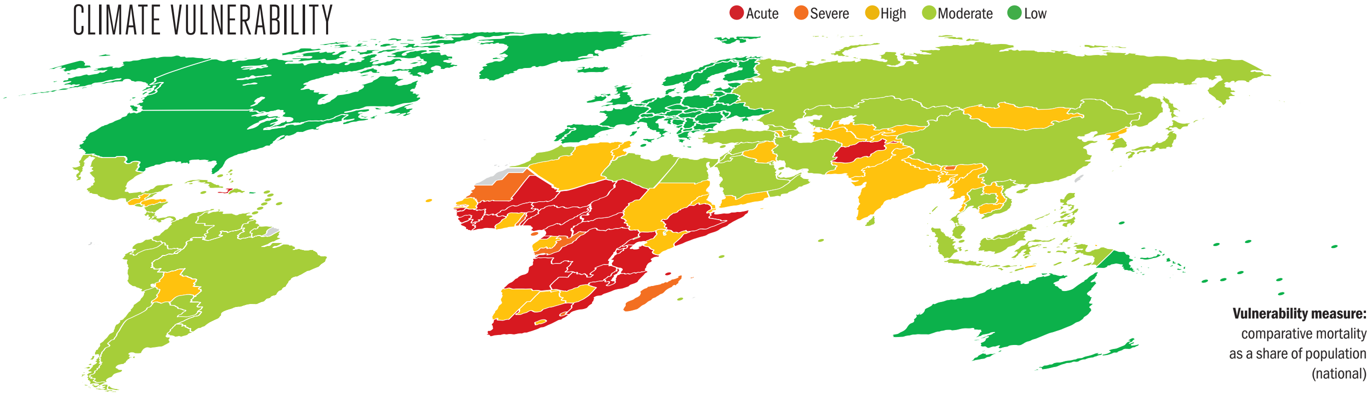
The indicator is a simple model that relates the incidence of meningitis to the incidence of drought. Global changes in the frequency of drought were linked to a meningitis risk model and population density, the indicator being highly sensitive to the latter, since close human contact is a major vulnerability driver for meningitis outbreaks (Sheffield and Wood, 2007; Adamo et al., 2011). The indicator then draws on the main WHO database to estimate how the current burden of meningitis evolves as drought incidence changes (WHO, 2011; WHO BDD, 2011). Uncertainty in relation to the climate effect is present due to the unpredictability of future rainfall patterns, a determining factor of drought.

ESTIMATES COUNTRY-LEVEL IMPACT

	☠		🧍	
COUNTRY	2010	2030	2010	2030
ACUTE				
Afghanistan	500	850	850	1,250
Angola	500	900	1,250	2,500
Benin	250	350	350	600
Burkina Faso	300	600	500	950
Burundi	200	300	300	500
Cameroon	500	700	800	1,250
Central African Republic	90	150	150	200
Chad	300	550	500	850
Comoros	15	25	25	35
Cote d,Ivoire	450	600	700	1,000
DR Congo	2,000	3,750	3,250	6,000
Equatorial Guinea	15	25	50	85
Ethiopia	2,000	3,000	3,250	5,000
Guinea	250	400	400	600
Guinea-Bissau	65	100	100	150
Haiti	200	300	350	500
Liberia	90	150	150	300
Malawi	400	650	650	1,000
Mali	250	400	400	650
Mozambique	400	550	600	900
Niger	450	800	700	1,250
Nigeria	3,500	5,250	5,500	8,750
Rwanda	150	250	250	400
Sierra Leone	150	300	300	450
Somalia	150	250	250	450
South Africa	700	700	2,250	2,250
Tanzania	800	1,250	1,250	2,000
Uganda	500	900	800	1,500
Zambia	250	400	400	600
SEVERE				
Bhutan	5	10	10	15
Congo	40	75	65	100
Gambia	15	25	30	40
Madagascar	200	300	300	500
Mauritania	45	75	70	100
Sao Tome and Principe	1	1	1	5
Swaziland	10	10	25	35
Togo	65	100	100	150
HIGH				
Algeria	150	200	350	550
Armenia	10	10	20	25
Bangladesh	600	800	950	1,250
Bolivia	45	75	150	200
Botswana	15	15	45	55
Cambodia	100	150	200	250
Cape Verde	1	5	5	10
Djibouti	5	5	10	15
Eritrea	25	35	40	60
Gabon	10	15	35	55
Ghana	95	150	150	200
Guatemala	50	90	150	250
Honduras	20	35	55	90
India	6,500	8,000	10,000	15,000
Iraq	150	250	400	700
Kenya	200	300	350	450
Kyrgyzstan	20	30	35	50
Laos	50	65	80	100
Lesotho	15	20	30	30
Mongolia	10	10	15	15
Myanmar	250	300	400	500
Namibia	10	15	25	40
Nepal	100	200	200	300
North Korea	90	100	150	150
Pakistan	700	1,000	1,250	1,750
Senegal	100	150	150	250
Sudan/South Sudan	350	550	550	900
Tajikistan	55	80	85	150
Timor-Leste	5	5	10	10
Tunisia	45	60	100	150
Turkmenistan	25	35	60	95
Uzbekistan	90	150	150	200
Yemen	150	300	200	500
Zimbabwe	85	100	150	200
MODERATE				
Antigua and Barbuda				
Argentina	40	55	150	200
Azerbaijan	20	25	55	70
Bahamas			1	1
Bahrain	1	1	5	10
Barbados			1	1
Belize			1	1
Brazil	200	300	550	750
Brunei			1	1
Chile	10	15	35	50
China	800	850	2,000	2,250
Colombia	55	75	150	200
Costa Rica	5	5	10	15
Cuba	5	5	15	20
Cyprus			1	1
Dominica				
Dominican Republic	15	20	40	60
Ecuador	20	30	55	80
Egypt	200	300	500	800
El Salvador	10	15	30	45
Georgia	5	5	15	15

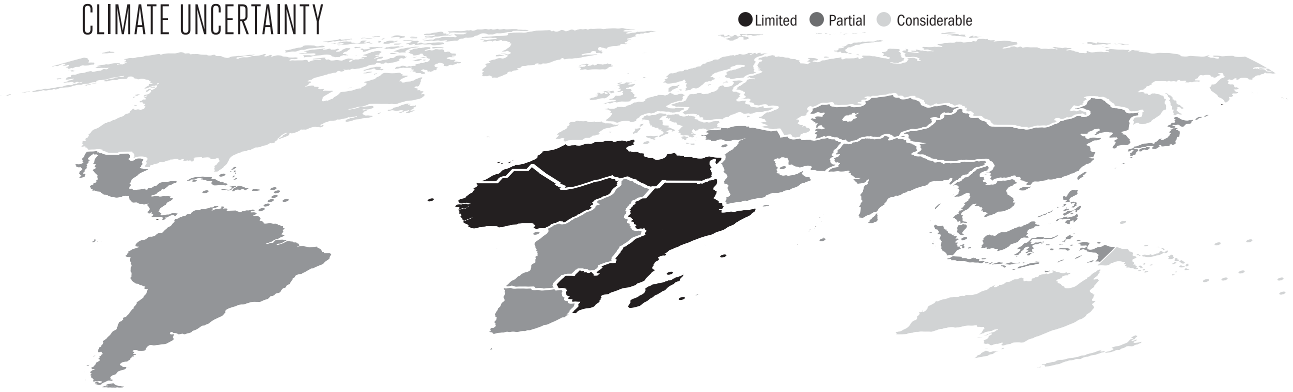
☠ Additional mortality due to climate change - yearly average

CLIMATE VULNERABILITY



Vulnerability measure:
comparative mortality
as a share of population
(national)

CLIMATE UNCERTAINTY



	☠		🚹	
COUNTRY	2010	2030	2010	2030
Grenada				1
Guyana	1	1	1	1
Indonesia	550	650	1,500	1,750
Iran	65	90	150	250
Israel	1	5	25	35
Jamaica	5	10	15	20
Japan	25	25	250	250
Jordan	10	15	25	40
Kazakhstan	40	45	100	100
Kuwait	1	1	5	10
Lebanon	5	5	15	25
Libya	5	10	20	25
Malaysia	10	15	30	40
Maldives	1	1	1	1
Mauritius	1	1	5	5
Mexico	30	45	100	150
Morocco	40	55	100	150
Nicaragua	15	20	20	35
Oman	1	1	1	5
Panama	5	5	10	20
Paraguay	15	25	40	65
Peru	55	75	150	200
Philippines	200	250	500	650
Qatar			1	1
Russia	200	200	650	650
Saint Lucia			1	1
Saint Vincent				
Saudi Arabia	15	25	150	300
Seychelles			1	1
Singapore	1	1	5	5
South Korea	5	5	45	50
Sri Lanka	25	25	65	75
Suriname	1	1	5	5
Syria	30	50	80	150
Thailand	40	50	100	150
Trinidad and Tobago	1	1	5	5
Turkey	100	150	350	450
United Arab Emirates	5	5	30	45
Uruguay	1	5	10	10
Venezuela	25	40	85	100
Vietnam	70	85	100	150
LOW				
Albania				
Australia				
Austria				
Belarus				
Belgium				
Bosnia and Herzegovina				
Bulgaria				
Canada				
Croatia				
Czech Republic				
Denmark				
Estonia				
Fiji				
Finland				
France				
Germany				
Greece				
Hungary				
Iceland				
Ireland				
Italy				
Kiribati				
Latvia				
Lithuania				
Luxembourg				
Macedonia				
Malta				
Marshall Islands				
Micronesia				
Moldova				
Netherlands				
New Zealand				
Norway				
Palau				
Papua New Guinea				
Poland				
Portugal				
Romania				
Samoa				
Slovakia				
Slovenia				
Solomon Islands				
Spain				
Sweden				
Switzerland				
Tonga				
Tuvalu				
Ukraine				
United Kingdom				
United States				
Vanuatu				

🚹 Additional persons affected due to climate change (thousands) - yearly average

INDUSTRY STRESS

AGRICULTURE

FISHERIES

FORESTRY

HYDRO ENERGY

TOURISM

TRANSPORT

50 BILLION LOSS	2010	●●●●	▶▶▶
350 BILLION LOSS	2030		
15 BILLION LOSS	2010	●●●○	▶▶▶
150 BILLION LOSS	2030		
5 BILLION LOSS	2010	●●○○	▶▶
45 BILLION LOSS	2030		
5 BILLION GAIN	2010	●○○○	◀◀
25 BILLION GAIN	2030		
NIL	2010	●●○○	❚❚
NIL	2030		
1 BILLION LOSS	2010	●●○○	▶
5 BILLION LOSS	2030		

AGRICULTURE

ESTIMATES GLOBAL CLIMATE IMPACT

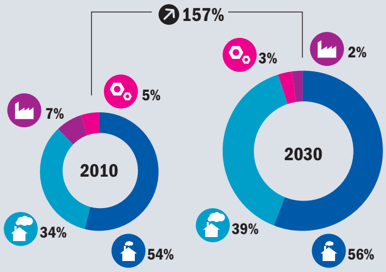
2010 EFFECT TODAY

USD **LOSS** PER YEAR **50 BILLION**

2030 EFFECT TOMORROW

USD **LOSS** PER YEAR **350 BILLION**

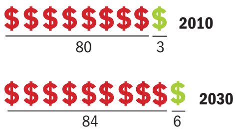
ECONOMIC IMPACT



CONFIDENCE
INDICATIVE

- Land-based agriculture is the sector worst affected by climate change, while global demand for food and agricultural products is booming
- Africa is most vulnerable, but several large Asian economies, small islands, and parts of Latin America also suffer
- The worst-affected economies have the highest shares of agricultural workers, so impacts will likely worsen national unemployment
- Adaptation responses abound, but technical solutions are not viable where farmers lack the means to take measures or finance them
- Extreme effects on rural subsistence farmers clearly delays human development, causing new food emergencies

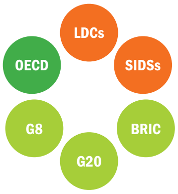
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
15,000	**INDIA**	100,000
5,500	**CHINA**	55,000
1,500	**PAKISTAN**	15,000
1,250	**THAILAND**	10,000
1,250	**INDONESIA**	9,500

GEOPOLITICAL VULNERABILITY



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

$ = Losses per 10,000 USD of GDP

↗ Change in relation to overall global population and/or GDP

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

Agriculture was one of the first sectors widely recognized to be heavily affected by climate change (IPCC, 1990; Cline, 1992). Agriculture is one of the most significant and best studied impacts of climate change assessed in the Monitor, and for many, the best known (Nordhaus and Boyer, 1999). Within regions and countries, some will be affected, while others will benefit (Bindi and Olesen, 2011). Climate change will have a particularly serious impact on farmers with limited possibilities for adapting to shifts in climate, e.g., by planting different varieties of plants and implementing new irrigation techniques (Kurukulasuriya et al., 2006; Easterling in Hillel and Rosenzweig (eds.), 2011). Agricultural losses from climate change harm subsistence farmers whose insufficient income or capital reserves prevent them from taking steps to adapt to weather change (IPCC, 2007). In developing countries with economies still heavily reliant on agriculture, the negative effects for this sector are estimated to be severe and widespread (World Bank Data, 2012). The research undertaken as a part of the Monitor's development underscored the importance of empowering vulnerable farmers to generate more value for their products in order to break the vicious spiral of poverty (see in particular the Ghana country study).

CLIMATE MECHANISM

Climate change increases heat stress and evaporation, and aggravates drought (Hansen et al., 2007). While many of these also change in relation to natural weather phenomena such as El Niño, recent evidence suggests a shift to more extreme warm weather conditions (Jung et al., 2010; Hansen et al., 2012). Climate change is altering the pattern of rainfall, which may become more or less abundant or more erratic (Kharin et al., 2007). Rainfall shifts can damage those crops and livestock, which are less suited to the changing weather or susceptible to disease or declining yield. Agricultural losses can be measured when climate deviates from optimal growing conditions, resulting in lower yield per acre (Cline, 2007). Gradual changes can be compounded by more extreme weather, especially large-scale floods (Mueller and Quisumbing, 2011).

