

Too close for comfort

The HSBC Climate Vulnerability Assessment – mapping risks for the G-20 in 2020

The world is already warming and decision-makers need to understand the near-term scale and nature of potential disruptions. In this report, we assess the climate vulnerability of the G-20 in 2020, concluding that India, Indonesia, Brazil, South Africa and China are the most vulnerable. We then look in detail at potential impacts on health, water and agriculture and estimate, for example, a 4.1-8.7% loss in food grain production by 2020. Finally, we provide climate vulnerability profiles for each of the G-20, highlighting key national and regional impacts of rising temperatures. It's time to confront the inevitable.

By Roshan Padamadan and Nick Robins

For audio summary, [click here](#)

Disclosures and Disclaimer This report must be read with the disclosures and analyst certifications in the Disclosure appendix, and with the Disclaimer, which forms part of it

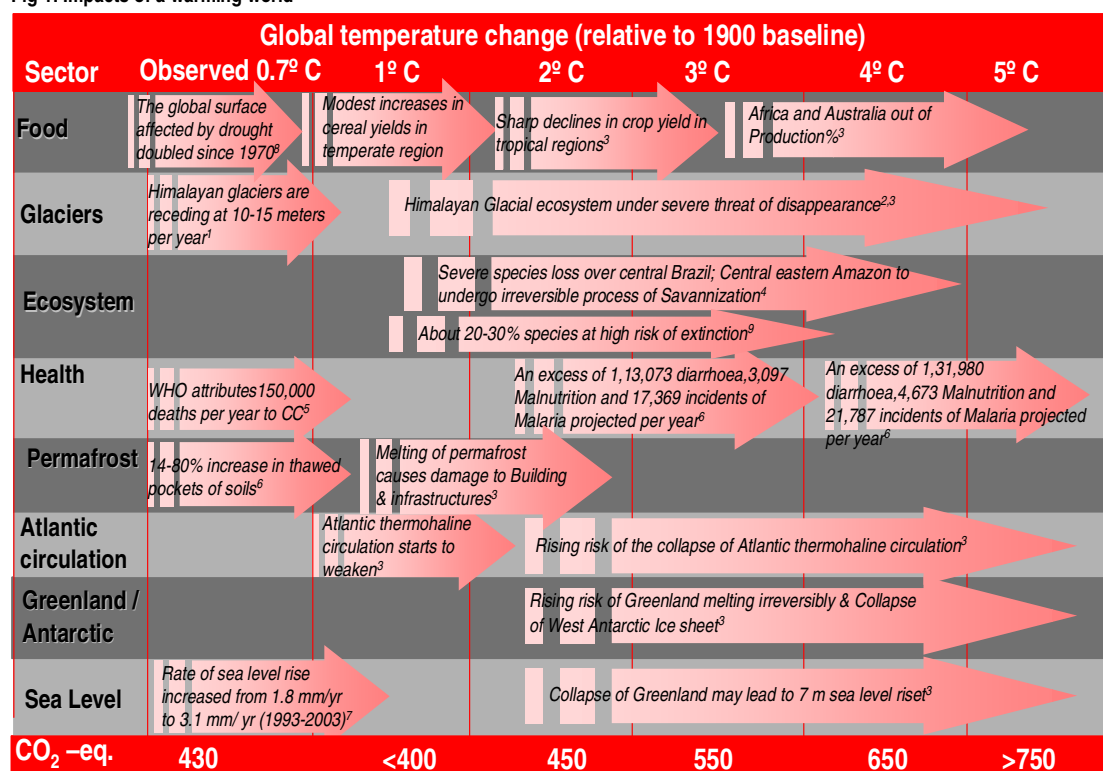
Summary

The world is warming, and past emissions ensure that it will get warmer still, with the latest science suggesting temperature shocks could be brought forward to the 2020s. Our Climate Vulnerability Assessment quantifies the risks for the G-20 in 2020 and finds that India, Indonesia, Brazil, South Africa and China are the most vulnerable. Climate change will exacerbate water stress and reduce agricultural output, putting strain on already thin global commodity markets.

Approaching the threshold

Average global temperatures have already warmed by 0.74°C between 1906 and 2005, and the warming trend over the last 50 years is twice that of the first half of the 20th century, according to the Fourth

Fig 1: Impacts of a warming world



Source: 1 UNDP, 2007; 2 WWF, 2005; 3 Stern 2006; 4 UNFCCC, 2007; 5 Patz et al., 2005 (Nature); 6 UNFCCC, 2007; 6, WWF Russia., 2008; 7 IPCC, 2007 WGI; 8 UNEP-FI, 2006; 9 IPCC, 2007 WGII..

Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). Over the past 20 years, we estimate that the G-20 has lost more than USD1trn from climate related disasters, with the annual average on an upward trend. Looking ahead, the IPCC has projected warming during the 21st century of 1.1-6.4°C, and the trajectory of recent emissions suggests that the world is heading for the upper band of this range. Scientists have identified 2.0°C as the threshold beyond which climate impacts become unmanageable and irreversible. Past emissions mean that regardless of action to curb greenhouse gases (GHGs), the world is committed to at least another 0.4°C of warming¹ over the next two decades, compared to the baseline for 1980-1999.

Understanding the impact

In this report, we conduct three interlocking pieces of sector analysis to understand the scale and scope of the likely impacts on the G-20 economies by 2020.

- ▶ first, we assess the relative risk of the G-20 to climate change in 2020 with the HSBC Climate Vulnerability Assessment (HCVA).
- ▶ second, independent of the HCVA, we look in more depth at absolute impacts on agriculture, water and health
- ▶ third, we examine in depth the country specific implications for the G-20.

The HSBC Climate Vulnerability Assessment

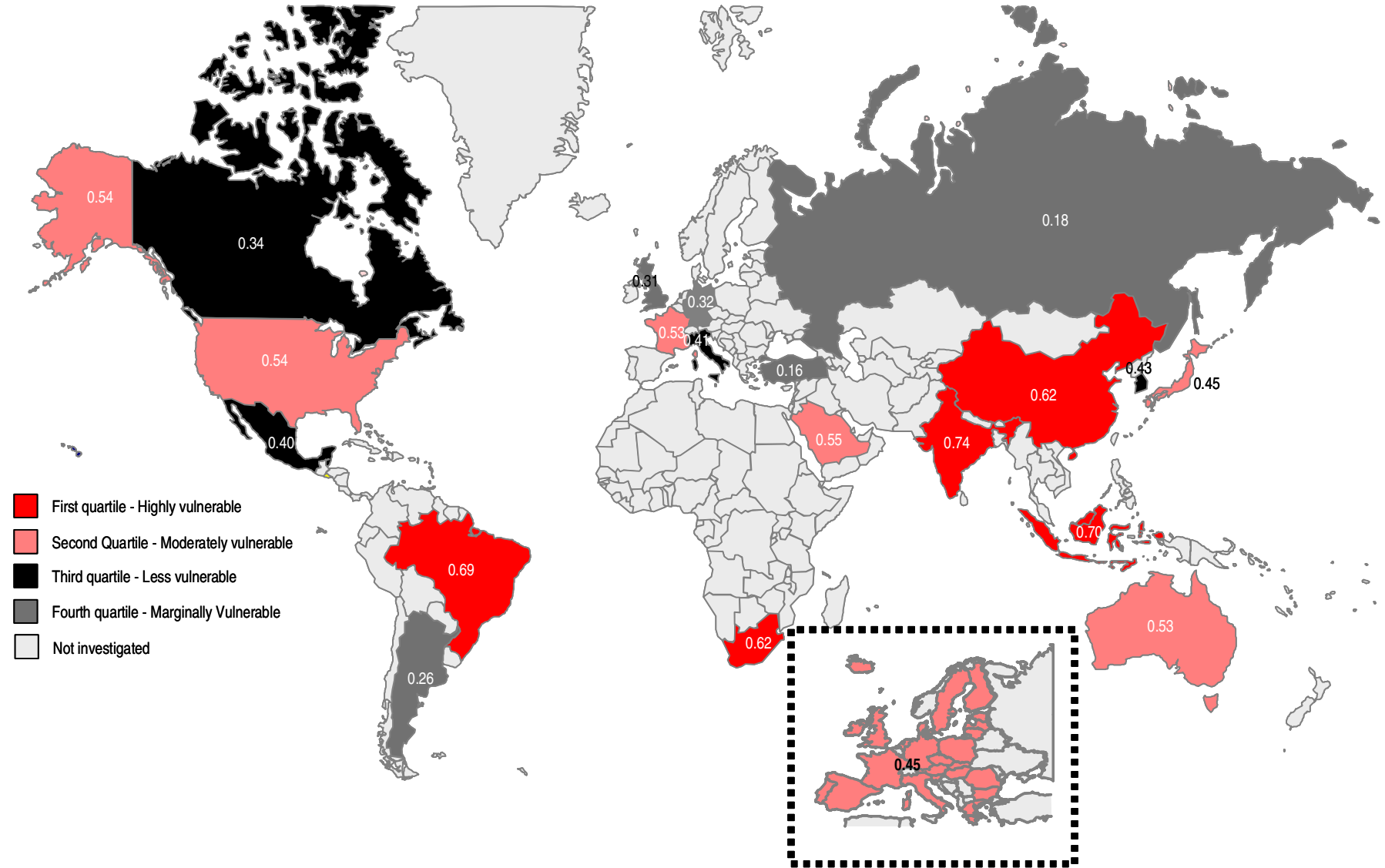
The climate vulnerability of a country is a function of its exposure to additional risks, adjusted for its sensitivity to these risks, and then modified according to its capacity to adapt to these risks. Using peer reviewed and publicly available datasets, we have conducted the first comparative assessment of the relative vulnerability of the G-20 to climate change in 2020.

Illustrated on Fig 2 on the next page, this assessment reveals that

- ▶ the top five most vulnerable economies in the G-20 are all emerging markets (India, Indonesia, Brazil, South Africa and China). This confirms previous assessments that it is the developing world that will be the hardest hit by climate change.
- ▶ the next basket of countries includes leading developed economies, where relatively high sensitivity to climate impacts magnifies underlying exposure, particularly in key regions: the US, France, Australia, Japan as well as Saudi Arabia
- ▶ the least vulnerable economies are Germany, the UK, Argentina, Russia and Turkey, although both Russia (on agriculture) and Turkey (on water and agriculture) could experience severe sectoral impacts.