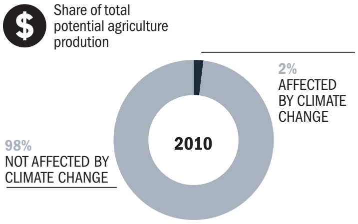
IMPACTS

Globally, climate change is already estimated to cause 50 billion dollars a year in agricultural losses, around 90% of which occur in developing countries, since the sector accounts for between just 1–5% of GDP in most developed countries. However, costs are still relatively small in most countries, except for a small handful of the most vulnerable, some of whom are already estimated to lose 1–2% of GDP. Low-income and least developed countries are more vulnerable and suffer the most extreme effects, creating serious concern for food security. Regionally, Sub-Saharan Africa is singled out, Central, East, and West Africa most seriously. Latin America, the Pacific, and parts of Asia also have elevated levels of vulnerability. India and China are currently estimated to suffer the greatest share of the total impact, each with 2010 losses estimated at over 5 billion dollars a year. A small fraction of countries are expected to experience any gains in the agricultural sector in the near future. The scale of effect jumps rapidly over the course of 20 years from less than 0.1% of global income in 2010, more than doubling as a share of global GDP to about 0.2% in 2030, or over 350 billion dollars in yearly losses. However, the rate of increase in damage is declining: as the share of global output in service and industrial sectors grows, agriculture is expected to continue to lose importance—in line with the expansion of industrialization over the next 20 years (OECD, 2012).

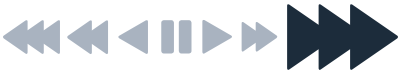
THE BROADER CONTEXT

The agricultural sector is also struggling to meet the food demands of growing and wealthier populations (FAOSTAT, 2012; Friedman, 2009). But climate change is preventing the sector from meeting this demand, as indicated by both scientific research and statistical analysis (Cline, 2007). It will also lower the comparative advantage of agriculture-based, lower-income economies, with effects estimated to be especially severe for Africa (Nelson et al., 2009; Tol, 2011). Nevertheless, carbon fertilization—through which high concentrations of CO2 in the atmosphere might improve plant productivity and agricultural outputs—is understood by researchers to outweigh losses due to climate change at least early on (Mendelsohn in Griffin (ed.), 2003). This effect is accounted for in the Carbon section of the Monitor; where large-scale benefits are estimated by the IPCC to be possible, they never outweigh the costs of climate

BIGGER PICTURE



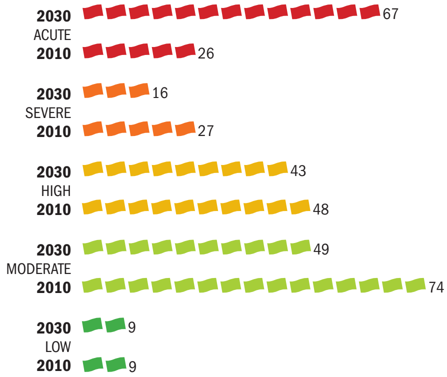
SURGE



OCCURRENCE

N/A

VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS

INDICATOR INFORMATION

MODEL: Cline, 2007

EMISSION SCENARIO: Cline, 2007

BASE DATA: FAOSTAT (2012)

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

change estimated here (IPCC, 2007). Recent research has been cautious about the practical realisation of these benefits (Ainsworth et al., 2008; Leaky et al., 2009). A World Bank study recently suggested that a high carbon fertilization effect would reduce adaptation costs by less than 10% (World Bank, 2010).

VULNERABILITIES AND WIDER OUTCOMES

Underscoring the vulnerability of developing countries, especially the least developed, is the significance at the national level of the size and composition of the agricultural sector in terms of output and workforce.

One of the few advantages that small-scale farmers have over large commercial operators is the ability to adjust crop varieties or experiment more readily with different crops. Agricultural companies that practice large-scale mono-cropping may suffer correspondingly large losses, if climate conditions shifted to the disadvantage of the chosen crops (Brondizio and Moran, 2008). Countries that rely heavily on just one or two cash crops face similar concerns, as highlighted in the Ghana country study in this report. Poor environmental protection also increases vulnerability, such as when biodiversity losses inhibit resistance to invasive species (Castree et al. (eds.), 2009). In general, rainfed-only agriculture is much more vulnerable than irrigated land (Kurukulasuriya et al., 2006).

Communities reliant on subsistence farming are dangerously vulnerable, as global warming accelerates; the World Health Organization has estimated climate change to be a major driver of contemporary malnutrition (WHO, 2004). These health effects are measured in the Health Impact section of the Monitor.

Climate change is a major risk for food insecurity, since a number of the world's food-insecure regions are expected to experience the most severe climate shocks (Lobell et al., 2008). Indeed, climate effects on agriculture harm development, since they diminish the disposable incomes of communities already struggling to achieve gains (UNDP, 2007). They also drive the seasonal rural-urban migration of young adults, as shown by the Ghana country study.

RESPONSES

The vast literature on the impact of climate change on agriculture cannot be summarized here. All societies are understood to be "adaptive," but communities differ considerably in this capacity (Adger et al., 2003; Dixon et al., 2003). Response options vary widely, including from large-scale or micro irrigation infrastructure, to index-based weather insurance, new/hybrid seeds, and education/rural extension programmes. The involvement of local communities in the design of adaptation measures is advised, so that initiatives are feasible and practical (Smit and Wandel, 2006). The Monitor's country studies emphasize that where farmers cannot afford to take measures, efforts should focus on increasing capacity for investment and enabling local products to access more lucrative global supply chains and markets. Farmers with growing incomes could make better use of parallel extension schemes that offer appropriate adaptation options. Development plans that promote biodiversity and crop and livestock diversification will also lower vulnerability to plant and animal disease. Macroeconomic risks can only be offset by ensuring steady growth of less sensitive industrial and service sectors.

THE INDICATOR

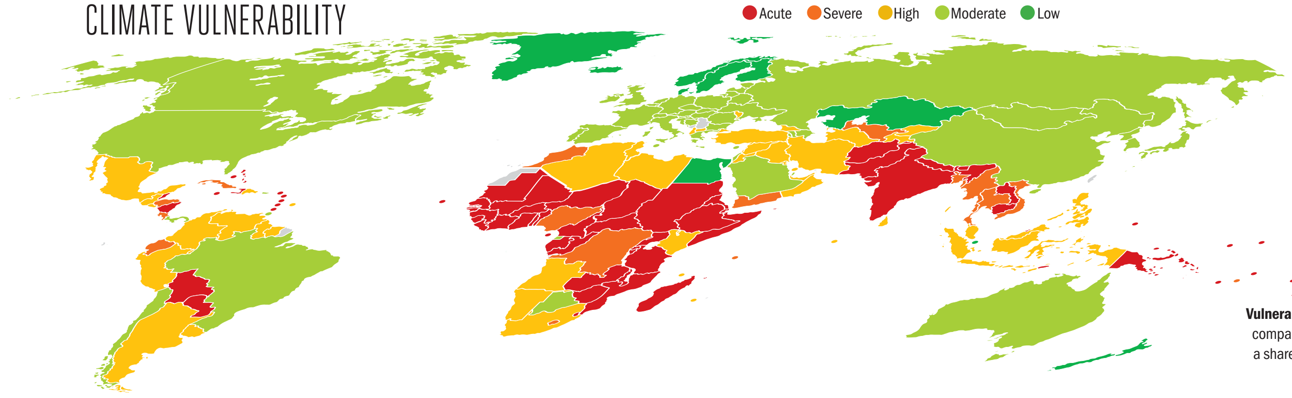
This Indicator relies on a recent and comprehensive global review of agricultural impacts of climate change that combines a wealth of experience from a range of methods and models (Cline, 2007). The difficulties in predicting rainfall accurately make some regions more uncertain about agriculture outcomes. Carbon fertilization or other effects related to atmospheric pollutants are not considered here. The Monitor accounts for the effect under Agriculture in the Carbon section of this report.

ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	$ 2010	$ 2030
ACUTE		
Afghanistan	85	700
Antigua and Barbuda	5	45
Bahamas	45	350
Belize	10	75
Benin	90	600
Bhutan	10	100
Bolivia	150	1,250
Brunei	75	650
Burkina Faso	70	450
Burundi	60	400
Cambodia	100	1,500
Cameroon	200	1,250
Cape Verde	5	45
Central African Republic	50	350
Chad	60	400
Congo	50	350
Cote d'Ivoire	150	900
Djibouti	10	70
Dominica	5	25
Eritrea	15	85
Ethiopia	450	3,000
Gabon	300	2,000
Gambia	15	100
Ghana	200	1,500
Grenada	5	35
Guinea	150	900
Guinea-Bissau	15	100
Haiti	35	300
India	15,000	100,000
Jamaica	250	2,000
Kiribati	1	20
Laos	90	1,000
Liberia	15	100
Madagascar	100	800
Malawi	150	1,000
Mali	150	1,000
Marshall Islands	1	15
Mauritania	40	250
Micronesia	5	30
Mozambique	100	800
Nepal	150	1,250
Nicaragua	55	450
Niger	65	450
Pakistan	1,500	15,000
Palau	1	10
Papua New Guinea	45	350
Paraguay	150	1,250
Rwanda	100	750
Saint Lucia	5	50
Saint Vincent	5	30
Samoa	5	30
Sao Tome and Principe	1	15
Senegal	250	1,750
Sierra Leone	30	200
Solomon Islands	5	60
Somalia	35	250
Sudan/South Sudan	650	5,000
Swaziland	15	100
Tanzania	350	2,500
Timor-Leste	10	80
Togo	55	400
Tonga	5	25
Tuvalu		1
Uganda	150	1,000
Vanuatu	5	40
Zambia	85	600
Zimbabwe	75	500
SEVERE		
Bangladesh	650	5,500
Costa Rica	100	850
Cuba	250	2,000
DR Congo	60	400
Ecuador	200	1,500
Fiji	10	75
Honduras	75	600
Lesotho	10	55
Morocco	400	3,000
Myanmar	200	1,500
Nigeria	900	6,250
Seychelles	5	30
Thailand	1,250	10,000
Uzbekistan	200	1,500
Vietnam	550	6,000
Yemen	100	800
HIGH		
Albania	15	100
Algeria	300	2,250
Angola	150	1,000
Argentina	550	4,500
Bahrain	25	200
Barbados	5	45
Colombia	300	2,500
Comoros	1	5
Dominican Republic	150	1,000
El Salvador	60	500

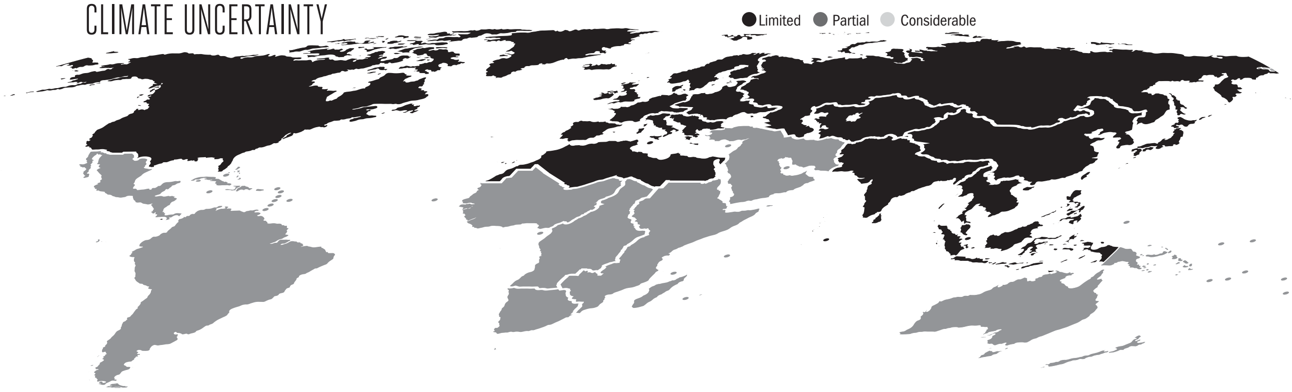
$ Additional economic costs due to climate change (million USD PPP) - yearly average

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY



$

COUNTRY	2010	2030
Georgia	15	100
Guatemala	100	850
Guyana	5	55
Indonesia	1,250	9,500
Iran	1,250	8,750
Iraq	150	1,000
Jordan	20	150
Kenya	60	400
Kuwait	95	750
Kyrgyzstan	15	100
Lebanon	70	550
Libya	150	1,000
Macedonia	15	100
Malaysia	500	4,000
Maldives	1	25
Mauritius	25	200
Mexico	1,250	7,750
Moldova	15	90
Namibia	10	80
Oman	60	500
Peru	250	2,000
Philippines	550	4,500
South Africa	550	3,750
Sri Lanka	100	900
Suriname	5	35
Syria	90	700
Tajikistan	15	100
Tunisia	150	1,000
Turkey	1,250	3,000
Turkmenistan	40	300
United Arab Emirates	200	1,500
Uruguay	30	250
Venezuela	350	2,750
MODERATE		
Armenia	5	45
Australia	450	1,000
Austria	15	35
Azerbaijan	25	200
Belarus	55	400
Belgium	35	85
Bosnia and Herzegovina	10	90
Botswana	1	10
Brazil	900	6,750
Bulgaria	40	250
Canada	35	80
Chile	150	800
China	5,500	55,000
Croatia	25	150
Cyprus	1	1
Czech Republic	25	100
Equatorial Guinea	5	50
Estonia	5	20
France	300	700
Germany	90	200
Greece	200	450
Hungary	30	150
Ireland	1	5
Israel	80	450
Italy	300	650
Japan	450	1,000
Latvia	5	30
Lithuania	15	100
Luxembourg		1
Malta		1
Mongolia	1	15
Netherlands	50	100
North Korea	10	100
Panama	20	150
Poland	90	500
Portugal	65	150
Qatar	1	10
Romania	100	800
Russia	400	2,750
Saudi Arabia	100	950
Slovakia	10	50
Slovenia	5	30
South Korea	550	3,250
Spain	350	850
Switzerland	10	25
Trinidad and Tobago	10	75
Ukraine	150	1,250
United Kingdom	60	150
United States	1,000	2,500
LOW		
Denmark	-25	-60
Egypt	-350	-2,750
Finland	-15	-35
Iceland		-1
Kazakhstan	-55	-400
New Zealand	-5	-10
Norway	-5	-15
Singapore		
Sweden	-20	-40