¹ <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1>

Fig 2 : HSBC Vulnerability Map for G-20 (2020) – (EU in inset)



Source: HSBC

G20 Sector Profiles: Agriculture, Water & Health

Agriculture

We estimate that climate change will reduce total food grain production in the G-20 by 4.1-8.7%, costing USD 10-28 bn per year by 2020. Saudi Arabia, Turkey, Russia, the US and India are among the hardest hit. Rising population levels mean that per capita food production falls by 12-16% across the G-20; in India, per capita food grain production could fall by 21-25% and by 20-24% in the US.

Water

Overall, water availability across the G-20 is likely to grow by 3% by 2025. But water stress as measured in terms of availability per capita will rise in 16 out of 20 countries, notably Australia, Brazil, Indonesia, Mexico and Turkey. On the back of rising population and urbanisation, water demand is expected to surge by 20% over the same period.

Health

Currently, climate change is the cause of less than 1% of the global disease burden, and the G-20 accounts for less than half of this. By 2020, we estimate that Disability Adjusted Life Years (DALYs) from climate change could double, with health costs due to floods quintupling.

The linkages between these key impact areas are profound. All of the G-20 major exporters of 'virtual water' are expected to have less per capita water availability in 2025. On top of this, the US, which is the world's leading exporter of cereal faces a decline in production of c11-15% by 2020.

In this report, we project some of the key climate impacts into the 2020s. Actual costs could be quite different, not least as a result of measures that governments, business and individuals take to adapt to change. This will involve addressing the underlying drivers of vulnerability, improving the capacity to respond, managing climate risks and confronting the specific challenges raised by climate change.

Table 1: Interlinkages between climate change impacts on the Water, Agriculture and Health sectors

	Impact on Water (2025) % change in per capita water availability	Impact on Agriculture (2020) % change in cereal production with CO2 fertilisation	% change in cereal production with No CO2 fertilisation	Impact on Health (2020) Multiplier of climate induced DALYs (2020/2000)
Argentina	-19.4	1.7	-3.1	4.3
Australia	-26.6	5.3	-0.1	3.0
Brazil	-28.7	-4.4	-8.8	4.5
Canada	-7.8	-1.1	-6.2	12.6
China	-8.2	-1.0	-5.6	1.8
EU (adjusted)	-0.5	1.2	-3.5	7.1
France	-8.7	2.4	-2.8	7.6
Germany	1.5	1.9	-3.1	6.8
India	-14.8	-7.2	-12.0	1.7
Indonesia	-20.3	0.5	-3.5	1.7
Italy	-1.9	1.4	-3.3	7.0
Japan	8.2	5.6	1.5	2.4
Mexico	-30.2	-6.9	-11.3	4.3
Russia	32.4	-12.8	-18.0	1.6
Saudi Arabia	-15.3	-85.05*	-85.70*	3.6
South Africa	-20.0	-6.6	-9.7	1.3
South Korea	2.7	2.9	-1.2	1.5
Turkey	-29.6	-12.6	-18.0	2.1
UK	-3.8	3.1	-2.4	7.5
US	-10.0	-10.5	-14.9	12.7
G-20 Average	-8.86	-4.1	-8.7	1.7

Source: HSBC (based on Alcamo et al., 2007; Rosenweig, 2003; and WHO, 2007) (*As a policy, Saudi Arabia is exiting wheat production by 2016)

Contents

A warming world	6	Indonesia	85
Assessing vulnerability	14	Italy	89
Sector Profiles	19	Japan	93
Food for thought	20	Mexico	97
Adding to water stress	26	Russia	101
An unhealthy climate	31	Saudi Arabia	105
Linking up the impacts	35	South Africa	109
Confronting the inevitable	40	South Korea	113
Country Profiles	45	Turkey	116
Argentina	47	UK	120
Australia	51	US	124
Brazil	56	Appendices	128
Canada	60	Appendix 1 SRES Scenarios	129
China	64	Appendix 2 Methodology	130
European Union	69	Appendix 3 Sensitivity Analysis	134
France	73	Appendix 4 HCVA FAQs	136
Germany	77	Disclosure appendix	138
India	80	Disclaimer	139

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A warming world

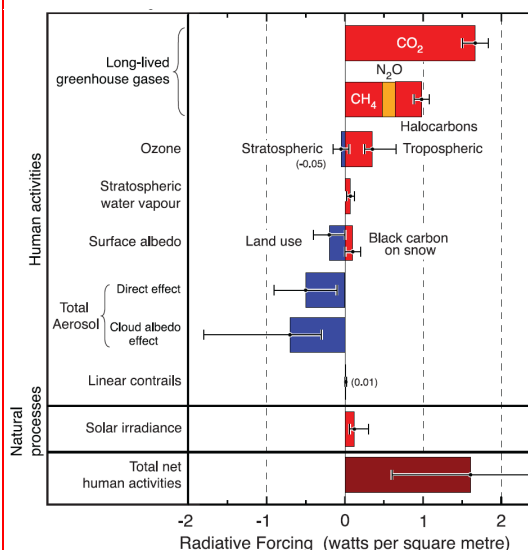
- ▶ Rising greenhouse gas emissions from energy, industry, agriculture and deforestation are driving a warming world
- ▶ Over the past 20 years, we estimate that the G-20 has lost more than USD 1 trn from climate-related disasters, an annual average of USD 52 bn²
- ▶ Past emissions guarantee a further 0.4°C over the next two decades, and current greenhouse gas emission trends point to a 6°C temperature rise by the end of the century

Getting warmer

Rising concentrations of greenhouse gases are trapping heat in the Earth's atmosphere. Although 2008 was the coolest year since 1997, it was still the ninth hottest since records began in 1850, according to the World Meteorological Organisation. Looking back, global average temperatures rose 0.74 °C during the period 1906-2005. This is greater than the 0.6°C reported for 1901-2000. The trend over the last 50 years is twice that of the first half of the 20th century, according to the 4th Assessment Report (AR4) of the Intergovernmental Panel on Climate Change. This number could rise further – the best estimate for the low scenario (B1, among IPCC's family of scenarios) is 1.8°C. This is dangerously close to the 2°C threshold beyond which climate change could drive irreversible and catastrophic disruptions- as illustrated in Fig 9 later on in this

chapter. The mean estimate of the high scenario (A1F1) is 4.0°C, with a likely range of 2.4-6.4°C.

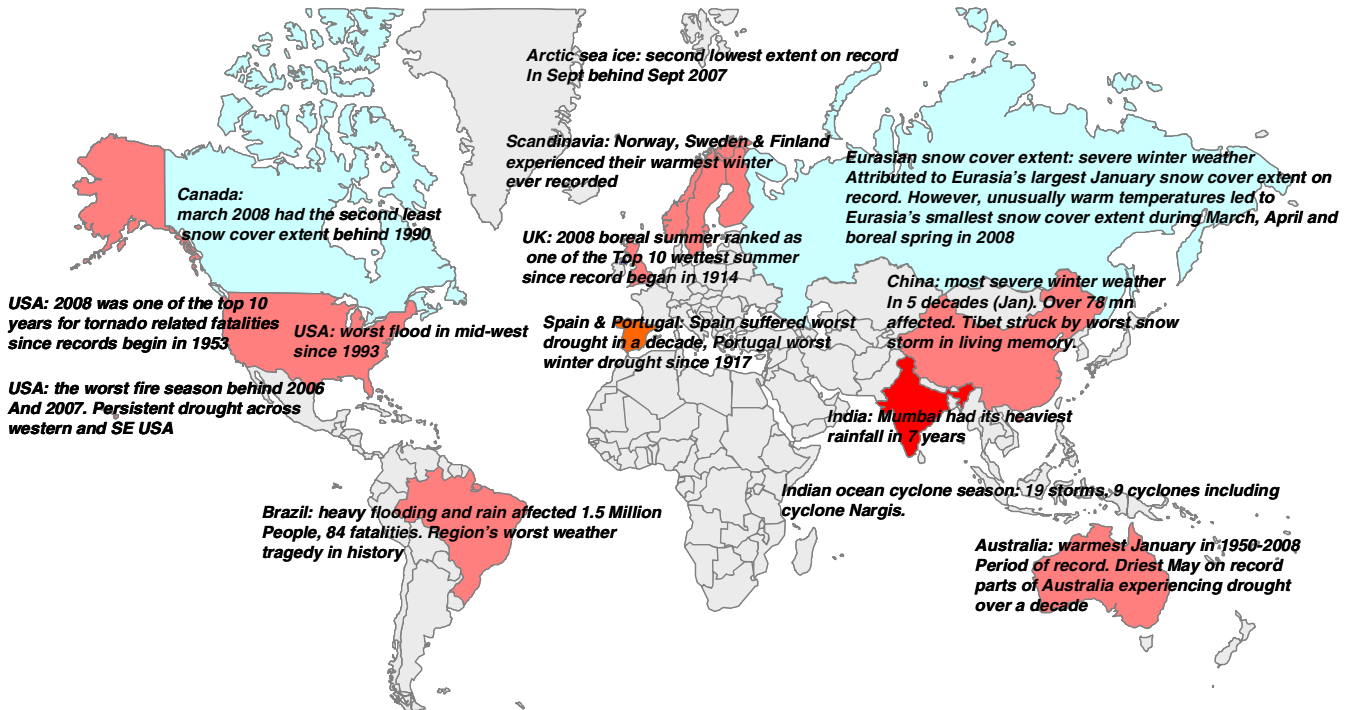
Fig 3: Global average radiative forcing in 2005 with respect to 1750



Source: IPCC, 2007; WG1

²Droughts, extreme temperatures (e.g. heat waves, cold waves), floods, insect infestation, mass movements wet and dry (landslides, etc.), storms and wild fires – For their detailed definitions see the section on Climate Risks.

Fig 4: Significant climate related events in 2008

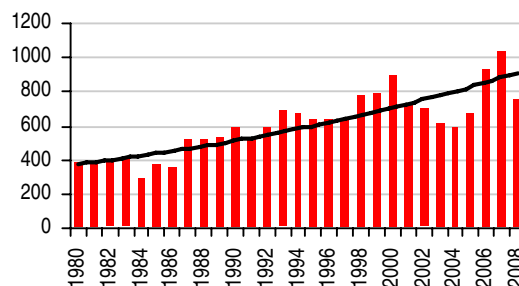


Source: HSBC drawing based on NOAA data, 2008

This global average masks much higher levels of warming at the poles and over land, where temperatures have climbed over 1°C, compared to a 0.5 °C increase at the ocean surface³.

Water is one of the key vectors by which climate change is expressed, and the National Oceanic and Atmospheric Administration (NOAA) statistics show that rainfall patterns have changed over the last 40 years in line with predictions from the climate models. As a result, there is an overall trend towards increasing precipitation in areas with already abundant rainfall and decreasing precipitation in areas already suffering from water shortages. Warmer air holds more moisture, and this increases the tendency for more concentrated rainfall, i.e. when it rains, it rains heavily.

Fig 5: Number of natural catastrophes worldwide (1980-2008)



Source: Munich Re, 2008

Pay no worship to the garish sun

Alternative explanations of global warming often point to changes in solar output (sun spots) as a key driver. However, the IPCC's AR4 in 2007 categorically concluded that anthropogenic GHG emissions were responsible for the overwhelming bulk of the observed change in the Earth's energy balance.

As shown in Fig 3, human induced GHGs have caused an additional average radiative forcing of

³ <http://lwf.ncdc.noaa.gov/sotc/?report=global&year=2009&month=9&submitted=Get+Report>

1.6 W/m² (watts per meter square) for the year 2005 as compared to 1750. By comparison, radiative forcing caused by the Sun has been estimated at only 0.12 w/m².

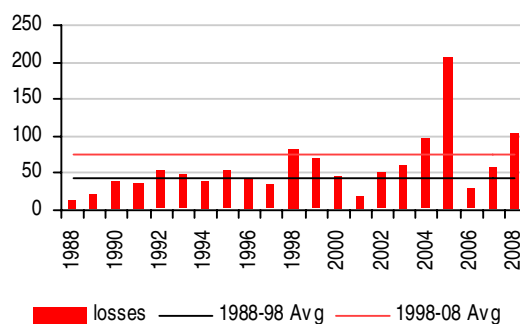
Direct measurements of solar output over the past 20 years since 1978 have shown a steady rise and fall over the 11-year sunspot cycle. But there is no observable upward or downward trend – unlike rising global average temperatures over the same period⁴.

Violent delights have violent ends

To date, climate change has been relatively modest. But it has already become a contributing factor to a rising trend in natural catastrophes worldwide (Fig 4). Fig 4 maps the significant climate related events in 2008, and commenting on the past year, Munich Re observed that it confirmed “the persisting trend of anthropogenic warming...of particular relevance for the insurance industry were the extreme weather events including heavy rain, windstorms, and severe local storms”⁵.

Based on the Emergency Disasters Database (EMDAT), we estimate that in the G-20, the annual average cost of climate related losses has risen from USD 42.4 bn over 1988-1998 to USD 75.4 bn over 1998-2008 (Fig 6). In total, this amounts to over USD 1 trillion over the past 20 years for the G-20. World wide, the top 5 losses are experienced in – storms, floods, droughts, extreme temperatures and wildfires. The US heads the pack in terms of climate-related losses between 1998-2008 at USD 463 bn, followed by China (USD 217 bn) and the EU (USD 175 bn).

Fig 6: Economic losses (in USD bn) from climate related disasters (1980-2008) in G-20



Source: HSBC (EMDAT database, 2009)

Looking ahead, higher levels of weather-related insured losses are expected across most of the developed world. Allianz estimates, for example, that the average annual insured loss from weather-related damage could rise from an average of \$33bn⁶ a year between 1999-2008 to \$41bn between 2010-2019, a 24.2% increase.

Citius, Altius, Fortius

The Olympic motto of ‘faster, higher, stronger’ could also be applied to the experience of climate change. Current levels of GHG concentrations in the atmosphere stand at more than 430ppm CO₂e.⁷

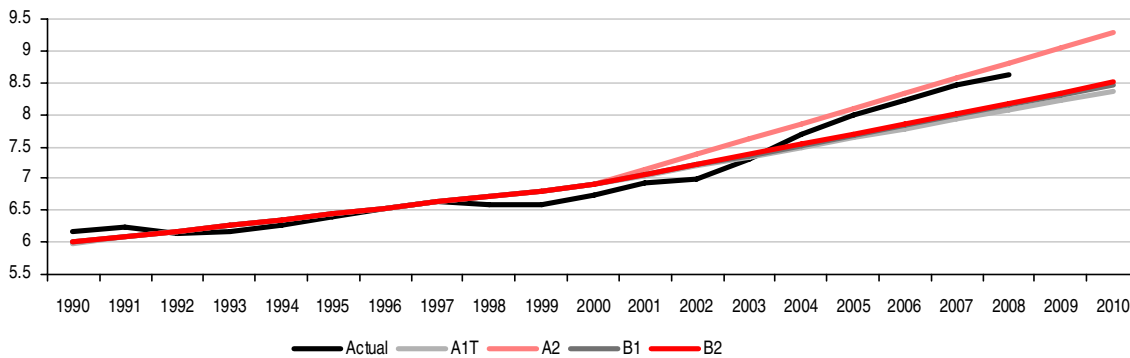
⁴ <http://www.newscientist.com/article/dn11650-climate-myths-global-warming-is-down-to-the-sun-not-humans.html>

⁵ Munich Re, *Natural Catastrophes 2008*, February 2009

⁶ Source: *Insurance Information*

⁷ N. Stern, 2008

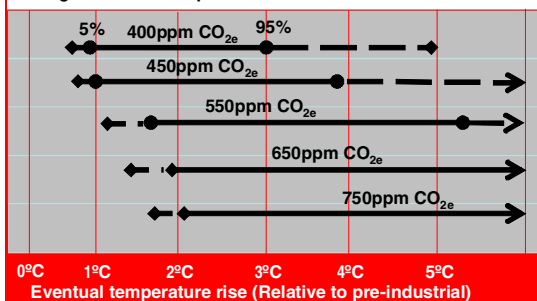
Fig 7: Trend in global GHGs vs. IPCC scenarios (AIM model scenarios) (values in gigatonnes of Carbon)



Source: HSBC ; IPCC, 2003; CDIAC, <http://edgar.jrc.ec.europa.eu> (2007 and 2008 values are estimates from EDGAR 4.0 (JRC/PBL, 2009))

At current growth rates of 2.5ppm CO₂e pa, concentrations could reach 450ppm CO₂e well before 2020, leading to a more than 75% likelihood that warming could exceed 2°C and an 18% chance that warming exceeds 3°C by the end of the century (see Fig 8).

Fig 8: Relationship between global CO₂ concentration rise and global mean temperature



Source: Schaeffer, 2008, Stern, 2008; drawing by HSBC

Scenarios contained within the IPCC's AR4 project further warming of between 1.1 - 6.4°C during the rest of the 21st century, with a best estimate of warming (i.e. the averages of the different scenarios) of between 1.5 and 4.5°C by 2100.

Until the onset of the global financial crisis, emissions were rising towards the top end of the range, which if left unchecked could result in a 7°C warming over the 20th and 21st centuries, an unprecedented shift in a 200 year period. The implications of extreme warming are set out in Fig 9.

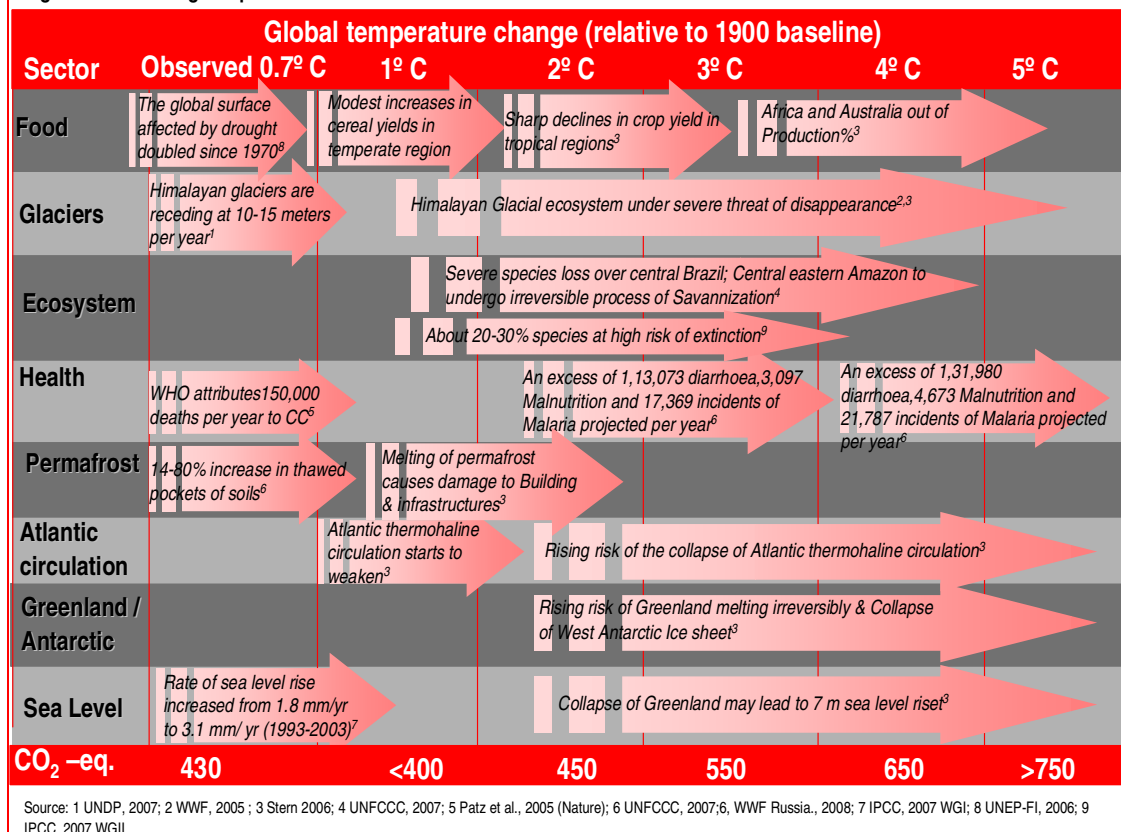
The financial crisis will cause a one-time drop of 3% in energy-related CO₂ pollution for 2009, according to the IEA⁸: energy-related CO₂ is about 2/3rd of total GHGs (IPCC, AR4). In Fig 7, we compare actual emissions with the GHG trajectories projected by the AIM model –one of the six models that formed the IPCC Special Report on Emission Scenarios in 2003. We compare them for the last two decades for which IPCC GHG trajectory predictions are available: Appendix 1 describes the individual scenarios and underlying assumptions. This shows that actual emissions have been rising towards the top end of the projected range.