FISHERIES

ESTIMATES GLOBAL CLIMATE IMPACT

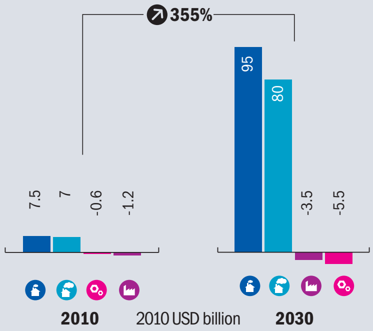
2010 EFFECT TODAY

USD **LOSS** PER YEAR **15 BILLION**

2030 EFFECT TOMORROW

USD **LOSS** PER YEAR **150 BILLION**

ECONOMIC IMPACT



SEVERITY

AFFECTED

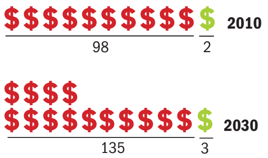
INJUSTICE

PRIORITY

MDG EFFECT

- Climate change is not just occurring over land, but also underwater
- Water temperature also rises as the planet heats up
- Over 1,000 commercially exploited fish species live in specific aquatic zones already affected: the location of their preferred waters shift as the tropics reach temperatures with no analogue to existing fish habitats and as cooler seas disappear
- Falling fish stocks will affect food security and human development in low-income fishing communities
- Increasing the sustainability of fishing operations and enhancing marine conservation zones may alleviate these strains

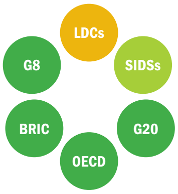
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
1,500	**VIETNAM**	25,000
1,500	**CHINA**	15,000
1,250	**PERU**	15,000
700	**THAILAND**	8,500
650	**INDONESIA**	7,750

GEOPOLITICAL VULNERABILITY



$ Economic Cost (2010 PPP non-discounted)

Developing Country Low Emitters | Developed

Developing Country High Emitters | Other Industrialized

$ = Losses per 10,000 USD of GDP

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

↗ Change in relation to overall global population and/or GDP

As climate change warms the world's oceans, seas, lakes and rivers, it is fundamentally changing the marine habitat, forcing fish to migrate or perish (Perry et al., 2005; Ficke et al., 2007; Rijnsdorp et al., 2009; Last et al., 2010; Cheung et al., 2011; Engelhard, 2011). Some far northern or southern zones may experience improved stocks as sea ice recedes and fish from the hottest waters seek relative cool (Hiddink and Hofstede, 2008). Declines brought about by climate change will only increase over time as temperature rise accelerates (Cheung et al., 2009). The world's fish stocks are in large-scale, long-term decline, with the ocean fish catch now half what it was 50 years ago due to an increase in commercial catch boats and unsustainable fishing (FAO, 2007; Watson et al., 2012). Climate change is the most significant driver of global marine ecosystem decline (Halpern et al., 2008). Responding effectively is challenging, since the international cooperation and regulations required are notoriously difficult to conclude, monitor, and enforce (Barkin in Dinar (ed.), 2011). In developing countries hard hit by declining fish stocks, food security and livelihoods are at risk (Srinivasan et al., 2010).

CLIMATE MECHANISM

Water temperature is a defining element of fish habitat (Hoegh-Guldberg and Bruno, 2010). Fish have low tolerance for thermal extremes (Pörtner and Rainer Knust, 2007). Part of the sea-level rise from climate change is caused by the thermal expansion of the seas as they warm (Domingues et al., 2008). As equatorial waters undergo unprecedented temperature increases beyond familiar heat thresholds for fish, the total available range of habitats is disappearing (Cheung et al., 2009). Nutrients are also declining in the warmest waters and reefs suffer as well (Brander, 2007; Munday et al., 2008). Considering the range of interconnected factors involved, from biological processes to changes in ocean current, the types of shocks that could occur in oceans which cover more than 70% of the planet's surface may be underestimated (Harley et al., 2006). The increase in temperature in polar waters shrinks the range of cold-water fish habitats towards the finite limit of the poles. Only the Arctic and southern oceans are compensating species loss by providing new ranges for an invasion of fish from other regions. Nearer the equator, decline will be permanent (Cheung et al., 2009). Inland, similar processes are underway, although with little or no scope for fish migration, depletion could be faster and more permanent (Ficke et al., 2007).

IMPACTS

The current cost of climate change on the fisheries sector is estimated to be about 10 billion dollars a year. By 2030, the impact is expected to be more than triple its share as a cost of global GDP, when estimated losses will be over 160 billion dollars per year.

The Pacific, South and Southeast Asia, and Africa, especially West Africa, are the regions worst hit by fishery sector losses due to climate change. Vietnam and China are estimated to suffer the greatest losses, with current impacts estimated to be in excess of 1 billion dollars per year. Vietnam could experience losses in excess of 20 billion dollars per year by 2030. Bangladesh, Indonesia, Myanmar, Morocco, Peru, and Thailand are also experiencing large-scale losses.

The countries with the most severe impacts relative to GDP include small island countries in the Pacific, such as Vanuatu, Tuvalu, or Micronesia; in the Indian Ocean, the Seychelles; and parts of West Africa, such as Sierra Leone and Gambia. By 2030, losses for these countries all exceed 4% of GDP.

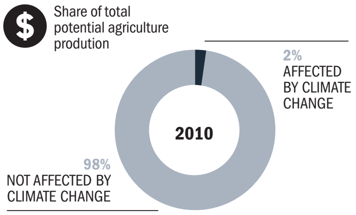
As traditional livelihoods are eroded, developing countries are worst affected, including a number of least developed countries and small island developing states, raising serious concerns for food security and poverty reduction efforts.

Only a handful of countries are expected to gain from the large-scale ecosystem shift, with the largest share attributed to Norway, Russia, and Iceland, and with total gains not exceeding 15 billion dollars in 2030.

THE BROADER CONTEXT

Global fish catch is on a trend toward predictable long-term expansion owing to increases in aquaculture production (Brander, 2007). Global fish stocks, on the other hand, are experiencing a predictable long-term decline, as the number of commercial fishing craft has increased ten-fold since the 1950s, and 25-fold in Asia (Watson et al., 2012). Experts have estimated that marine fisheries declined by 40% between 1970 and 2007 (Hutchings et al., 2010). With or without climate change, global fisheries are endangered (Halpern et al., 2008). Unsustainable fishing

BIGGER PICTURE

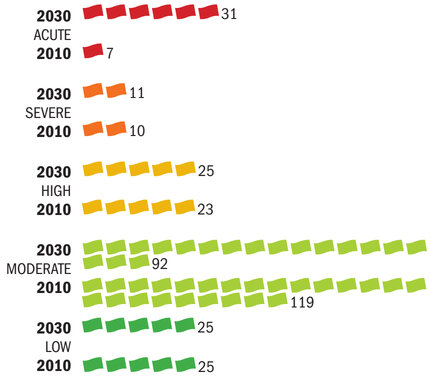


SURGE

OCCURRENCE

N/A

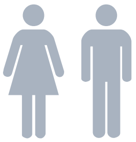
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: Cheung et al., 2010; O´Reilly et al., 2003

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: FAOSTAT (2012)

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

and environmentally unsound fishing practices, such as poison dumping, use of narrow-gauge nets that capture immature fish, bottom-dragging, and illegal fishing are important factors in the decline (Gray, 1997; Agnew et al., 2009; FAO, 2012). Bringing these practices under control will be key to responding to climate change-related fishery impacts.

VULNERABILITIES AND WIDER OUTCOMES

Countries with the highest levels of vulnerability are heavily dominated by lower-income nations which depend to a larger extent on fisheries as a share of GDP and are located in highly exposed latitudes or in particular geographical configurations, such as those near to closed water bodies (Allison et al., 2009). Effects will be most severe for subsistence or near-subsistence fisherfolk and fish-reliant communities, both coastal and inland (Srinivasan et al., 2010). The impacts of climate change on the fishing sector will therefore have significant effects on food security and human development progress and will likely feed migration trends (IOM, 2008; Le Manach et al., 2012).

RESPONSES

Responses concern three main types of fish zones where managed (aquaculture) and unmanaged (commercial) fishing are practised, including oceanic marine fish stocks, inland lake or river fish, and brackish or semi-salt waters.

In marine and inland environments, sustainable fisheries management will be key. This can include the strict setting and implementing of fishing quotas, net size restrictions, poison bans, and control of waters from exploitation, including by foreign fishing interests (Grieve and Short, 2007; FAO, 2007). When catch size reductions are unavoidable, compensatory measures can be implemented to ensure that there is no loss in community welfare; efforts can also be made to diversify livelihoods (Sumaila and Cheung, 2010). The establishment, expansion, and conservation of fish sanctuaries can also play an important role in sustaining or even increasing the resilience of stressed aquatic ecosystems (Gray, 1997).

In brackish environments and in all managed fishing regimes, the quality of otherwise high-risk hatchery production is vital. Post-larvae fish or shrimp carrying disease as they leave hatcheries have the potential to contaminate whole aquaculture farms or systems in an area. Therefore, system-wide quality controls, from hatcheries through nurseries to pre-marketing grow-out ponds, will improve end-to-end resilience and resistance to disease. Here, water temperature is a principal environmental factor (Gilad et al., 2003).

As with agriculture, affected fisherfolk, if given access to higher levels of disposable income and diversified livelihoods, will have more scope for autonomous action (Teh et al., 2008). With surging global demand for food products, more benefits could be gained through strategies that increase the portion of the global value chain enjoyed by small-scale fisherfolk, as highlighted in the Ghana country study in this report. One example is the promotion of local light industrial processing, such as freezing and packaging works for marketing local fish products through global supply chains.

THE INDICATOR

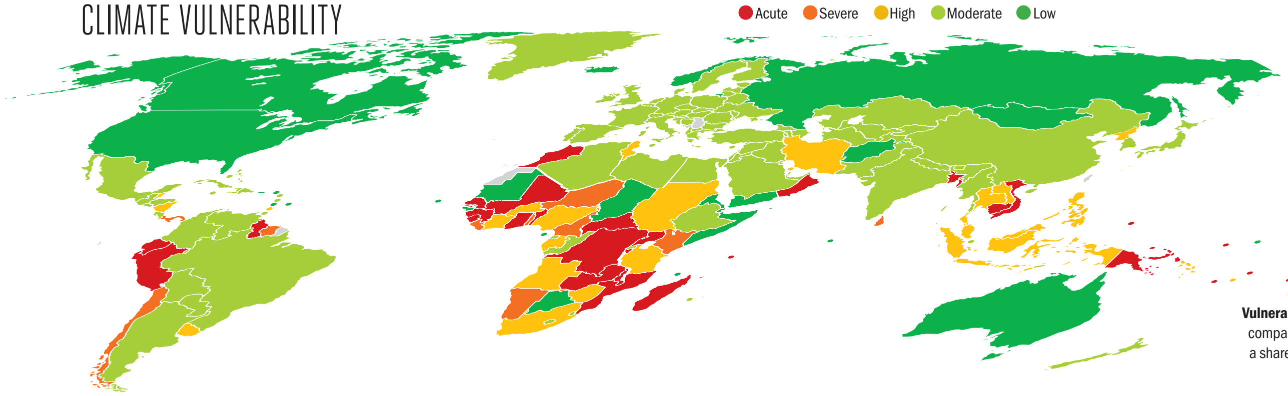
The indicator relies on a global high resolution bio-climate study that maps the change in preferred water climates due to global warming for over a thousand key commercial species, as compared to their current habitats (Cheung et al., 2010). The main limitation is that the inland aspect of the indicator relies on a study carried out in one area (O'Reilly et al., 2003). Ocean temperature changes are fairly well studied and understood and the economic data from the UN Food and Agriculture Organization is comprehensive and accurate, all of which contributes to the robustness of the indicator (Domingues et al., 2008; FAOSTAT, 2012). Economic data on various segments of global fishery production could have been of a higher standard for the purpose of this analysis.

ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	2010	2030
ACUTE		
Bangladesh	500	7,750
Benin	25	350
Burundi	15	200
Cambodia	150	3,000
Central African Republic	10	150
DR Congo	150	1,750
Ecuador	300	3,250
Gambia	45	450
Ghana	200	2,250
Guinea	55	550
Guyana	25	300
Madagascar	65	700
Malawi	60	900
Mali	60	850
Micronesia	15	150
Morocco	650	7,250
Mozambique	65	700
Myanmar	600	7,500
Oman	200	2,000
Palau	1	5
Papua New Guinea	95	1,250
Peru	1,250	15,000
Samoa	5	40
Senegal	90	950
Seychelles	70	700
Sierra Leone	65	650
Tuvalu	1	15
Uganda	200	3,000
Vanuatu	80	950
Vietnam	1,500	25,000
Zambia	35	500
SEVERE		
Cameroon	70	850
Chile	850	6,500
Kenya	90	1,250
Kiribati	1	10
Liberia	1	25
Namibia	30	300
Niger	15	200
Panama	85	1,000
Sri Lanka	150	2,000
Suriname	10	100
Togo	10	150
HIGH		
Angola	80	800
Bahrain	20	200
Belize	1	20
Burkina Faso	10	150
Cote d,Ivoire	20	200
Fiji	5	65
Gabon	20	200
Grenada	1	10
Indonesia	650	7,750
Iran	450	5,000
Laos	5	150
Malaysia	500	5,750
Nicaragua	15	200
Nigeria	300	3,750
North Korea	20	300
Philippines	450	5,000
Solomon Islands	1	20
South Africa	300	3,000
Sudan/South Sudan	40	650
Tanzania	20	300
Thailand	700	8,500
Tonga	1	10
Tunisia	90	1,000
Uruguay	30	350
Zimbabwe	5	70
MODERATE		
Albania	1	20
Algeria	30	350
Argentina	80	950
Armenia		1
Austria		
Azerbaijan		5
Bahamas	1	35
Belarus	1	5
Belgium	1	5
Bhutan		1
Bolivia	5	65
Bosnia and Herzegovina	1	10
Brazil	55	500
Brunei	1	30
Bulgaria	1	25
China	1,500	15,000
Colombia	40	500
Congo	1	20
Costa Rica	5	55
Croatia	5	65
Cuba	5	35
Cyprus	1	5
Czech Republic	1	10
Denmark	35	100
Dominica		1

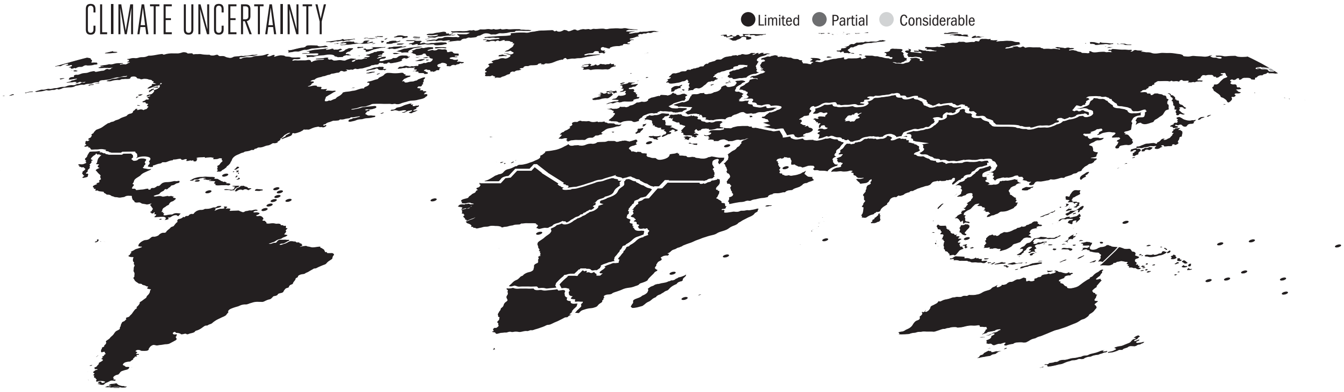
$ Additional economic costs due to climate change (million USD PPP) - yearly average

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY



	$	
COUNTRY	2010	2030
Dominican Republic	5	65
Egypt	150	2,250
El Salvador	5	85
Equatorial Guinea	1	25
Estonia	15	90
Ethiopia	15	200
Finland	15	55
France	30	90
Georgia	10	95
Germany	15	55
Greece	10	25
Guatemala	5	85
Haiti	1	15
Honduras	5	65
Hungary	1	15
India	650	6,000
Iraq	20	250
Ireland		
Israel	1	15
Italy	20	60
Jamaica	5	65
Japan	200	600
Jordan		5
Kazakhstan	5	85
Kuwait	5	40
Kyrgyzstan		
Latvia	15	150
Lebanon	5	35
Lesotho		
Libya	25	300
Lithuania	15	150
Macedonia		1
Malta		1
Mauritius	5	55
Mexico	100	950
Moldova		5
Nepal	5	75
Netherlands	15	45
New Zealand	30	90
Pakistan	100	1,250
Paraguay		5
Poland	25	200
Portugal	20	60
Qatar	10	150
Romania	1	10
Rwanda	5	55
Saint Lucia	1	10
Saudi Arabia	85	950
Singapore	1	10
Slovakia	1	5
Slovenia		1
South Korea	200	1,750
Spain	35	100
Swaziland		
Sweden	10	25
Switzerland		1
Syria	5	80
Tajikistan		1
Timor-Leste		5
Trinidad and Tobago	1	25
Turkey	400	1,250
Turkmenistan	5	65
Ukraine	55	600
United Arab Emirates	40	450
United Kingdom	1	1
Uzbekistan	1	10
Venezuela	65	800
LOW		
Afghanistan		
Antigua and Barbuda		
Australia	-10	-25
Barbados		
Botswana		
Canada	-45	-100
Cape Verde		
Chad		
Comoros		
Djibouti		
Eritrea		
Guinea-Bissau		
Iceland	-350	-1,000
Luxembourg		
Maldives		
Marshall Islands		
Mauritania		
Mongolia		
Norway	-900	-2,750
Russia	-1,250	-8,250
Saint Vincent		
Sao Tome and Principe		
Somalia		
United States	-300	-1,000
Yemen		

FORESTRY

ESTIMATES GLOBAL CLIMATE IMPACT

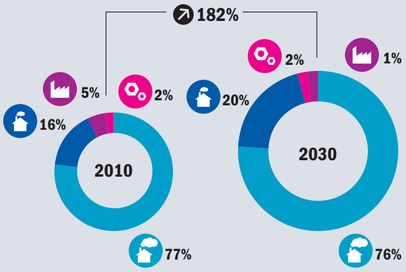
2010 EFFECT TODAY

$ USD **LOSS** PER YEAR **5 BILLION**

2030 EFFECT TOMORROW

$ USD **LOSS** PER YEAR **45 BILLION**

ECONOMIC IMPACT

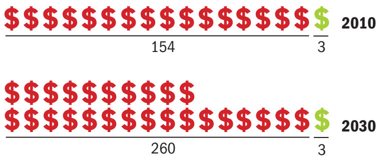


CONFIDENCE
INDICATIVE

SEVERITY	● ● ○ ○
AFFECTED	
INJUSTICE	● ○ ○ ○
PRIORITY	● ○ ○
MDG EFFECT	● ○ ○ ○ ○ ○ ●

- Climate change is shifting the world's climate zones as the planet warms
- As this occurs, commercial and native tree stands are becoming stranded in climate zones with less than optimal growing conditions
- Many forests are suffering from invasive species, more extreme weather, and flooding, further compounding stresses
- As a result, forests in all regions of the world are in decline or a state of flux, although gains in forest area and growth are evident in some regions
- Reversing the large-scale, rampant deforestation of recent decades would help to attenuate new losses due to climate change

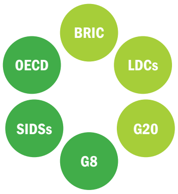
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
2,500	**BRAZIL**	20,000
1,000	**MEXICO**	7,750
450	**ANGOLA**	4,500
400	**VENEZUELA**	4,500
400	**BOLIVIA**	4,250

GEOPOLITICAL VULNERABILITY



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

$ = Losses per 100,000 USD of GDP

Change in relation to overall global population and/or GDP

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

Forests cover nearly one-third of the world's land surface, and both commercial and native forests nearly everywhere are affected by the changing climate (Shvidenko et al. in Hassan et al. (eds.), 2005; Bolte et al., 2009). The potential for large-scale tree diebacks and loss of vegetation and forest biodiversity is considered significant.

As the planet warms, climate zones are shifting, with stationary forests now in inhospitable conditions, triggering rapid decline and widespread tree mortality, although in some cases forests may be expanding into new areas (Gonzalez et al., 2010). The permanence of forests presents a unique challenge in terms of long-term planning and management, such as substituting tree varieties, although this is not a concern for seasonal crop-based agriculture. Communities that rely on forestry in threatened zones, including indigenous groups, are particularly at risk. If empowered through knowledge, resources, and legal support, these same communities can play a key role in helping forests to adapt. Forests are also a vital carbon sink, helping to contain GHG emissions, which widespread tree mortality counteracts (Kurz et al., 2008).

CLIMATE MECHANISM

Heat stress, increased propensity to drought and flooding, all consistent with climate change, can damage tree growth and forest stands (Allen et al., 2009; Lewis et al., 2011; Kramer et al., 2008). Growing risks from fires, pests, and disease are also of concern (Kurz et al., 2008). Above all, it is the shift taking place in forest habitats that outpaces the ability of stationary forests to naturally adapt (Shvidenko et al. in Hassan et al. (eds.), 2005; Bonan, 2008). Particularly affected are those tropical zones already at the maximum heat threshold, which will see further reductions in their viability as rainfall decreases. Boreal forests established at high altitudes or forest stands on permanently frozen land also risk the inevitable disappearance of their natural habitat as warming increases. Elsewhere forests have been observed, and are expected, to grow faster (McMahon et al., 2010).

IMPACTS

The impact of climate change on the world's commercial and native forests is currently estimated to incur annual losses of around 5 billion dollars, increasing by 2030 to around 45 billion dollars or triple the cost as a share of global GDP.

Brazil and Mexico incur the largest overall losses at around 10–20 billion dollars a year in 2030. A number of lower-income countries such as Angola, Central African Republic, Timor Leste and Zambia suffer the most severe effects as a share of GDP. Other South America countries, such as Bolivia, Chile, Colombia, Paraguay, and Venezuela are all also estimated to experience large-scale impacts.

In general, developing countries on all continents are significantly affected. Among developed countries, Australia and Canada stand out, as well as those in Southern Europe, while Russia incurs the largest scale losses among industrialized nations.

The negative effects are quite widespread, with around 50 countries showing vulnerability levels of high or above. Around 20 countries experience gains that are mainly small in scale, with the exception of Argentina, whose gains are already significant, reaching almost 10 billion dollars a year in 2030.

THE BROADER CONTEXT

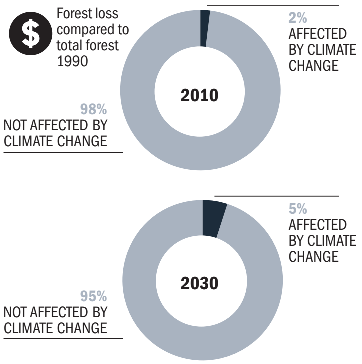
The Forestry sector is relatively stable, with increasing value but fluctuating production over the last decade (FAOSTAT, 2012). Demand for forest products of all kinds including timber is expected to increase significantly over the coming decade. Illegal logging and deforestation, especially of native forests, remains a serious and widespread concern, with rates estimated at about 10 million hectares per year—an area larger than Greece—although in parts of Europe and North America in particular reforestation is significant (Shvidenko et al. in Hassan et al. (eds.), 2005).

VULNERABILITIES AND WIDER OUTCOMES

The size of forests as an economic sector and their land area constitute the main components of structural vulnerability for countries in the affected zones. In 2005, 25 countries were estimated to have no remaining forest cover; other countries have less than 10% of forest cover remaining.

High rates of deforestation clearly also accentuate vulnerability by diminishing local bio-capacity to withstand changes and increasing risks of invasive pests, flooding, drought, and irrigation-driven water stress (Shvidenko et al. in

BIGGER PICTURE

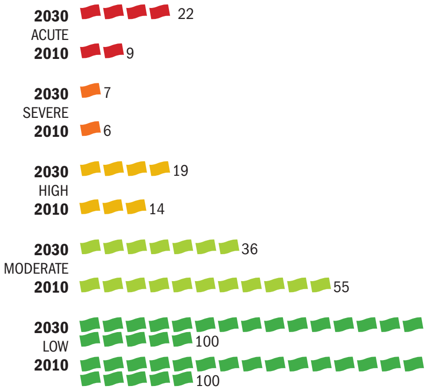


SURGE

OCCURRENCE

N/A

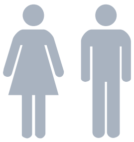
VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS



INDICATOR INFORMATION

MODEL: US Forest Service (2010)

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: FAOSTAT (2012)

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

Hassan et al. (eds.), 2005; Bolte et al., 2009). Vegetation vulnerability is widespread globally, with forest stands at risk on every continent and in almost all regions, and with Boreal conifer and tropical broadleaf forests equally threatened (Gonzalez et al., 2010). Reliance on forests for market and non-market benefits, from water to biodiversity to wildlife or plant products, is highest among lower-income groups. Forest-based or forest-reliant indigenous groups are also heavily dependent on the health of local forest stands (Munasinghe, 1993; Salick and Byg, 2007). Accordingly, lower-income countries and countries with significant indigenous groups have accentuated vulnerability to the impact of climate change on forests. The loss of vital ecological services as forests die back or decline is a major concern for human development (SCBD, 2009).

RESPONSES

Despite the challenges presented, numerous responses can be foreseen to stem forest decline as a result of climate change or other man-made factors. Stand substitution with more suitable tree varieties can occur progressively; however, the substitution options for the hottest and driest tropical zones are much more limited than elsewhere. Planting, harvesting and thinning regimes and schedules can be adjusted in accordance with altered local conditions (Bolte et al., 2009). Expanding primary forest conservation, particularly in high-risk developing countries, is a priority, but requires increasing capacity to implement that will depend in many cases on foreign assistance (Lee and Jetz, 2008). Additional adaptation strategies may include the establishment and management of biodiversity corridors that reinforce self-supporting connections between forest and non-forest ecosystems (Tabarelli et al., 2010). Pest management could be considered in some managed forest situations. Community forest programmes that support local groups in taking a more proactive involvement in forest conservation and management or sustainable agroforestry projects have the potential to yield double dividends for the environment and development (Hella and Zavaleta, 2009). This could be extended to specific support to indigenous communities (Salick and Byg, 2007). Finally, strong environmental governance, especially if it is community-based, is also key to protecting forest ecosystems, including threats from illegal or condoned deforestation (Baltodano et al., (eds.), 2008). Payment for ecosystem services has met with success in some countries for preserving and enhancing forest ecosystems, Costa Rica being a prime example (Pagiola, 2006).