A recent report released by the Global Carbon Project⁹ confirms that the world is already firmly set on a path to a 6°C temperature rise by the end of the century. It further notes that carbon dioxide emissions from burning fossil fuels have increased by 29% between 2000 and 2008, including a 2% increase in 2008. The fraction of CO₂ that remains in the atmosphere has grown from 40% in 1959 to 45% in 2008, demonstrating that the world's land and oceans are fast losing their ability to absorb CO₂ from the atmosphere.

⁸ IEA World Energy Outlook, 2009

⁹ <http://www.independent.co.uk/environment/climate-change/world-on-course-for-catastrophic-6deg-rise-reveal-scientists-1822396.html>

Fig 9: Climate Change: Implications for our world



The environment is responding to increasing GHG concentrations in other ways. For example, the IPCC concluded in the AR4 that Arctic sea ice might disappear completely each summer by the second half of the century. However, more recent observations suggest that Arctic summer ice is set to disappear completely, as early as in the next 20-30 years¹⁰. While this opens up the Arctic sea route for new commerce, it will accelerate global warming, since the open sea has lower reflectivity than ice. The once 'permanent' Arctic ice cap will now only be a seasonal feature.

The integration of feedback effects such as these could make a real difference. A new study published in September 2009 by the UK Met Office¹¹ incorporates feedback effects into its modelling, which amplifies the warming. The

result is that a 4°C rise could come as early as 2064 – within the lifetimes of most people alive today; 2°C could be reached as early as 2024.

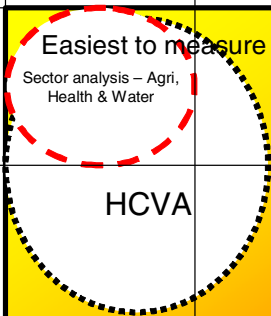
The challenge for national and global climate policies is to avoid catastrophic climate damage by reducing global emissions by 50-85% by 2050 (see Nick Robins et al, *The Emperor, the Nightingale and the Phoenix*, Sep 18, 2009). But this will still leave an unavoidable amount of warming which economies and businesses will need to respond to – the challenge of climate vulnerability and adaptation.

Focusing on 2020

The stock of GHGs released over the past century means that the world is committed to at least another 0.4°C of warming over the next two decades, compared to the baseline for 1980-1999. By 2020, the world economy is estimated to be

¹⁰ Peter Wadhams, Polar Physics Group, Cambridge
¹¹ Four Degrees and Beyond, UK Met office, 2009

Fig 10: A matrix of climate change risk

	Types of impact	Market impacts	Non-market physical impacts	Socially contingent impacts
Predictability ↓	Examples → ↓	Agri, health costs, property loss etc	Deaths, extinctions, Ecosystem damages	Migration response to food & water shortages
Averages	Temperature, sea levels, CO2 steady increment			
Extremes	Increased frequency and strength of heat waves, storms, droughts, floods etc			
Catastrophes	Polar ice sheets melting turning off major ocean currents			Hardest to measure

Source: HSBC (adapted from (http://foe.co.uk/resource/reports/econ_costs_cc.pdf) original source Downing and Watkiss, 2003)

over 1.5 times bigger in 2008 Purchasing Power Parity (PPP) terms, reaching over USD 100 trn¹².

In this report, we evaluate the scale and significance of these unavoidable impacts for the G-20 countries by 2020. Over the next two decades, the impacts of climate change are likely to be within the range of natural variability. This does not mean that the consequences will be insignificant as there is already an 'adaptation deficit' in terms of the ability of many countries to remain resilient in the face of climate change.

Our focus on the G-20 is driven by a desire to examine the vulnerabilities of greatest relevance to the global economy. The G-20 accounted for almost two-thirds of global population and 87% of world GDP in 2008¹³. It contains wide disparities of incomes, with the US having the highest per

capita GDP of over USD 47,600 in Purchasing Power Parity terms, compared with India at just over USD 2,800¹⁴. Actual vulnerability may well be greater in other parts of the world, notably small island states and least developed countries.

Chronic and acute impacts

Global warming has both 'chronic' and 'acute' effects, changing both the underlying mean as well as the extremes of key climate related phenomena (see Fig 10).

The movement in averages

Sea Level Rise: Sea level rise (SLR) is a slow moving phenomenon. The rate of increase has increased to 3.1mm per year (1993-2003) compared to 1.7mm a year during the last century as a whole (IPCC AR4). The impact on coastline change from sea level rise by 2020 is not significant, and we do not model sea level rise in

¹² How the Energy Sector can deliver on a Climate Agreement in Copenhagen, October 2009

¹³ http://www.euromonitor.com/G20_In_focus

¹⁴ Ibid. (2008 figures)

this report. There is a link between SLR and hurricane/storm damage. Higher sea levels mean more water near the shore for tropical storms to pick up, causing more damage inland even for the same strength of storm. In a recent observational study¹⁵, the Georgia Institute of Technology found no statistically significant increase in the world-wide frequency of tropical cyclones over the last 30 years. However, it found significantly more storms at higher strengths levels (Category 4 and 5), which is an indication that storms have become stronger. For the western North Pacific region, the number of category 4 and 5 storms has grown from 5.7 per year during the first 15 years to 7.7 per year during the second half.

Agricultural output

Rising temperature changes the growing conditions affecting yield, positively and negatively depending on what the ambient temperature was before. Studies show that rising CO₂ might actually help some plant varieties grow faster, and this carbon fertilisation effect can be modeled. Yield increases from better strains of crops have, however, seen a plateau. For this study, we keep yields constant at current levels, and model the G-20 and country specific impacts of food production with and without carbon fertilisation.

Health: Climate change increases the incidence of certain kinds of diseases, exacerbates the impacts of heat stress and increases vulnerability to extreme events. In this report, we examine the specific health and economic costs of malaria, malnutrition, diarrhoea and flood-related climate impacts.

Water: Changing rainfall and temperature patterns by 2020 will exacerbate underlying problems of increasing water scarcity. Added to this will be the implications of retreating glaciers across the globe.

Changes in extremes¹⁶

Extreme events are those which cause a large impact in a short time period. They are perhaps better described as 'acute events'.

Droughts: A drought is an extended period of time characterised by a deficiency in a region's water supply that is the result of constantly below average precipitation. A drought can lead to losses to agriculture, affect inland navigation and hydropower plants, and cause a lack of drinking water and famine. Among the G-20, Australia has suffered a long drought since 2003 (see the Australia country profile for a discussion).

Heat wave: A heat wave is a prolonged period (typically 5 days or more) of excessively hot and sometimes also humid weather relative to normal climate patterns of a certain region. The 2003 European heat wave lasted for over 20 days, raising summer temperatures 20 to 30% over the seasonal average over a large portion of the continent.¹⁷

Cold wave: Conceptually similar to a heat wave, any prolonged period with excessively cold weather and the sudden invasion of very cold air over a large area. Along with frost, it can cause damage to agriculture, infrastructure and property.

Flood: This is any significant rise of water level in a stream, lake, reservoir or coastal region. If the rise of water is very rapid due to intense rainfall, such sudden flooding is defined as a flash flood.

Insect infestation: Pervasive influx and development of insects or parasites affecting humans, animals, crops and materials.

Mass movement dry and wet: Landslides, rockfall, subsidences and avalanche¹⁸

¹⁶ Definitions from EMDAT Glossary

¹⁷ http://www.grid.unep.ch/product/publication/download/ew_heat_wave.en.pdf

¹⁸ <http://www.ifrc.org/what/disasters/about/types/hydrological/avalanches.asp>

¹⁵ IPRC Hawaii

Storms: A severe storm or thunderstorm is the result of convection and condensation in the lower atmosphere and the accompanying formation of a cumulonimbus cloud. A severe storm usually comes along with high winds, heavy precipitation (rain, sleet, hail), thunder and lightning. A storm surge is the rise of the water level in the sea, an estuary or lake as result of strong wind driving the seawater towards the coast. The mean high water level can be exceeded by five and more metres. The areas threatened by storm surges are coastal lowlands.

Wild fires: Fires in forests can cause extensive damage. They may start by natural causes such as volcanic eruptions or lightning, or they may be caused by arsonists or by accident, or by those clearing a forest area. The additional risk from a warmer climate is that drier leaves catch fire more easily. There is a correlation with insect infestations, to the extent that such insects, such as pine beetles in Canada, make trees drier, making them more susceptible to forest fires.

We take into account the losses from all these extremes in calculating the exposure of a country to climate change related disaster losses. Worldwide losses are highest from storms followed by floods, droughts and extreme temperatures. Wildfires, mass movement wet and dry account for least of the damages.

Measuring climate vulnerability

Future climate impacts are by nature uncertain – and only a small proportion can be captured in market-based calculations. Fig 10 shows the intersection of changes in averages, extremes and catastrophes with market, non-market risks (such as deaths, extinctions and biodiversity losses) as well as socially contingent risks (such as migration, displacement and loss of livelihood).

In this report, we evaluate the market impacts for agriculture and health, as affected by climate change and link them with how water demand and water stress changes in different countries. We then make estimates for the market value of changes in food production (agriculture) and human productivity (health). All these losses are expressed in current prices.

To provide a ranking of the comparative levels of risk, we developed a new metric, the HSBC Climate Vulnerability Assessment.

Assessing vulnerability

- ▶ Among the G-20, India, Indonesia, Brazil, South Africa, and China are in the top quartile of climate vulnerability in 2020.
- ▶ Germany, UK, Argentina, Russia and Turkey are the least vulnerable, and could see some temporary benefits
- ▶ These relative rankings should not obscure increased sector- and region-specific vulnerabilities in all countries

Ranking country risks

The HSBC Climate Vulnerability Assessment (HCVA) produces an index for the G-20, based on projected impacts data, past climate related disaster loss experiences and the socio-economic health of each economy.

We define Climate Vulnerability as a function of the exposure of the country to climate risks, adjusted for the sensitivity of the country to these risks, and the adaptive capacity of the country.

A full description of the methodology is given in Appendix 2. In essence, exposure scores are calculated for each country for the year 2020, based on academic models developed by Lord Nicholas Stern and Robert Mendelsohn. The

sensitivity scores are based on the latest per capita climatological disaster loss estimates averaged over the time period 1988 to 2008. Adaptive capacity is calculated on the basis of latest available estimates (2006-2008) for literacy, life expectancy as well as per capita income.

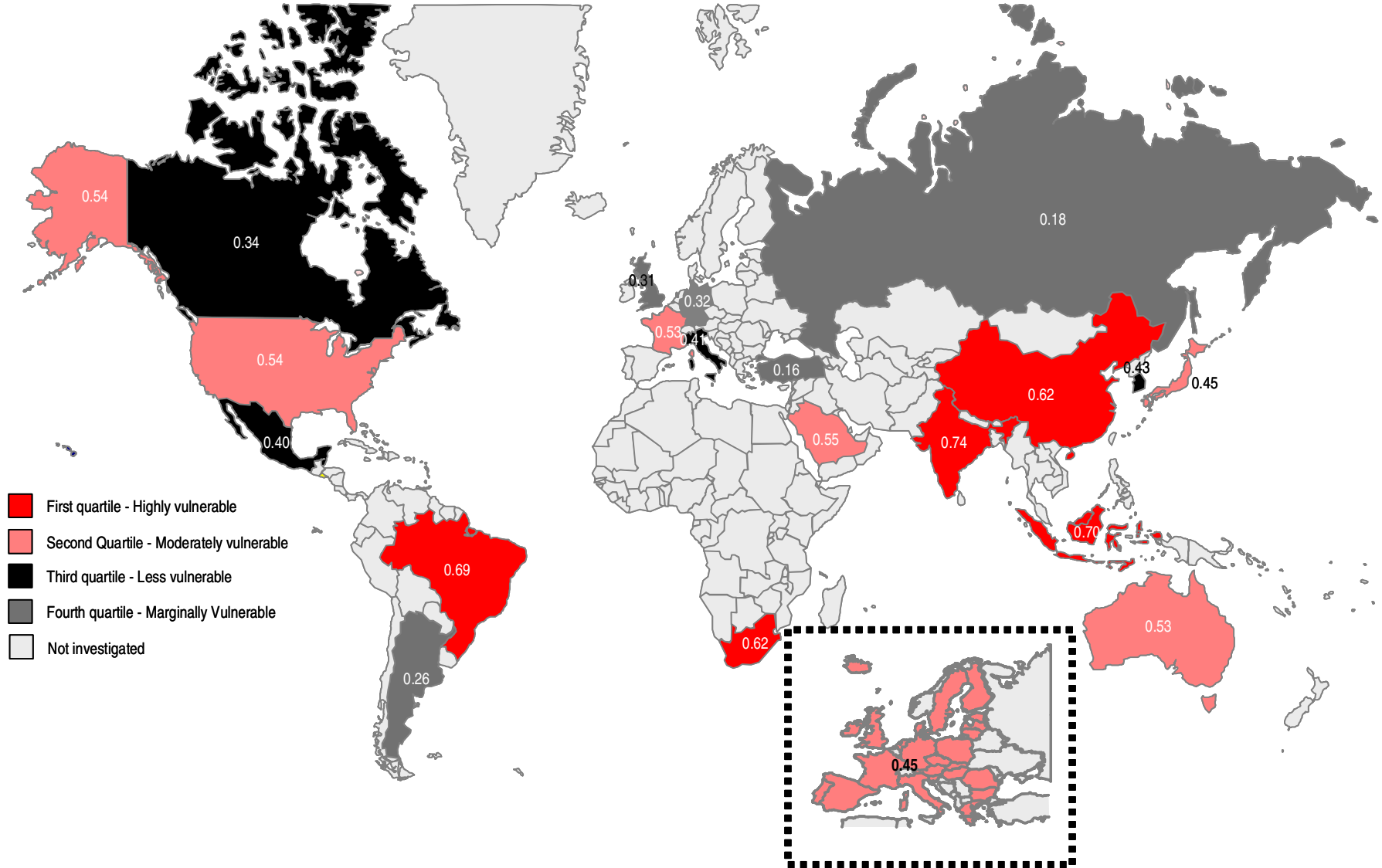
The high-level results presented in Table 2 as well as Fig 11 show that India, Indonesia, Brazil, South Africa and China are highly vulnerable amongst the G-20 countries. This outcome confirms previous assessments which conclude that developing countries are most exposed and least adapted to change.

Table 2: HSBC Climate Vulnerability Assessment (HCVA): high score = high risk

Most vulnerable...	HCVA score	HCVA rank	... less vulnerable	HCVA score	HCVA rank
India	0.74	1	EU as a whole	0.45	=10
Indonesia	0.70	2	South Korea	0.43	12
Brazil	0.69	3	Italy	0.41	13
South Africa	0.62	=4	Mexico	0.40	14
China	0.62	=4	Canada	0.34	15
Saudi Arabia	0.55	6	Germany	0.32	16
US	0.54	=7	UK	0.31	17
France	0.53	=8	Argentina	0.26	18
Australia	0.53	=8	Russia	0.18	19
Japan	0.45	=10	Turkey	0.16	20

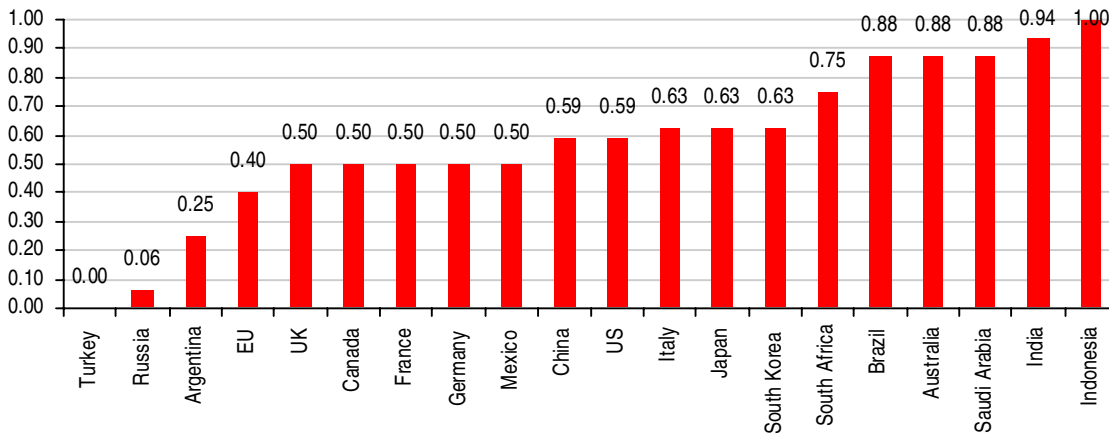
Source: HSBC

Fig 11 : HSBC Vulnerability Map for G-20 (2020) – (EU in inset)



Source: HSBC

Fig 12: HCVA exposure subscore of G-20 Countries (2020)



Source: HSBC

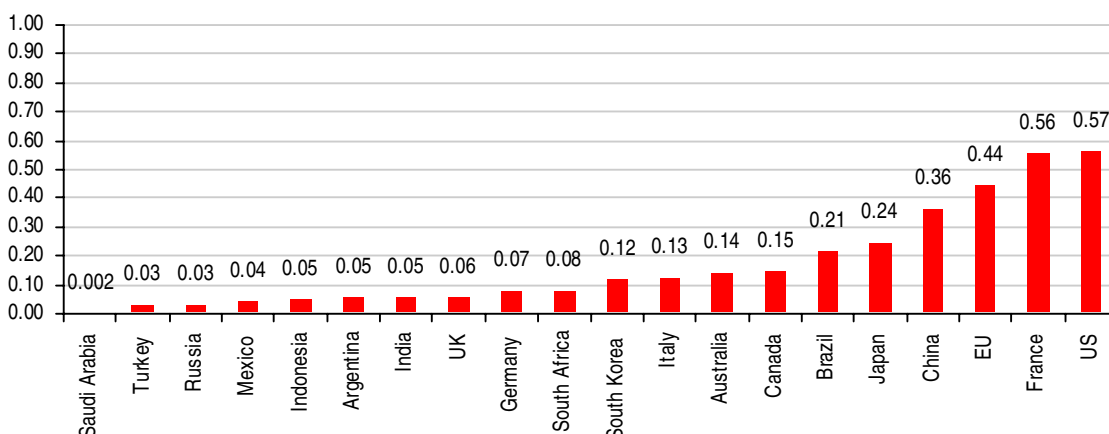
Evaluating climate exposure

According to the IPCC, exposure provides a measure of the character, magnitude, and rate of climate change and variation to which a system (e.g. a country or a sector of the economy) is affected. We rank G-20 member states based on their relative exposure scores, which vary from a minimum of 0 to a maximum of 1. Here we have taken 'the projected (%) impact on GDP' as an indicator of exposure to climate change.

Comparing with the overall vulnerability scores, the exposure score is similar in that it indicates Indonesia, India, Saudi Arabia, Australia, Brazil

and South Africa to be most exposed economies to the vagaries of climate. It also suggests that Russia, Argentina and Turkey are among the least exposed nations, very much in line with the vulnerability scores. The limited availability of country specific assessments for Turkey makes us introduce a note of caution for its apparently low ranking, which appears to be at odds with potentially high impacts in key sectors such as agriculture and water. As more country level estimates become available, these rankings may change (see Appendix 3 for sensitivity analysis).

Fig 13: HCVA sensitivity subscore of G-20 countries



Source: HSBC

Evaluating impact sensitivity

Impact sensitivity measures the degree to which a system is affected, either adversely or beneficially, by climate variability. It provides information as to how a particular system (in this case a particular nation or a particular sector of the economy) has performed under similar stresses. In this study, we have collected data on the following parameters for 20 years (1988-2008):

- ▶ No. of deaths
- ▶ No. of homeless people
- ▶ No. of people affected (displaced, etc.)
- ▶ The value of assets lost (in USD)

These datasets were normalized by the size of the respective country populations.

Fig 13 shows that the US, France, EU, China, and Japan have incurred the highest per capita damages due to climate related disasters in the last two decades. Saudi Arabia, Turkey, Russia and Mexico seem to have suffered the least climate related damages in the last 20 years. Climate related disasters in this report refer to all the extreme events defined in the previous chapter - droughts, extreme temperature events, floods, insect infestations, storms, landslides, subsidence (etc.) and wild fire.