THE INDICATOR

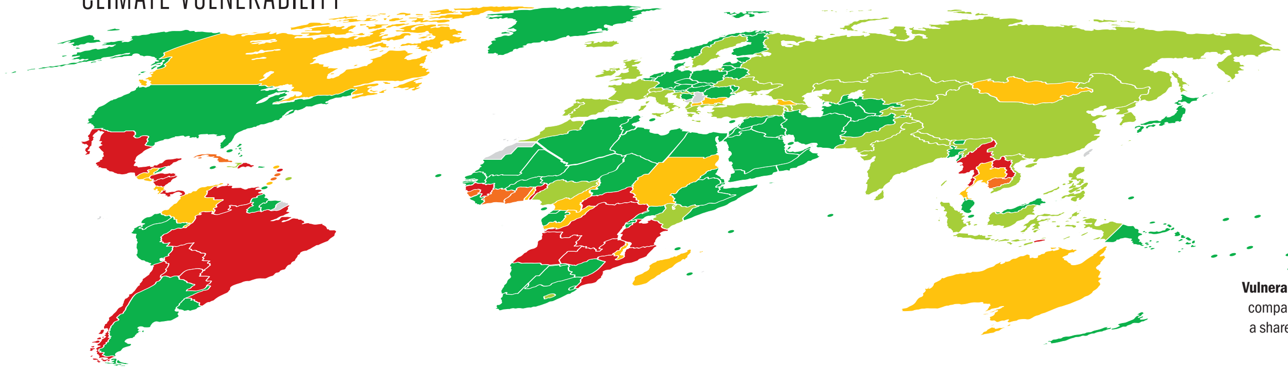
The indicator considers the scale of estimated shifts in the location and area of different forest biomes due to climate change (Gonzalez et al, 2010). Forestry and biodiversity losses are well recognized in climate science, and are closely linked to significant temperature changes (IPCC, 2007). A key limitation is the valuation method for forests of commercial and non-commercial types, including all varieties of trees in every continent. To simplify the problem, generic values are used for topical and non-tropical forest stands, including bundled biodiversity values (Costanza et al., 2007).

ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	2010	2030
ACUTE		
Angola	450	4,500
Benin	20	200
Bolivia	400	4,250
Brazil	2,500	20,000
Central African Republic	5	75
Chile	300	2,000
Dominica	1	10
Dominican Republic	55	600
DR Congo	15	150
Guinea	10	100
Honduras	25	300
Laos	5	100
Mexico	1,000	7,750
Mozambique	75	700
Myanmar	50	600
Nicaragua	10	150
Panama	35	400
Paraguay	100	1,250
Tanzania	35	350
Timor-Leste	20	250
Venezuela	400	4,500
Zambia	150	1,500
SEVERE		
Cambodia	10	150
Cote d,Ivoire	10	100
Cuba	40	450
Ghana	15	150
Saint Lucia	1	5
Saint Vincent		5
Sierra Leone	1	10
HIGH		
Antigua and Barbuda		1
Australia	100	300
Bulgaria	10	100
Cameroon	10	90
Canada	150	500
Colombia	80	900
Congo	1	20
Costa Rica	10	150
El Salvador	5	75
Georgia	1	20
Grenada		5
Guatemala	10	150
Macedonia	5	35
Madagascar	1	25
Malawi	1	10
Mongolia	1	30
Sudan/South Sudan	10	100
Thailand	100	1,500
Togo	1	10
MODERATE		
Albania		1
Armenia	1	5
Azerbaijan	1	25
Barbados		1
China	60	650
Croatia		
France	30	90
Greece	10	25
Haiti	1	5
Iceland		
India	10	80
Indonesia	30	350
Ireland	1	1
Italy	15	50
Kazakhstan	5	75
Kenya	5	30
Kyrgyzstan	1	5
Lesotho		
Morocco	5	75
Nepal		1
Nigeria	25	200
North Korea	1	5
Pakistan	1	15
Philippines	1	30
Portugal	5	20
Russia	150	850
South Korea	1	15
Spain	35	100
Sri Lanka	1	15
Sweden	10	25
Switzerland	1	1
Tajikistan		1
Turkey	5	20
Ukraine	1	10
United Kingdom	5	10
Vietnam	1	20
LOW		
Afghanistan		
Algeria		
Argentina	-950	-10,000
Austria	-1	-10
Bahamas		
Bahrain		
Bangladesh		-1

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

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY

$

COUNTRY	2010	2030
Belarus	-1	-15
Belgium		
Belize		
Bhutan		
Bosnia and Herzegovina		
Botswana		
Brunei		
Burkina Faso		
Burundi		
Cape Verde		
Chad		
Comoros		
Cyprus		
Czech Republic		
Denmark		
Djibouti		
Ecuador	-40	-500
Egypt		
Equatorial Guinea		
Eritrea		
Estonia		-1
Ethiopia		
Fiji		
Finland	-5	-15
Gabon		
Gambia		
Germany	-1	-10
Guinea-Bissau		
Guyana		
Hungary	-1	-10
Iran		
Iraq		

$

COUNTRY	2010	2030
Israel		
Jamaica		
Japan	-10	-30
Jordan		
Kiribati		
Kuwait		
Latvia		
Lebanon		
Liberia		
Libya		
Lithuania	-1	-5
Luxembourg		
Malaysia		
Maldives		
Mali		
Malta		
Marshall Islands		
Mauritania		
Mauritius		
Micronesia		
Moldova		
Namibia		
Netherlands		
New Zealand		
Niger		
Norway	-1	-5
Oman		
Palau		
Papua New Guinea		
Peru	-70	-800
Poland	-5	-40
Qatar		

$

COUNTRY	2010	2030
Romania		-1
Rwanda		
Samoa		
Sao Tome and Principe		
Saudi Arabia		
Senegal		
Seychelles		
Singapore		
Slovakia		
Slovenia		
Solomon Islands		
Somalia		
South Africa	-5	-60
Suriname		
Swaziland		
Syria		
Tonga		
Trinidad and Tobago		
Tunisia		
Turkmenistan		
Tuvalu		
Uganda	-1	-10
United Arab Emirates		
United States	-90	-300
Uruguay	-5	-80
Uzbekistan		
Vanuatu		
Yemen		
Zimbabwe		

HYDRO ENERGY

ESTIMATES GLOBAL CLIMATE IMPACT

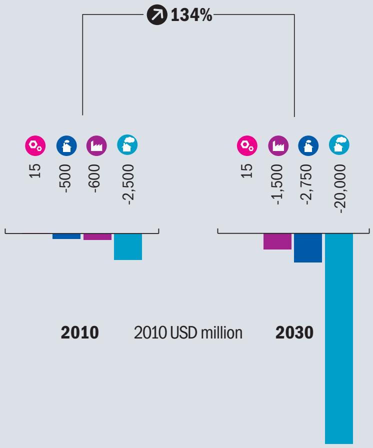
2010 EFFECT TODAY

USD **GAIN** PER YEAR **5 BILLION**

2030 EFFECT TOMORROW

USD **GAIN** PER YEAR **25 BILLION**

ECONOMIC IMPACT

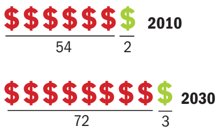


CONFIDENCE

INDICATIVE

- The world will benefit from increasing hydro energy wealth as climate change brings more rain to many places
- Some regions will be heavily affected by localized reductions in rainfall and a corresponding loss of energy potential for existing hydropower installations
- Additional hydro energy capacity can already be foreseen in zones where there is high certainty of more useable rainfall, especially in high latitudes
- The negative effects of hydro energy can be offset by measures such as expanding reservoirs to increase water holding capacity in affected zones, and through a forward-looking diversification of energy supply

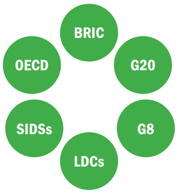
RELATIVE IMPACT



HOTSPOTS

2010		2030
150	**UKRAINE**	800
30	**ROMANIA**	250
85	**TURKEY**	250
25	**IRAN**	150
35	**ITALY**	100

GEOPOLITICAL VULNERABILITY



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

= Losses per 100,000 USD of GDP

Change in relation to overall global population and/or GDP

= Millions of USD (2010 PPP non-discounted)

Vulnerability of hydropower to climate effects can be high: in Brazil in 2001, intense drought was a key contributor to a “virtual breakdown” of power generation from hydro sources, a dominant energy supply for the country (IPCC, 2012b). Such extreme hydrological events are becoming more common (IPCC, 2007; Hansen et al., 2012). According to the assessment made here, however, fewer than 20 countries would be negatively affected to any significant degree, and many more could benefit. This is because water availability is increasing in many areas of the world as a result of climate change (Bates et al., 2008).

New opportunities will arise over the next 30 years as precipitation increases global hydro energy capacity, and when access to this established clean energy technology will be most needed. Where reductions do occur, they may be severe: a study of nearly 6,000 European hydro stations concluded that 25% reductions in power generation could become a reality for the southern and Mediterranean areas (Lehner et al., 2005). Where the effects are likely to be negative, economies should plan for a diversification to other energy sources, and mitigate the effects of rainfall loss through measures such as reservoir expansion. The intrinsic uncertainty of rainfall will make planning for these large-scale and capital-intensive energy systems difficult (IPCC, 2012b).

CLIMATE MECHANISM

The hydro energy sector has recognized sensitivities to climate change. This is because climate change alters the water cycle of the planet, notably accelerating it and increasing the amount of available rainfall, water, and river flow (Huntington, 2006; Stromberg et al., 2010). However, many countries will not experience an improvement in water availability, but will see declines, as water replenishments fail to keep pace with rising heat (Chu et al., 2009). In the long term, melting glaciers may further increase water scarcity, but in the coming years it is likely to increase water flows (Olefs et al., 2009). All these factors can have an impact on the power generation capacity of hydro energy installations (Lehner et al., 2001; Pereira de Lucena et al., 2009; Hamududu and Killingtveit, 2012). Globally, major rivers are expected to increase in flow or decline depending on local and regional climate conditions—although these are uncertain for many areas (Nohara et al., 2006). Evidence tends to favour an increase in rainfall (or runoff) in the far north and south, and a decrease in tropical regions (Helm et al., 2010).

IMPACTS

Given the still relatively small scale of hydro power installations in the global energy mix—although it is still by far the largest source of renewable energy—the positive effect worldwide is small at around 4 billion dollars in 2010 (US EIA, 2011).

Losses by comparison are estimated at around 0.5 billion dollars.

The worst affected zones are Southern Europe and Central America, while the largest total gains include China, Canada, and the US, subject of course to different degrees of uncertainty linked to rainfall projections to 2030.

Between 2010 and 2030 the estimated effect more than doubles as a proportion of GDP, with around 25 billion dollars in yearly gains by 2030. The number of worst affected countries has more than doubled, and there is a significant increase in gains among the many countries that are projected to benefit.

THE BROADER CONTEXT

The hydro energy sector has undergone continued expansion in recent decades—although not as rapidly as renewable energy technologies—and is expected to continue to grow as a source of power generation (US EIA, 2011; BP, 2012). Given the large-scale up-front capital investment involved and the long-term shelf life of installations, careful consideration should be given to new investments, particularly since several episodes of decline in water-fed energy supply have already been observed in different areas (IPCC, 2012b). Significant opportunities to support an expansion of hydro energy are emerging in some areas, especially high-latitude regions where there is much greater certainty of increasing rainfall over the next 20 years and beyond (Bates et al., 2008; Helm et al., 2010).

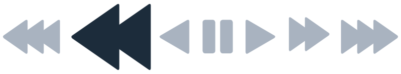
VULNERABILITIES AND WIDER OUTCOMES

Watershed or water catchment capacity in reservoirs is a key contributor to resilience of hydro power installations, since these can stock water during

BIGGER PICTURE

N/A

SURGE

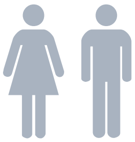


OCCURRENCE

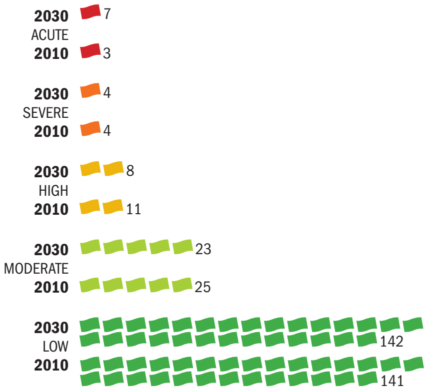
PEAK IMPACT

N/A

GENDER BIAS



VULNERABILITY SHIFT



INDICATOR INFORMATION

MODEL: Lehner, 2003; Nohara, 2006

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: IEA, 2011; Lehner, 2001

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

extended periods of drought, and retain water deposited at inconvenient times of the year and saved for later use (IPCC, 2012b). Hydro installations that are powered only by river flow and not through a reservoir are particularly exposed to diminished rainfall and water runoff, as was pointed out in the Vietnam country study in this report. Whether environmental management is poor or sound may also play a role: for example, Costa Rica, one of the countries worst hit, has begun to reverse its deforestation process, which is expected to result in improved watershed capacity, although only high altitude or mature forests are understood to add to surrounding water supplies (Morse et al., 2009; Postel and Thompson, 2005; Hamilton, 2008). Lower-income countries are relatively well shielded since investment in capital-intensive hydro power installations in these countries has so far been marginal (UNEP Risoe, 2012). Both the Ghana and Vietnam country studies in this report highlight the potential negative effects of hydro installations for coastal erosion, which can compound climate change-induced sea-level rise.