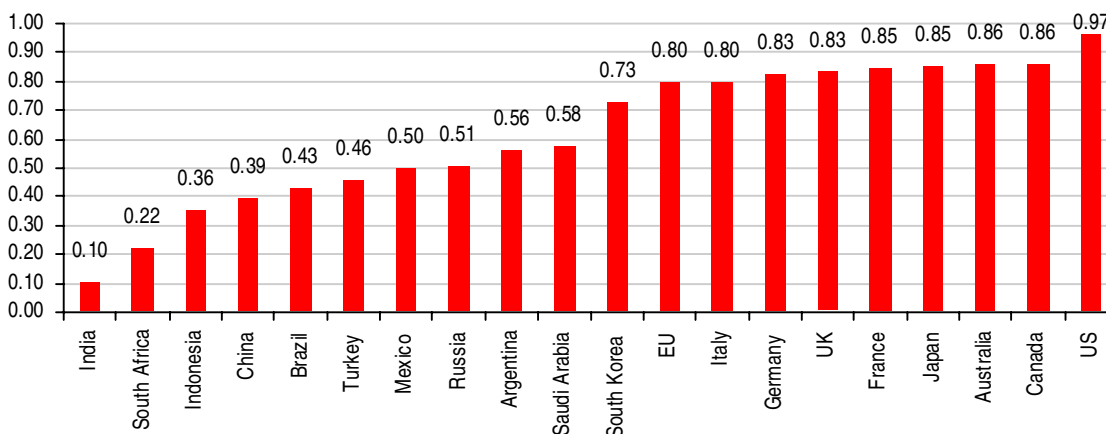
Evaluating adaptive capacity

The IPCC defines adaptive capacity as the ability of a system such as a national economy to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. A number of G-20 countries are starting to put in place policies for adapting to climate change. But in lieu of accurate assessments of the effectiveness of these policies, we measure for the potential resilience of each G-20 economy in terms of per capita GDP, life expectancy and literacy. We note that the last two factors do have a correlation and we have performed a sensitivity analysis contained in Appendix 3.

As a result of higher per capita income, higher life expectancy and universal literacy, the US, Canada, Australia, Japan and France lead the pack on this subscore, with India, South Africa, Indonesia, China and Brazil with the lowest adaptive capacity. This is not an unsurprising result (Fig 14).

This measure only addresses the adaptive potential – not the actual ability to respond to climate change through policy, institutional and market innovation. As a result, countries with large adaptive potential may not deploy this to actually protect people and assets, while countries that are relatively weak in adaptive potential could make a disproportionate effort to translate limited resources into real capacity.

Fig 14: HCVA adaptive capacity sub score of G-20 countries



Source: HSBC

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Sector Profiles

Food for thought

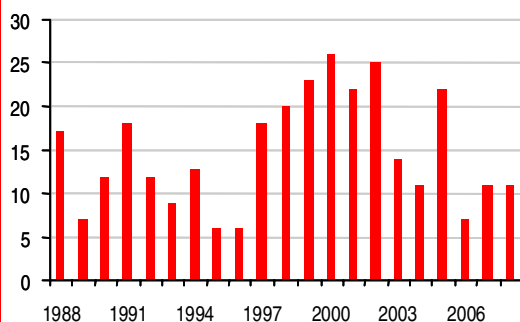
- ▶ We estimate that total food grain production losses for the G-20 from climate change could be about 70-150 mn tonnes pa by 2020, a decline of 4.1%-8.7%.
- ▶ In terms of value, we estimate the annual G-20 loss in cereal production could be USD 10-28 bn
- ▶ Rising population levels mean that the decline in per capita G-20 food production could be more pronounced at 12-16% by 2020

A climate sensitive sector

Agriculture is a climate sensitive sector as the growth, germination and flowering of crops are invariably linked with temperature and rainfall patterns.

This sector is already reeling under multiple stresses especially in developing countries with increasing frequency of droughts, floods, forest fires, pest attacks and increased storminess. The frequency of droughts in the last two decades can be seen in Fig 15.

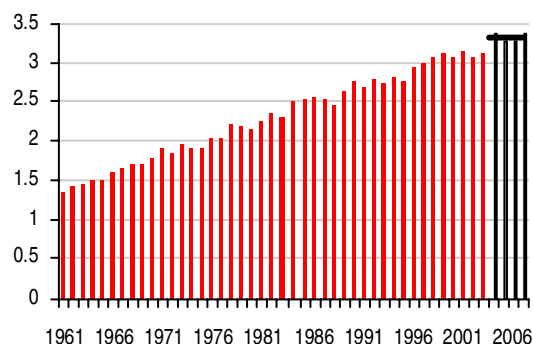
Fig 15: Frequency of drought events (1998-2008) G-20



Source: EMDAT database

Climate change is not only likely to impact the intensity and frequency of 'extreme' events; it is also likely to bring changes to 'mean' events such as crop yields pa. Agricultural yields have increased substantially as a result of improved irrigation, hybrid seeds, as well the use of insecticides and fertilizers, over the last few decades. (Fig 16). However we note that the trend has flattened over the past few years.

Fig 16: Global average cereal yield (tonnes/ha) (1961-2006)



Source: FAO

How green is my valley?

Table 3: How green is my valley?

	% Arable land	Agriculture, as % of GDP	Agriculture, as % of employment
Argentina	10	8.5	1
Australia	6	2.8	4
Brazil	7	5.2	21
Canada	5	2.3	3
China	15	11.7	21
EU27	26	2	6
France	34	2	2
Germany	34	0.9	2
Indonesia	13	13	42
India	54	18.3	58*
Italy	26	1.9	4
Japan	12	1.5	4
Mexico	13	3.9	15
Russia	7	4.9	10
Saudi Arabia	2	3.0	7
South Africa	12	2.8	10
South Korea	16	3.3	8
Turkey	6	2.8	4
UK	24	0.9	1
US	19	0.9	2

*Indian Census 2001
Source: The Economist,

The countries in the G-20 will have very different sensitivities to changes in agricultural output from climate change. Natural endowments of arable land and water resources vary widely within and between countries. Furthermore, countries can choose to deploy their agricultural resources for domestic self-sufficiency (e.g. China, and Saudi Arabia until recently), or for export earnings (e.g. Argentina, Brazil, Argentina, US). (Table 3)

The impact of climate change

Most of the IPCC studies suggest a drop in the global yields in a changed climate. However, in some countries, where the short length of growing period currently constitutes a limiting factor, yields are likely to be impacted positively up to a certain point: higher temperatures might lengthen the growing period in some of the colder countries, for example.

We use the results of the crop modelling analysis carried out by Cynthia Rosenzweig and Ana

Iglesias (2003)¹⁹. We chose this model for the following reasons:

- 1 The model provides outputs for 2020
- 2 It provides estimates for all the major crops such as rice, wheat, pulses and coarse grains
- 3 The model is based on an agricultural research spanning two decades by a team of agricultural scientists from 18 countries based on underlying crop model data from 125 agricultural sites from across the globe.
- 4 It considers three levels of adaptation – which makes the scenarios more realistic. In this report, we make use of only Level 1 adaptation, which involves simple steps by the farmers such as shifts in planting dates by less than one month, shifts to other available varieties and crops, and increased irrigation using existing systems.
- 5 The robustness of this model has been tested by recent field research. Rosenzweig-Iglesias estimates place the carbon fertilisation impact at about +17 percent by the 2080s. This impact is close to the 15 percent as identified as the proper target for carbon fertilisation by this period on the basis of the recent free air concentration enrichment (FACE) field experiments²⁰.

However, the crop model has several limitations which should be borne in mind when interpreting the impacts. The potential effects of climate change on crop damages due to pests and diseases are not considered and are assumed to remain at current levels. At present, the pest and disease damage is estimated to reduce potential global crop yield by 30%. The model does not capture the interannual and interseasonal climatic variability. Finally, it does not account for

¹⁹ http://sedac.ciesin.org/giss_crop_study/CCMmethod.html

²⁰ William R. Cline, 2007 "Global warming and Agriculture – Impact estimates by country"

stochastic (i.e. uncertain) events such as cyclones, hurricanes and prolonged floods²¹.

In our estimates, we have assumed that the net sown area remains constant. This is not unrealistic as the world has very little buffer farmland which can be brought into production, the exception being Western Europe. Much of this was brought into production following the price spikes of 2007-08. We assume no major adaptation efforts are taken (except for Level 1 adaptation, as already discussed).

In this report, the words cereals and food grains are used interchangeably.

We have also assumed the absence of major technological breakthroughs in food production techniques. This means in the case of Russia that we do not take into account the likely expansion of agriculture in northern Russia (new potential lands) by 2020, while we do take into account the decreased productivity in southern Russia due to water limitations.

Finally, we have not modelled the implications of any further diversion of agricultural land and food crops to bio-energy production: given existing policy commitments, this would reduce available agricultural output in 2020 for human consumption.

Although the model provides outputs for a number of scenarios, we discuss in detail only one of the scenarios, the CM3 scenario output, which we consider as the most likely scenario. We interpret the results for this, with and without factoring in the carbon fertilisation effect.

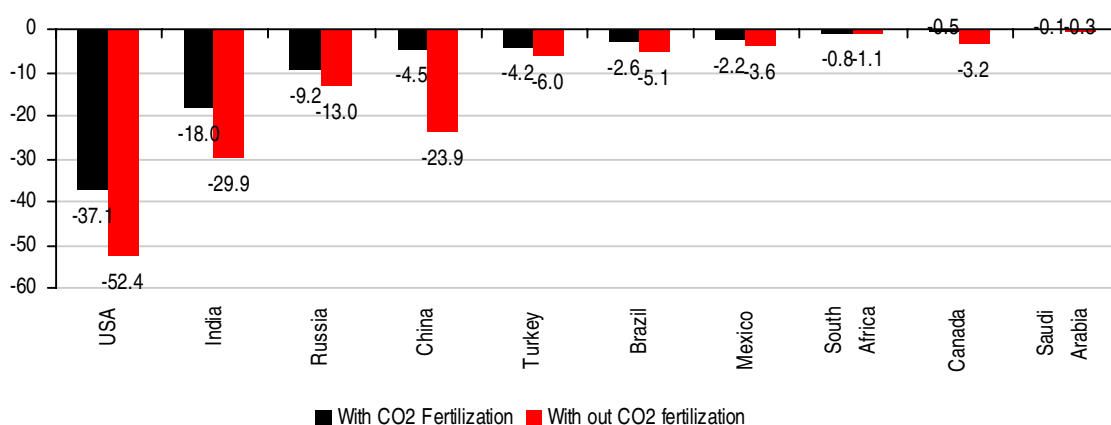
The carbon fertilisation effect

Photosynthesis is the process through which plants create carbohydrates, and in turn biomass. This process involves the uptake of CO₂ and the use of water. It is sometimes argued that in an enriched CO₂ environment the rate of photosynthesis may increase especially in certain plant varieties, such as wheat, rice and soybean known as C₃ plants, thereby increasing the productivity. This phenomenon is commonly termed the CO₂ fertilisation effect. However, the CO₂ fertilisation effect is not without contention as it is sometimes argued that additional CO₂ may not lead to increased biomass production in the absence of other nutrients such as nitrogen.

Assuming that we indeed see the beneficial effects of higher CO₂ makes these estimates somewhat *optimistic*.

²¹ http://sedac.ciesin.org/giss_crop_study/CCMdata/limits.html

Fig 17: Change in *cereal production (in mn tonnes) 2020 forecast from climate change (Top 10 most affected of G-20)



*Cereals: wheat, rice, coarse grain and pulses. Note: Changes for Saudi does not include policy changes.
Source: HSBC (based on FAO & Rosenzweig et al., 2003)

We note that ozone levels are rising²² and this too damages crops²³. We do not adjust for ozone in any of our estimates in this study.

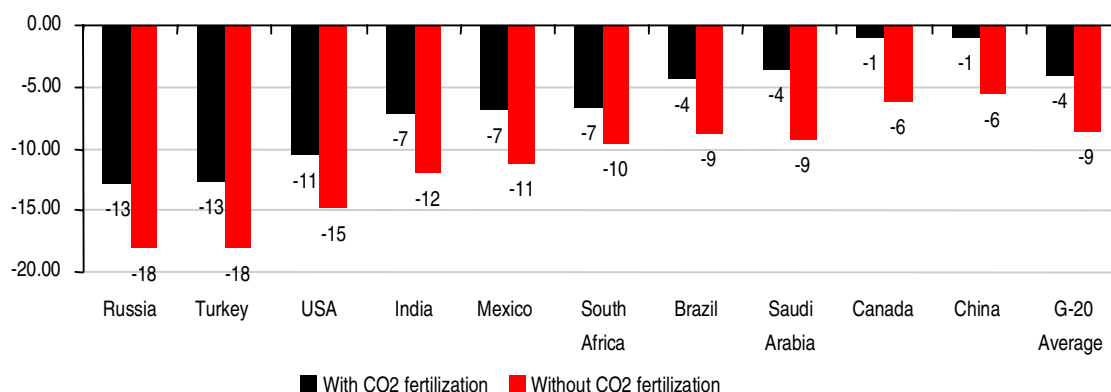
The bottom line

Currently the G-20 produces around 1,737 mt of cereals annually. Our analysis suggests that overall the G-20 could lose a total of around 70 mn tonnes pa by 2020 under CO2 fertilisation assumptions, which is 4.1% of the current (2007) production.

As expected, the losses are much more severe in the absence of CO2 fertilisation, at about 151 mn tonnes pa, which is 8.7% of the current production (2007).

In the case of CO2 fertilisation, our analysis suggests that the US, India, Russia, China, Brazil and Mexico together lose 78 mn tonnes pa. The US is projected to lose 37 mn tonnes pa, followed by India at 18 mn tonnes. At the same time, EU, Argentina, Japan and Australia make minor gains, resulting in the net loss of 70 mn tonnes (Fig 17).

Fig 18: Impact of climate change on *cereal production (%) – with and without carbon fertilisation (2020)

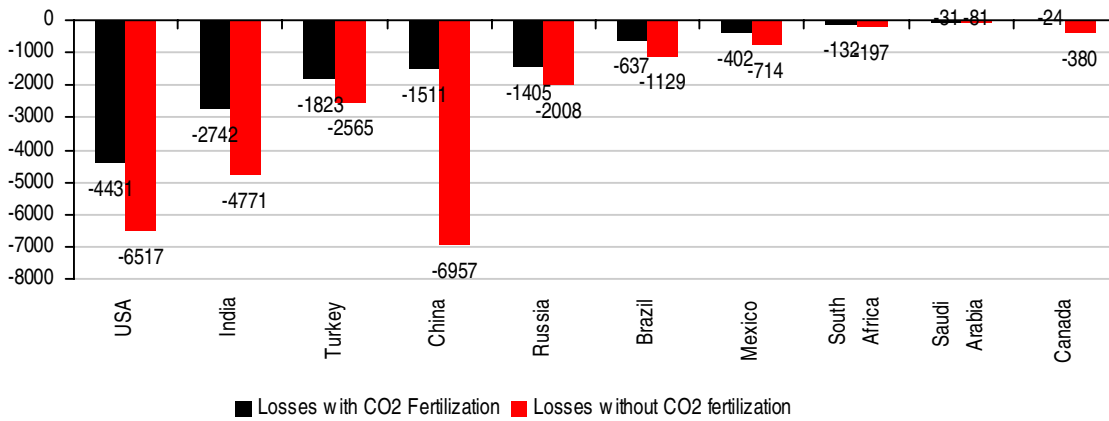


*Cereals: wheat, rice, coarse grain and pulses. Note: Changes for Saudi does not include policy changes.
Source: HSBC (based on FAO & Rozenweig et al., 2003)

²² <http://www.springerlink.com/content/x2rmg61g70847j8h/>

²³ Rita Van Dingenen et al., 2008 (*Atmospheric Environment*; Volume 43, Issue 3, January 2009, Pages 604-618)

Fig 19: *Cereal production related losses/gains with carbon fertilisation and without carbon fertilisation in G-20 by 2020 in USD mn



*Cereals: wheat, rice, coarse grain and pulses. Note: changes for Saudi do not include policy changes.
Source: HSBC (Based on FAO and Rosenweig et al., 2003);

The case of Russia is quite intriguing and surprising. It is expected that a warmer climate would be beneficial for agriculture in the high latitudes. However, this general tendency is not necessarily true for all northern countries, as a short growing period is not the only factor limiting agriculture. For Russia, a 2007 modelling study²⁴ by Nikolai Dronin and Andrei Kirilenko suggests that increasing droughts in the currently most productive southern Russia would bring down productivity sharply. Even though central and northern-forested regions would experience an increase in productivity, it would not compensate for a sharp drop in yields in the southern European regions.

Overall, we estimate that the G-20 loses agricultural production worth USD 10 bn pa by 2020 owing to the impacts of climate change; the losses escalate to USD 27 bn under the assumption of no CO₂ fertilisation.

In percentage terms, Russia, Turkey and US see the biggest losses, as shown in Fig 18. China is the country the most sensitive to the presence or absence of carbon fertilisation, as the loss could vary from USD 1.5 bn to nearly USD 7 bn in the absence of CO₂ fertilisation. (Fig 19)

²⁴ <http://www.springerlink.com/content/b680351263278215/>

Accounting for population growth

Currently 4.1 bn people (adjusted for the double counting of France, Germany, Italy and the UK) inhabit the G-20, which is projected to increase to up to 4.5 bn (adjusted for double counting of France, Germany, Italy and the UK) by 2020.

Increasing population as well as decreasing agricultural yield impacts the per capita production of cereal grain in these countries (see Table 4). Under the assumption that land area remains stable and no major adaptation efforts are made as well as no major technological breakthroughs take place, our analysis suggests that among the G-20, in the absence of the CO₂ fertilisation effect the per capita food grain production declines by 16%. We note that Australia, South Korea and Japan will see a net benefit under CO₂ fertilisation, with yield increases of over 5%. But the overall result for the

G20 will still be negative, at -12%. Saudi Arabia sees the biggest change in per capita terms, as it abandoned a long-held policy of food sufficiency, due to shortage of water. It is exiting wheat production in phases, and will depend fully on global markets from 2015.

The G-20 per capita food production loss figures, of 12-16% overall, are much higher than the 4.1%-8.6% loss in G-20 food production. From this, we can deduce that population growth has a multiplier effect on the “food stress” the world will face, gearing it up around 2-3 times. This could be transmitted to global markets through price shocks. We look at that issue more in our chapter on *Linking up the impacts*.

Table 4: Per capita current (2007) and projected food grain production in G-20 by 2020

Country	Base production (Mn tonnes per Year)	Per capita food grain production - current (tonnes / year)	Per capita food grain production - 2020 – NCF (tonnes / yr)	Per capita food grain production - 2020 – CF (tonnes/ yr)	% Change in per capita food grain production - NCF	% Change in per cap food grain production - CF
Argentina	37.03	0.92	0.81	0.85	-12.66	-8.31
Australia	33.89	1.54	1.45	1.52	-6.18	-1.09
Brazil	58.36	0.30	0.24	0.25	-20.41	-16.64
Canada	51.97	1.54	1.33	1.41	-13.38	-8.59
China	429.87	0.32	0.29	0.30	-11.36	-7.12
EU adjusted	135.07	0.27	0.26	0.28	-2.26	2.45
France	65.88	1.01	0.99	1.04	-2.43	2.80
Germany	45.31	0.55	0.54	0.57	-1.86	3.21
India	249.20	0.21	0.16	0.17	-25.22	-21.15
Indonesia	63.65	0.28	0.23	0.24	-15.27	-11.74
Italy	20.85	0.35	0.34	0.36	-0.67	4.21
Japan	12.14	0.10	0.10	0.10	4.00	8.26
Mexico	31.85	0.30	0.23	0.25	-20.80	-16.89
Russia	71.96	0.51	0.45	0.47	-12.18	-6.60
Saudi Arabia*	2.76	0.11	0.01*	0.01*	-88.55*	-88.03*
South Africa	11.76	0.24	0.21	0.21	-13.15	-10.23
South Korea	7.04	0.15	0.15	0.15	2.06	6.20
Turkey	33.52	0.47	0.32	0.34	-31.88	-27.43
UK	22.36	0.36	0.34	0.36	-6.12	-0.86
US	352.08	1.14	0.88	0.92	-23.50	-19.60
G-20 Total	1736.58	0.37	0.31	0.33	-16.11	-11.85

CF- carbon fertilisation, NCF – No carbon fertilisation. *Including impact of Saudi Arabia's policy decision to exit wheat production by 2016
Source: HSBC (based on FAO, WRI and Rosenzweig et al., 2007);

Adding to water stress

- ▶ Water stress is a growing threat, and among the G-20, Saudi Arabia, South Africa, South Korea, India and Germany have the least water per capita
- ▶ Overall, the G20 is likely to have 3% more water in the 2020s. But in terms of per capita availability, 16 of the 20 will likely experience a decline, notably Australia, Brazil, Indonesia, Mexico and Turkey
- ▶ On the back of rising population, water demand is expected to surge by more than 20% over the same period

A liquid tug of war

Only 2.5% of the world's water is fresh and available for living beings. Of this, 69.6% is locked in glaciers and icecaps and 30% is below the ground. This leaves just 0.01% of total water resources readily available.