RESPONSES

Where energy potential is set to decline, there are two main response areas: first, undertaking or intensifying measures aimed at improving the supply of water through enhanced watershed catchment and upstream water resource conservation. Increasing forest area and certain types of nature reserves can help build up the water capacity under certain conditions (Postel and Thompson, 2005). Depending on the type of installation, expanding the size of drawing reservoirs to stock more water may also provide a buffer against declining rainfall. In more arid regions, managing upstream water consumption, such as irrigation, may also yield positive results by lessening water withdrawals (Kang et al., 2004). Second, ensure diversification of future energy investments away from hydro power. At the same time, there is a danger that affected economies compensate for lost production in the hydro energy sector through an increase in carbon intensive modes of energy supply. In some major economies, experts have recently been recommending further investment in oil and gas energy generation as a least-cost adaptation option for hydro energy and other renewable energy sources that may be affected by climate change (Pereira de Lucena et al., 2010). Conversely, certain experts have argued that the promotion of hydropower has caused serious environmental damage and should be reconsidered (Haya, 2007).

THE INDICATOR

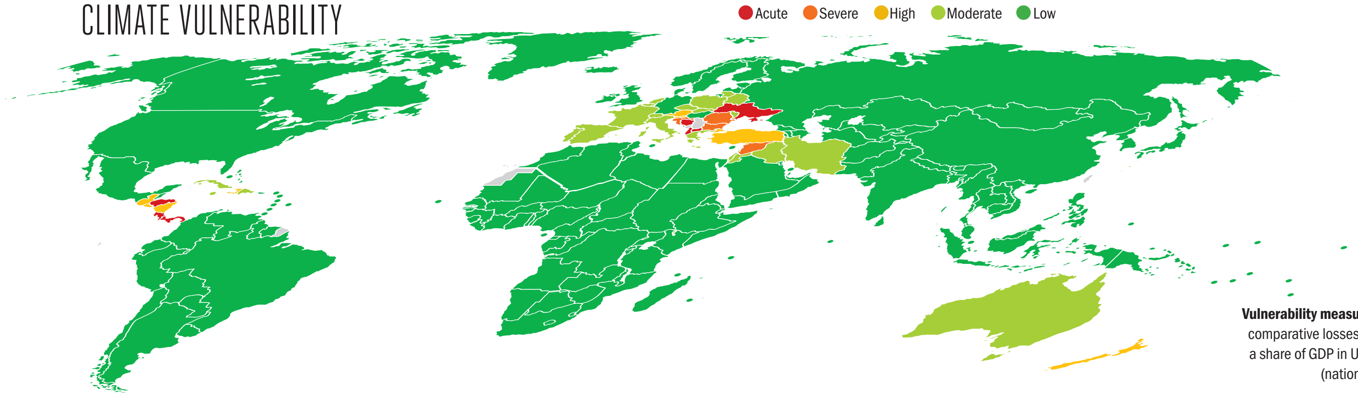
The indicator maps changes in river discharge in relation to estimated effects of climate change and the corresponding effect on the global hydro-energy potential of existing installations, and draws on International Energy Agency data (Lehner et al., 2001; IEA, 2012b). Key limitations relate to the scale of the information and uncertainty in the direction and magnitude of rainfall changes. The main model is geographically limited to Europe, and effects are extrapolated using river flow information (Nohara et al., 2006). Differences in anticipated changes in rainfall patterns could mean very different outcomes in river discharge and energy potential for those areas where there is less agreement and certainty around the direction of the change (Bates et al., 2008; Hamududu and Killingtveit, 2012).

ESTIMATES COUNTRY-LEVEL IMPACT

	$	
COUNTRY	2010	2030
ACUTE		
Albania	10	100
Bosnia and Herzegovina	15	100
Costa Rica	15	100
Honduras	10	70
Macedonia	5	30
Panama	10	80
Ukraine	150	800
SEVERE		
Bulgaria	5	95
Croatia	10	75
Romania	30	250
Syria	20	100
HIGH		
Austria	10	50
El Salvador	5	35
Guatemala	10	55
Haiti	1	5
New Zealand	10	25
Nicaragua	1	10
Slovenia	5	40
Turkey	85	250
MODERATE		
Australia	5	15
Belarus		
Belgium		
Cuba		1
Czech Republic		5
Dominican Republic	1	20
France	25	100
Greece	1	20
Iran	25	150
Iraq	1	15
Israel		1
Italy	35	100
Jamaica	1	1
Jordan		1
Lebanon	1	15
Lithuania		
Moldova		1
Netherlands		
Poland	5	20
Portugal	-1	20
Slovakia	5	35
Spain	10	95
Switzerland	1	30
LOW		
Afghanistan		
Algeria		
Angola	-1	-5
Antigua and Barbuda		
Argentina	-20	-150
Armenia	-1	-15
Azerbaijan	-5	-20
Bahamas		
Bahrain		
Bangladesh	-1	-20
Barbados		
Belize		
Benin		
Bhutan		
Bolivia	-1	-10
Botswana		
Brazil	-150	-750
Brunei		
Burkina Faso		
Burundi		
Cambodia		
Cameroon	-5	-20
Canada	-350	-800
Cape Verde		
Central African Republic		
Chad		
Chile	-10	-60
China	-2,250	-20,000
Colombia	-20	-100
Comoros		
Congo		-1
Cote d,Ivoire	-1	-5
Cyprus		
Denmark		
Djibouti		
Dominica		
DR Congo	-5	-30
Ecuador	-5	-40
Egypt	-15	-95
Equatorial Guinea		
Eritrea		
Estonia		
Ethiopia	-1	-10
Fiji		
Finland	-10	-30
Gabon	-1	-5
Gambia		
Georgia	-15	-75
Germany	-10	-10

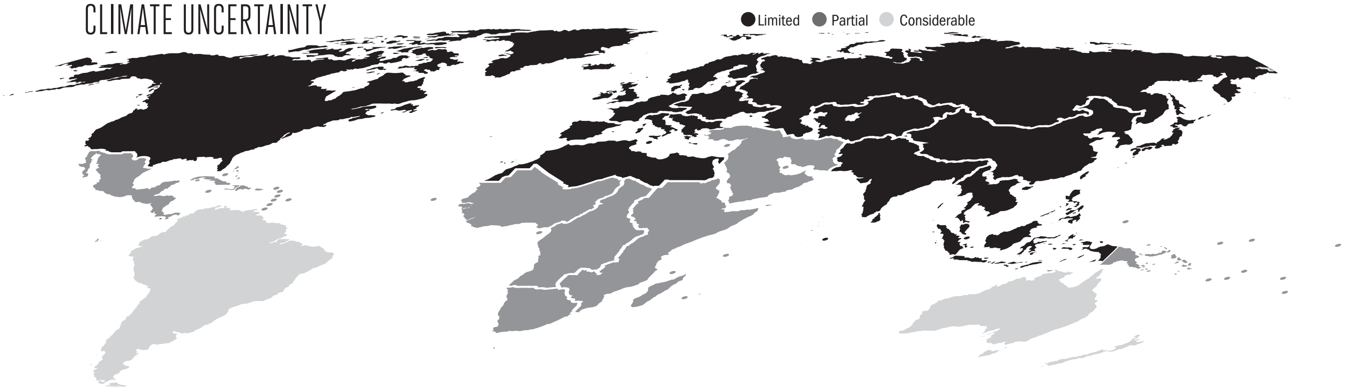
$ Additional economic costs due to climate change (million USD PPP) - yearly average

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY



COUNTRY	2010	2030
Ghana	-5	-35
Grenada		
Guinea		
Guinea-Bissau		
Guyana		
Hungary		-1
Iceland	5	-1
India	-250	-1,500
Indonesia	-10	-75
Ireland	-1	-1
Japan	-80	-150
Kazakhstan	-10	-70
Kenya	-1	-5
Kiribati		
Kuwait		
Kyrgyzstan	-40	-250
Laos		
Latvia	-1	-15
Lesotho		
Liberia		
Libya		
Luxembourg		
Madagascar		
Malawi		
Malaysia	-10	-65
Maldives		
Mali		
Malta		
Marshall Islands		
Mauritania		
Mauritius		
Mexico	-60	-350
Micronesia		
Mongolia		
Morocco	-1	-5
Mozambique	-10	-55
Myanmar	-1	-15
Namibia	-1	-5
Nepal	-5	-30
Niger		
Nigeria	-5	-30
North Korea	-25	-200
Norway	35	-150
Oman		
Pakistan	-55	-350
Palau		
Papua New Guinea		
Paraguay	-40	-250
Peru	-10	-75
Philippines	-10	-75
Qatar		
Russia	-300	-1,500
Rwanda		
Saint Lucia		
Saint Vincent		
Samoa		
Sao Tome and Principe		
Saudi Arabia		
Senegal		
Seychelles		
Sierra Leone		
Singapore		
Solomon Islands		
Somalia		
South Africa	-1	-5
South Korea	-5	-40
Sri Lanka	-10	-55
Sudan/South Sudan	-1	-5
Suriname		
Swaziland		
Sweden	40	-60
Tajikistan	-45	-250
Tanzania	-1	-15
Thailand	-10	-60
Timor-Leste		
Togo		-1
Tonga		
Trinidad and Tobago		
Tunisia		-1
Turkmenistan		
Tuvalu		
Uganda		
United Arab Emirates		
United Kingdom	-5	-5
United States	-300	-700
Uruguay	-5	-20
Uzbekistan	-15	-90
Vanuatu		
Venezuela	-30	-200
Vietnam	-30	-300
Yemen		
Zambia	-5	-25
Zimbabwe	-1	-15

TOURISM

ESTIMATES GLOBAL CLIMATE IMPACT

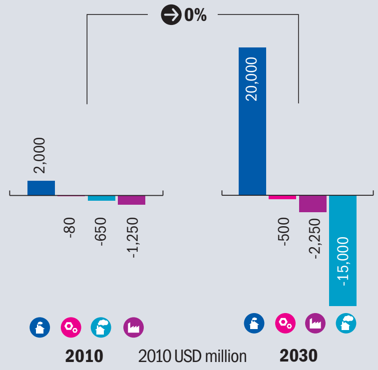
2010 EFFECT TODAY

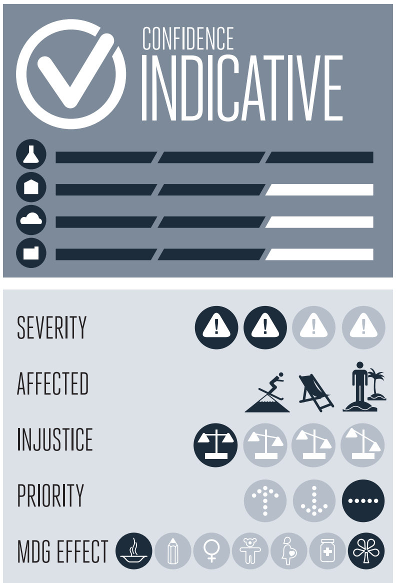
USD **LOSS** PER YEAR **NIL**

2030 EFFECT TOMORROW

USD **LOSS** PER YEAR **NIL**

ECONOMIC IMPACT





- Impacts will affect tropical beaches and island destinations reliant on seaside and tropical reef tourism and low-elevation winter resorts as reefs die and snowfall becomes unreliable
- Extreme and hot weather will affect tourism, but is not yet well understood
- Net global impact of climate change on tourism may not be negative; effects may redistribute tourism revenues among cooler countries with perceived climate advantages
- Adapting to impacts of climate change on tourism is challenging

RELATIVE IMPACT

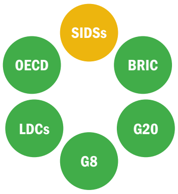
$$$$$$ 55 | $ 1 **2010**

$$$$$$$ 67 | $ 3 **2030**

HOTSPOTS

2010	$	**2030**
1,250	**INDONESIA**	10,000
1,250	**MALAYSIA**	10,000
800	**INDIA**	8,000
600	**EGYPT**	5,000
200	**SRI LANKA**	1,750

GEOPOLITICAL VULNERABILITY



$ Economic Cost (2010 PPP non-discounted)

Developing Country Low Emitters

Developed

Developing Country High Emitters

Other Industrialized

$ = Losses per 10,000 USD of GDP

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

Change in relation to overall global population and/or GDP

Tourism is clearly a climate-dependent sector. Weather conditions affect business in this sector, and general theory on the impact of climate change on tourism has been understood to favour cooler countries over tropical ones (Wall, 1998; Hamilton et al., 2005; Amelung et al., 2007). Yet there are exceptions: experts have suggested that Switzerland may see half of its ski stations become snow unreliable, with the snow reliability altitude rising from 1,200 metres today to over 1,800 metres, effectively stranding large, profitable, and irreplaceable ski zones (Elsasser and Bürki, 2002). Some economists have put forward evidence that the impact of climate change on tourism might result in an overall loss to global welfare (Berrittella et al., 2004).

Tourism is currently a fast growing industry, however, and in the near term it is more likely that any impacts would instead trigger redistribution of tourism revenues away from low- and middle-income tropical coastal resorts to other global destinations, in particular high-income countries, which benefit from more pleasant weather as the planet warms (UNWTO, 2012; Harrison et al., 1999). Experts have been unsure about national outcomes for some countries—such as the tourist magnet France—which are exposed to a range of positive and negative tourism-related concerns (Ceron and Dubois, 2004). The full range of possible effects for tourism is large in scale, given the heavy reliance on outdoor recreation and environmental leisure activities (Jones and Phillips eds., 2011). This assessment is anchored in two relatively well-studied concerns: decline of reef-based and low-elevation winter sports tourism (Steiger, 2011; ECLAC, 2011). In this way, the Monitor's tourism indicator serves to ensure that adequate attention is given by policymakers to the issue of tourism and climate change, despite the lack of comprehensiveness in analysis here, since even through this narrow lens, some countries may experience 1% losses of GDP by 2030.

CLIMATE MECHANISM

The climate effect assessed here examines only the effects for reef-based and mountain tourism. The degradation and bleaching of coral reefs and a decline of tropical fish stocks is a clear consequence of the steady warming of the atmosphere and oceans (Hoegh-Guldberg et al., 2007). Likewise, climate propelled sea-level rise is leading to coastal erosion, affecting beaches and coral reefs (Nicholls and Cazenave, 2010). Cultural heritage sites around the world's coastlines are also affected or threatened by this erosion (UNESCO, 2010). These effects penalize tourism that has flourished in places where there is an abundance of coral for diving and other related pursuits (Uyarra et al., 2005; ECLAC, 2011).

Other clear effects on tourism are a general onset of shorter, milder winters, long-term glacier decline and a snow-line gradually gaining in elevation in mid- to high-latitude regions (Euskirchen et al., 2006; Kelly and Goulden, 2008). These combined effects entail a slight and gradual degradation of mountain resort offerings, especially in low-elevation areas, which in turn can limit revenues in a high-risk industry (Koenigg and Abegg, 1997; Scott, 2003; Steiger, 2011).

IMPACTS

While the global effect is expected to be cost neutral, losses to affected countries are currently estimated at around 5 billion dollars a year, building to over 40 billion dollars, with an almost double share of global GDP in losses by 2030. Small island paradises such as the Bahamas, the Maldives, and Fiji dominate the list of countries most vulnerable to the negative effects of climate change on tourism. More marginal effects will also be felt in traditional skiing destinations, such as Australia, Austria, France, and Switzerland.

By 2030, lost revenue in tourism could cost upwards of 1% of GDP for several of the worst affected small island nations, although the greatest overall losses will be incurred in larger economies such as Egypt, Indonesia, or Malaysia. The effects for winter tourism host countries are expected to be marginal on a national scale, but could be highly unfavourable to mountain communities, which rely on short, peak seasons for the bulk of annual profits. Around 20–30 countries are estimated to experience serious effects; losses are estimated to be redistributed among high-latitude countries where domestic and foreign tourism is expected to improve along with favourable climate change. High-altitude ski resorts may also see surges in demand.

THE BROADER CONTEXT

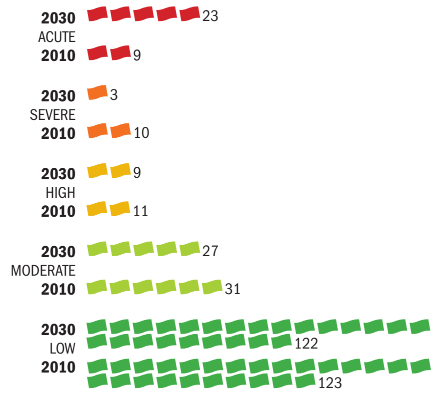
Tourism is a major growth industry globally, due especially to income and population trends that bolster

BIGGER PICTURE

N/A

SURGE

VULNERABILITY SHIFT



OCCURRENCE

N/A

PEAK IMPACT

N/A

GENDER BIAS

INDICATOR INFORMATION

MODEL: ECLAC, 2011; Steiger, 2011

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: Vanat, 2011; WTTC Website

▬ = 5 countries (rounded)

● Acute ● Severe ● High ● Moderate ● Low

the leisure sector (UNWTO, 2012). Given this growth, it is unlikely that any areas will experience significant absolute declines in revenues in the next few years (Hamilton et al., 2005). However, some niches in the industry grow more slowly than others: ski trips to mountain resorts have been stable over the last decade (Vanat, 2011). The broader industry context suggests that countries are more likely to have the growth of their tourism revenue slowed, rather than incur absolute losses, at least in the near term. This assessment represents an estimate of the potential opportunity cost for affected communities.

VULNERABILITIES AND WIDER OUTCOMES

KPMG identified the tourism sector as one of the industries most vulnerable to climate change, especially in light of physical risks, but also as one of the industries least prepared and therefore most likely to incur losses (KPMG, 2008). Geography clearly plays a role in physical risk, given the emphasis some experts have given to winners and losers in the global tourism industry depending on latitude (Amelung et al., 2007). The risks of coastal and mountain dependent tourist zones are also covered above. The size of the tourism sector and the level of its exposure to climate-related risks are the key determinants of vulnerability. Particularly in small island states, tourism is a large-scale revenue generator, whose remote locations allow unique access to a lucrative global market (Uyarra et al., 2005). Long-term sector decline could damage national income prospects and state expenditure on public goods such as schools, since tourism is an important form of public revenue in popular areas (Archabald and Naughton-Treves, 2001; Gooroochurn and Sinclair, 2005).

RESPONSES

In many cases, adaptation will require a diversification of the value offering of affected market segments, diversification away from long-term tourism-based risks where possible, and support or rehabilitation programmes to assist worst affected communities. Overcoming the unpreparedness of the sector to address climate stresses through awareness and education at different levels is of vital importance (Scott, 2011). However, the lack of preparedness of the sector underscores fundamental gaps in current response strategies (Scott et al., 2009). A variety of quite costly coastal conservation measures exist to stem beach and coastland erosion, but are unlikely to render such places more attractive to tourists (Klein et al., 2001). Strong environmental protection and sustainable fishing regulations, along with the promotion and expansion of natural marine reserves or mangrove forests can also help to boost local ecosystem resilience against coral and fish stock decline (Hughes et al., 2003; Corcoran et al., 2007). For low-elevation winter ski spots, relying on energy-intensive snow-making can assist to some degree, but would constitute a paradoxical response to the locally felt effect of global climate change on these vulnerable mountain tourist areas (Dawson et al., 2009). More generally, experts have raised concern about the potential for the tourism sector to become a major contributor to GHG emissions in the coming decades (Scott et al., 2010).

THE INDICATOR

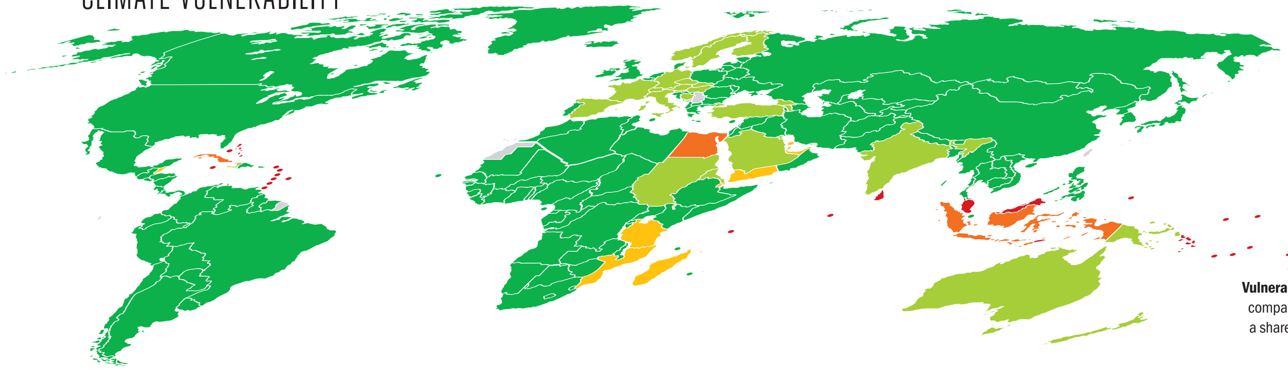
The indicator measures the effects of the loss in tourism revenue potential in tropical seaside resorts and winter ski resorts, based only on two separate studies on the question (Steiger, 2011; ECLAC, 2011). Given the climate factors involved, such as ocean temperatures and the length and temperature of winter ski seasons, the IPCC has been firm on the anticipated effects for the tourism industry (IPCC, 2007). The indicator should still be considered only to address the types of effects countries with a heavy reliance on reef and winter tourism might face. The main limitation is the lack of scope of the indicator, which captures only a fraction of the broader problem.

ESTIMATES COUNTRY-LEVEL IMPACT

	$	
COUNTRY	2010	2030
ACUTE		
Antigua and Barbuda	10	100
Bahamas	65	550
Barbados	40	400
Dominica	5	30
Fiji	20	200
Grenada	1	25
Jamaica	100	950
Kiribati	1	10
Malaysia	1,250	10,000
Maldives	15	150
Marshall Islands	1	5
Micronesia	1	15
Palau	1	5
Saint Lucia	10	100
Saint Vincent	5	25
Samoa	5	35
Seychelles	15	100
Solomon Islands	5	45
Sri Lanka	200	1,750
Timor-Leste	5	65
Trinidad and Tobago	100	900
Tuvalu		1
Vanuatu	10	100
SEVERE		
Cuba	150	1,250
Egypt	600	5,000
Indonesia	1,250	10,000
HIGH		
Bahrain	15	150
Belize	1	20
Djibouti	1	15
Madagascar	15	100
Mozambique	10	65
Tanzania	25	200
Tonga	1	5
United Arab Emirates	150	1,500
Yemen	30	250
MODERATE		
Armenia		
Australia	150	400
Austria	55	300
Bosnia and Herzegovina		5
Czech Republic	5	70
Eritrea	1	10
Finland	1	5
France	30	200
Georgia		
Germany	10	70
Haiti	1	25
Hungary	-1	5
India	800	8,000
Italy	15	85
Myanmar	10	95
New Zealand	1	5
Norway	1	15
Papua New Guinea	1	25
Qatar	10	80
Saudi Arabia	100	1,000
Slovakia	5	50
Slovenia	1	25
Spain	5	30
Sudan/South Sudan	10	60
Sweden	1	15
Switzerland	20	90
Turkey		1
LOW		
Afghanistan		
Albania		
Algeria		
Angola		
Argentina	-10	-65
Azerbaijan		
Bangladesh		
Belarus	-1	-20
Belgium	-1	-1
Benin		
Bhutan		
Bolivia		
Botswana		
Brazil		
Brunei		
Bulgaria	-1	-5
Burkina Faso		
Burundi		
Cambodia		
Cameroon		
Canada	-100	-200
Cape Verde		
Central African Republic		
Chad		
Chile	-1	-15
China	-3,500	-40,000
Colombia		
Comoros		
Congo		

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

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY

COUNTRY	2010	2030
Costa Rica		
Cote d,Ivoire		
Croatia		
Cyprus		
Denmark	-1	-1
Dominican Republic		
DR Congo		
Ecuador		
El Salvador		
Equatorial Guinea		
Estonia		-1
Ethiopia		
Gabon		
Gambia		
Ghana		
Greece		
Guatemala		
Guinea		
Guinea-Bissau		
Guyana		
Honduras		
Iceland		
Iran		
Iraq		
Ireland	-1	-1
Israel		
Japan	-55	-5
Jordan		
Kazakhstan		
Kenya		
Kuwait		
Kyrgyzstan		

COUNTRY	2010	2030
Laos		
Latvia	-1	-1
Lebanon		
Lesotho		
Liberia		
Libya		
Lithuania	-1	-5
Luxembourg		
Macedonia		
Malawi		
Mali		
Malta		
Mauritania		
Mauritius		
Mexico		
Moldova		-1
Mongolia	-1	-5
Morocco		
Namibia		
Nepal		
Netherlands	-1	-5
Nicaragua		
Niger		
Nigeria		
North Korea	-15	-150
Oman		
Pakistan		
Panama		
Paraguay		
Peru		
Philippines		
Poland	-10	-65

COUNTRY	2010	2030
Portugal		
Romania	-1	-10
Russia	-65	-500
Rwanda		
Sao Tome and Principe		
Senegal		
Sierra Leone		
Singapore		
Somalia		
South Africa	-60	-400
South Korea	-35	-150
Suriname		
Swaziland		
Syria		
Tajikistan		
Thailand		
Togo		
Tunisia		
Turkmenistan		
Uganda		
Ukraine	-5	-35
United Kingdom	-5	-15
United States	-1,500	-3,250
Uruguay	-1	-5
Uzbekistan		
Venezuela		
Vietnam		
Zambia		
Zimbabwe		

TRANSPORT

ESTIMATES GLOBAL CLIMATE IMPACT

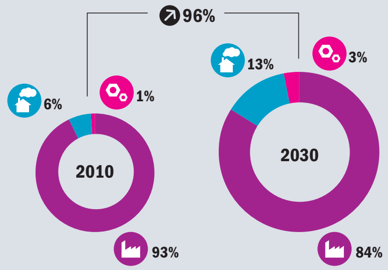
2010 EFFECT TODAY

$ USD **LOSS** PER YEAR **1 BILLION**

2030 EFFECT TOMORROW

$ USD **LOSS** PER YEAR **5 BILLION**

ECONOMIC IMPACT



CONFIDENCE
SPECULATIVE

SEVERITY

AFFECTED

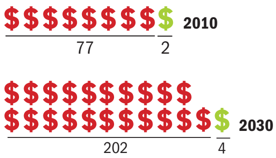
INJUSTICE

PRIORITY

MDG EFFECT

- The impact of climate change on the transport sector is relatively unstudied compared to other areas
- Changes will lead to geographic shifts in volume rather than overall losses
- Apparent net negative effects relate to losses incurred through increasing costs of logistics for inland transport, as some important river levels decline
- These losses are not expected to be offset by gains in transport effectiveness in parts of the world experiencing more flooding of river-ways due to climate change
- Water resource management and conservation are required to limit these effects

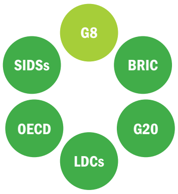
RELATIVE IMPACT



HOTSPOTS

2010	$	2030
1,000	**USA**	5,750
75	**MEXICO**	950
45	**GERMANY**	200
35	**NETHERLANDS**	150
10	**ROMANIA**	100

GEOPOLITICAL VULNERABILITY



$ Economic Cost (2010 PPP non-discounted)

Developing Country Low Emitters

Developed

Developing Country High Emitters

Other Industrialized

$ = Losses per million USD of GDP

Change in relation to overall global population and/or GDP

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

Only the impact of climate change on river transport is considered here. Many other negative and positive effects of climate change on the transportation sector are conceivable, but difficult to simulate (Koetse and Rietveld, 2009; Eisenack et al., 2012). Climate change, however, can clearly affect the flow of rivers, increasing or decreasing the rate and volume of water over which goods are transported (Stromberg et al., 2010). A number of the world's waterways are already independently stressed due to infrastructure, pollution, or water withdrawals, which can reduce river flows and make them more vulnerable to climate change impacts (Palmer et al., 2008; Sabater and Tockner, 2010). Climate change has been simulated to have potentially serious negative effects on the river levels of some of the world's most important waterways, including the Danube, the Rhine, and the Rio Grande rivers (Nohara et al., 2006). Lower water levels will continue to increase shipping costs for major global transport conduits affected by river level decline, with potentially significant effects for affected communities—for example, the Rhine carries around 70% of all inland waterway transport of the pre-2004 EU-15 (Jonkeren et al., 2007).

CLIMATE MECHANISM

There are also discernable linkages between river flows and climate factors, such as extreme heat, rainfall, and drought (Kaczmarek et al. (eds.), 1996). Increasing temperatures, the earlier onset of spring, longer, hotter summers, long-term glacial decline, and changes in rainfall patterns, among other effects characteristic of climate change, will have an increasing role in determining water levels in the world's rivers. Increased rainfall and heavy flooding will also affect rivers in some places. However, there is little evidence of any beneficial effect from higher river levels, which are more likely to increase flooding and other risks, since most additional water will fall during the rainy season, when flows and supply are in abundance (Arnell, 2004). When river levels decline, an economic loss arises by affecting the maximum cargo payload that can be transported, or the size of ships transporting goods. The inefficiencies thus created increase shipping costs in a predictable way (Jonkeren et al., 2007).

IMPACTS

Only a handful of countries are affected in any significant way by the impact of climate change on river transportation. This is because large-volume, inland, water-borne transportation is a major economic activity in only a few river basins of the world (UNECE, 2012a). Moreover, only a small number of river basins are currently projected to see continued decline, mainly because in many areas rainfall will increase with climate change (Nohara et al., 2006). The costs of climate change on the transport sector as a result of effects for inland water-borne logistics are currently estimated at 1 billion dollars per year, increasing to over 7 billion dollars by 2030 as the effect intensifies and the overall impact grows as a share of GDP. The bulk of all losses are estimated to be incurred in the United Sates, with European countries along the Rhine and Danube, such as Germany and the Netherlands, as well as Bulgaria and Romania, affected to lesser degrees. Mexico also shows high levels of vulnerability, linked to decline of the Rio Grande.

Caution is suggested with regard to the assessment results, which may underestimate the vulnerabilities of several river basins if rainfall patterns were to evolve differently than expected, based on the research relied upon here.

THE BROADER CONTEXT

Many factors other than climate change—especially water withdrawals from rivers due to growth in agricultural, industrial, and municipal water demand—can play a central role in the level of rivers (Alcamo et al., 2003). Indeed, so-called "basin" closure—the inability of a waterway to meet local water demands for part of the year—currently affects 1.4 billion people in various river basins around the world (Falkenmark and Molden, 2008). Population growth exacerbates these issues when alternate resources are not adequately managed (Vösösmarty et al., 2000; Palmer et al., 2008).

The transportation and logistics sector is a steady growth industry in a globalizing economy, with no expectation of declining demand, except for passenger transportation in some industrialized country settings (US DoT, 2010; Millard-Ball and Schipper, 2011). Therefore, losses are unlikely to lead to unemployment issues, but rather to generate additional costs for communities that have relied on highly efficient inland water-borne transportation, which can be a major economic benefit.

BIGGER PICTURE

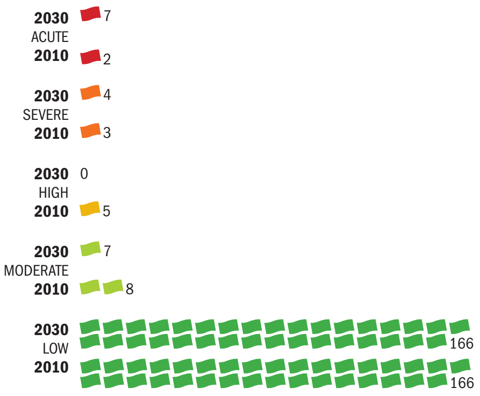
N/A

SURGE

OCCURRENCE

N/A

VULNERABILITY SHIFT



PEAK IMPACT

N/A

GENDER BIAS

INDICATOR INFORMATION

MODEL: Jonkeren et al., 2011; Nohara et al., 2006

EMISSION SCENARIO: SRES A1B (IPCC, 2000)

BASE DATA: UNECE (2012a)

▬ = 5 countries (rounded)

🔴 Acute 🟠 Severe 🟡 High 🟢 Moderate 🟢 Low

VULNERABILITIES AND WIDER OUTCOMES

In arid regions, water demand for irrigation has an amplified effect on river levels (Kang et al., 2004). Africa may be particularly vulnerable as a result (de Wit and Stankiewicz, 2006). Smaller rivers may also be asymmetrically affected (Pandey et al., 2010). Free-flowing rivers are more resilient than riverways with dams (Palmer et al., 2008). Deforestation or expanded agricultural and industrial activity can further lower resilience to any shocks and river-level decline brought on by climate change (Sahin and Hall, 1996; Conway, 2005). As the effects are currently interpreted, the narrow economic impact is not expected to have many discernable wider outcomes, aside from burdening a handful of countries/communities with additional costs.

RESPONSES

With glacial retreat, growing heat, and rainfall decline out of societal control, responses would likely include some form or combination of water resource management and the enhancement of catchment potential (Palmer et al., 2008; Falkenmar and Molden, 2012). Water resource management could seek to minimize or reduce water withdrawals, especially during high summer or drought periods, as well as increase water re-use and reduce water contaminants from industrial or agricultural sources (Geng et al., 2001; Friedler, 2001; Asano, 2002). Government quotas on irrigation could stimulate broader use of micro-irrigation and other water conservation actions (Pereira et al., 2002; Barret and Wallace, 2011). Water catchment potential can be enhanced through such measures as large-scale forestry expansion and conservation (Sahin and Hall, 1996). Limiting riverine infrastructure also improves resilience (Palmer et al., 2008).

THE INDICATOR

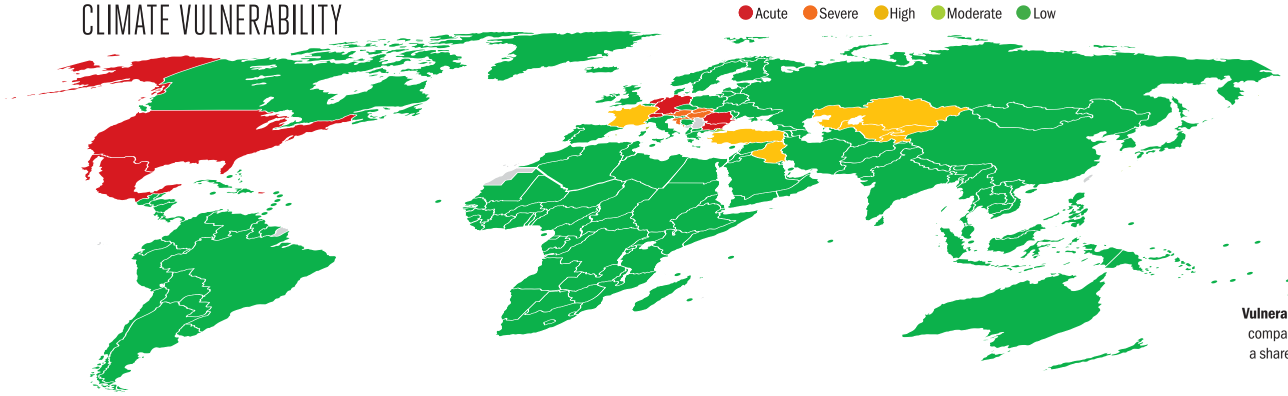
The indicator is considered uncertain and speculative for those countries assessed—provided projections for river flow and levels are accurate (Nohara et al., 2006). The economic effect of river decline relies on a study conducted in the Netherlands, not global research (Jonkeren et al., 2007). But the main limitation of the transport sector indicator relates to its scope, as increasing severity and variability of weather, growing heat stress, and other elements will likely affect the transport industry. Growing tire failure, increased delays and congestion, accidents, and port infrastructure damage have not been studied sufficiently to to build even speculative indicators of global effects (Koetse and Rietveld 2009; Eisenack et al., 2012). The rapid opening of previously inaccessible Arctic passageways will likely benefit, but its dynamics are difficult to ascertain (Macdonald et al., 2005). Additional investigation is needed to better understand the global effects of climate change on the transport sector.

ESTIMATES COUNTRY-LEVEL IMPACT

	$	
COUNTRY	2010	2030
ACUTE		
Bulgaria	5	65
Germany	45	200
Mexico	75	950
Netherlands	35	150
Romania	10	100
Switzerland	5	30
United States	1,000	5,750
SEVERE		
Austria	5	15
Croatia	1	10
Hungary	1	25
Slovakia	1	15
MODERATE		
France	5	25
Iraq		
Kazakhstan		
Kyrgyzstan		
Tajikistan		
Turkey		
Uzbekistan		
LOW		
Afghanistan		
Albania		
Algeria		
Angola		
Antigua and Barbuda		
Argentina		
Armenia		
Australia		
Azerbaijan		
Bahamas		
Bahrain		
Bangladesh		
Barbados		
Belarus		
Belgium		
Belize		
Benin		
Bhutan		
Bolivia		
Bosnia and Herzegovina		
Botswana		
Brazil		
Brunei		
Burkina Faso		
Burundi		
Cambodia		
Cameroon		
Canada		
Cape Verde		
Central African Republic		
Chad		
Chile		
China		
Colombia		
Comoros		
Congo		
Costa Rica		
Cote d'Ivoire		
Cuba		
Cyprus		
Czech Republic		
Denmark		
Djibouti		
Dominica		
Dominican Republic		
DR Congo		
Ecuador		
Egypt		
El Salvador		
Equatorial Guinea		
Eritrea		
Estonia		
Ethiopia		
Fiji		
Finland		
Gabon		
Gambia		
Georgia		
Ghana		
Greece		
Grenada		
Guatemala		
Guinea		
Guinea-Bissau		
Guyana		
Haiti		
Honduras		
Iceland		
India		
Indonesia		
Iran		
Ireland		
Israel		
Italy		

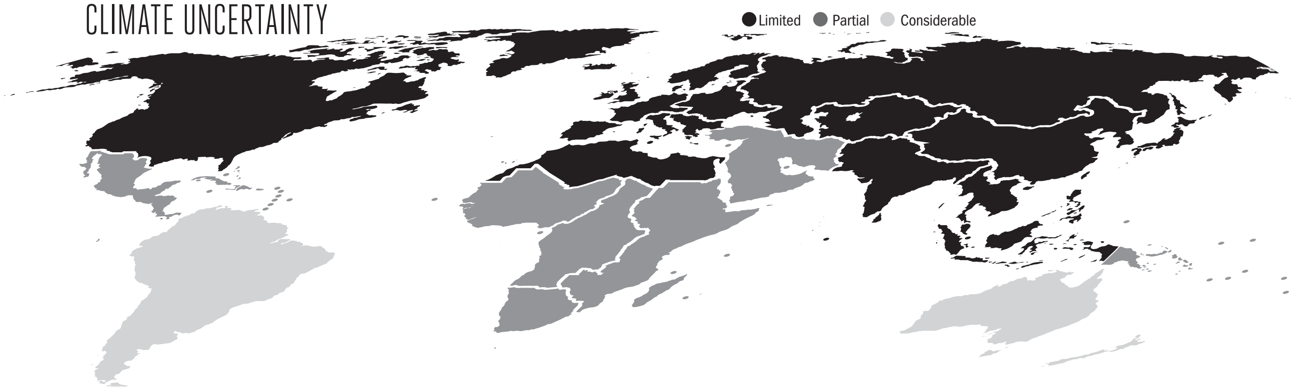
$ Additional economic costs due to climate change (million USD PPP) - yearly average

CLIMATE VULNERABILITY



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

CLIMATE UNCERTAINTY



COUNTRY	2010	2030
Jamaica		
Japan		
Jordan		
Kenya		
Kiribati		
Kuwait		
Laos		
Latvia		
Lebanon		
Lesotho		
Liberia		
Libya		
Lithuania		
Luxembourg		
Macedonia		
Madagascar		
Malawi		
Malaysia		
Maldives		
Mali		
Malta		
Marshall Islands		
Mauritania		
Mauritius		
Micronesia		
Moldova		
Mongolia		
Morocco		
Mozambique		
Myanmar		
Namibia		
Nepal		

COUNTRY	2010	2030
New Zealand		
Nicaragua		
Niger		
Nigeria		
North Korea		
Norway		
Oman		
Pakistan		
Palau		
Panama		
Papua New Guinea		
Paraguay		
Peru		
Philippines		
Poland		
Portugal		
Qatar		
Russia		
Rwanda		
Saint Lucia		
Saint Vincent		
Samoa		
Sao Tome and Principe		
Saudi Arabia		
Senegal		
Seychelles		
Sierra Leone		
Singapore		
Slovenia		
Solomon Islands		
Somalia		
South Africa		

COUNTRY	2010	2030
South Korea		
Spain		
Sri Lanka		
Sudan/South Sudan		
Suriname		
Swaziland		
Sweden		
Syria		
Tanzania		
Thailand		
Timor-Leste		
Togo		
Tonga		
Trinidad and Tobago		
Tunisia		
Turkmenistan		
Tuvalu		
Uganda		
Ukraine		
United Arab Emirates		
United Kingdom		
Uruguay		
Vanuatu		
Venezuela		
Vietnam		
Yemen		
Zambia		
Zimbabwe		