Table 5: Rising water stress

Region	Current Vulnerability
North America	Multi-year droughts in US and Southern Canada
Mexico	Land subsidence in Mexico City
South America	Water supply affected by shrinking glaciers in the Andes
Brazil	Water supply reduced by erosion
Africa sub-Saharan	Rural water supply affected by extended dry season
	Area of Lake Chad declining
South Asia	Health problems due to arsenic and fluoride in ground water
	Flood is a menace. For example, 70% of Bangladesh was inundated in 1998.
Europe	Damage to riparian ecosystem due to flood protection along Elbe river
China	Huanghe river has temporarily run dry due to decrease in rainfall and increased irrigation
Australia	Damage to aquatic ecosystem due to decreased streamflow and increased salinity in Murray – Darling basin.

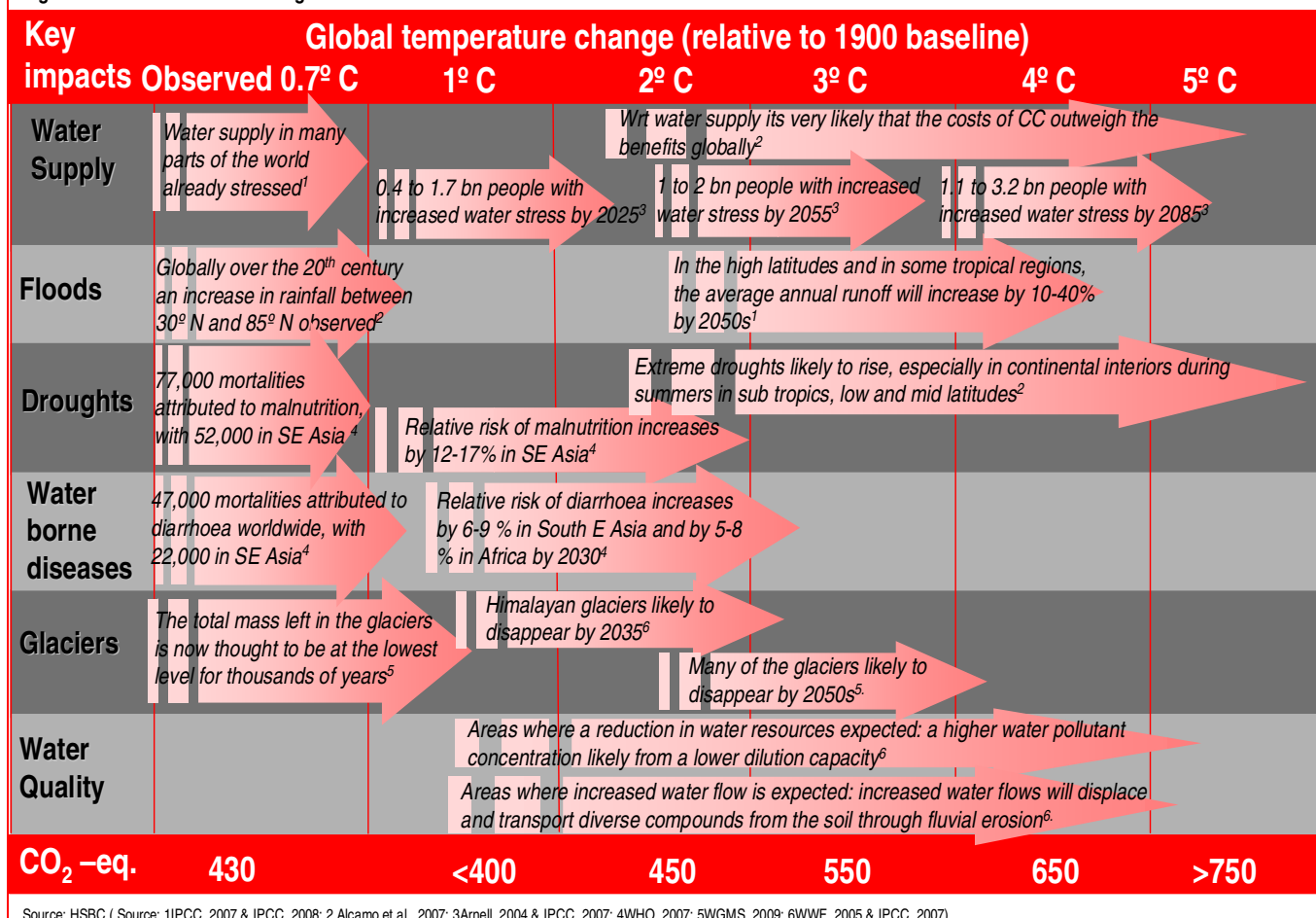
Source: IPCC, 2007

According to the IPCC's AR4, the world has already experienced an increase in rainfall above 30° N and a decrease between 10° S and 30° N. A decrease in snow cover and increased thawing of permafrost has also been observed along with increased evapo-transpiration (IPCC, 2007). Based on the EMDAT database²⁵, our analysis suggests that the G-20 nations have suffered USD 330 bn in damages from droughts and floods in the last two decades (1988 to 2008). China alone accounts for USD 153 bn, mostly due to floods (USD 134 bn). It is hard to predict how flood losses will evolve in a changed climate, as this depends on multiple factors such as location, timing of rainfall, and defensive measures in place.

Projections for the future paint a troubled picture with many regions of the world likely to experience significant impacts on their water resources and water security as a result of a changing climate. The AR4 highlights the following water trends.

²⁵ <http://www.emdat.be/advanced-search>

Fig 20: Water outlook in a warming world



- ▶ In the high latitudes and in some tropical regions, the average annual runoff is likely to increase by 10-40% by the middle of this century.
- ▶ It is likely that more areas will be affected by droughts and water shortages will be more common across the globe.
- ▶ An overall increase in the frequency of heavy downpours is predicted as warmer air can hold more moisture. This also makes it more likely that human settlements will experience severe damage through flooding.
- ▶ The volumes of water stored in glaciers and the snow packs is likely to decline over the course of this century. This means that after a phase of increased discharge, there will be less water

available in regions supplied by meltwater runoff from major mountain chains.

This is an ominous development, because over a sixth of the world's population currently lives in these regions. For example, a global mean temperature rise of over 2°C could cause the disappearance of Himalayan glaciers by as early as 2035. These glaciers serve some of the major river systems of the Indian subcontinent, as well as China. Without these glaciers, perennial rivers such as the Ganges, Indus and the Brahmaputra might become seasonal rivers, with rivers flowing only in the rainy season. This could potentially reduce the number of harvests from 3 to just 1-2 a year. India, Nepal and China are now putting in place monitoring systems for measuring glacier melt and further research is underway to ascertain the changes.

Table 6: Current and projected water demand in the G-20

Country	Total water demand -2000 (bn m3 =km3= trillion litres)	Total water demand -2025 (bn m3 =km3= trillion litres)	% Change in total water demand	Per capita water demand – 2002 (000s litres or m3)	Per capita water demand – 2025 (000s litres or m3)	% Change
Argentina	29.20	54.70	87.32	774.80	1186.09	53.08
Australia	23.90	23.56	-1.42	1218.00	965.88	-20.70
Brazil	59.30	160.09	169.97	331.10	699.61	111.30
Canada	46.00	52.19	13.47	1468.00	1376.72	-6.22
China	630.30	812.37	28.89	487.50	561.89	15.26
EU	275.12	309.50	12.50	580	631	8.85
France	40.00	46.05	15.12	667.90	700.17	4.83
Germany	47.10	52.98	12.49	472.80	659.45	39.48
India	645.80	672.59	4.15	599.10	464.65	-22.44
Indonesia	82.80	126.54	52.83	392.60	466.54	18.83
Italy	44.40	45.26	1.94	770.50	779.34	1.15
Japan	88.40	78.05	-11.71	695.80	641.76	-7.77
Mexico	78.20	141.57	81.04	766.50	1135.36	48.12
Russia	76.70	78.82	2.76	527.60	614.83	16.53
Saudi Arabia	23.70	25.26	6.60	959.10	726.06	-24.30
South Africa	12.50	15.08	20.64	270.60	288.33	6.55
South Korea	18.60	21.29	14.46	396.00	434.31	9.67
Turkey	40.10	48.63	21.27	614.00	542.99	-11.57
United Kingdom	9.50	11.17	17.56	160.00	171.31	7.07
United States	479.30	521.87	8.88	972.10	1470.36	51.26
G-20 total*	2610	3142	20.4	671.98	714.8	6.37

Source: HSBC (2000 figures are the latest water withdrawal statistics available and are taken from World Bank Statistics, while per capita figures are available for 2002 as well and taken from FAO-AQUASAT). 2025 projections are obtained based on Alcamo et al., 2007 who report 2025 projections with regard to a 1995 baseline. Modelled baseline estimates were compared with the observed data spanning the same time period from World Bank Statistics and the differences were added to the projections (Method of anomalies) to make the two datasets comparable (Observed - model baseline = anomalies; Actual Projections = model projections + anomalies); For Saudi Arabia water demand estimates (total and per capita) refer to 2006 and 2007 – earlier estimates not available; * Adjusted for double counting of France, Germany, Italy and UK.

Increasing water demand

While the world's population tripled in the 20th century, the use of water resources grew six-fold. A 2007 study by Joseph Alcamo and his colleagues forecasts the changes in water withdrawal as a result of trends in socio-economic drivers (using the A2 scenario of the IPCC). From this, we estimate that water withdrawal will increase by more than 20% by 2025 in the G-20 countries (see Table 6). As a result, total water withdrawal of 2,610 km³ per year goes up to 3,142 km³ (Bn m³ = Km³ = Trillion litres) by 2025. Only Australia and Japan are projected to have a small decline in demand. In Brazil, demand is projected to climb 169%, followed by Argentina (87%) and Mexico (81%).

Declining water supply

Freshwater distribution is highly skewed across the globe. Table 7 shows the current water availability among G-20 member states, and forecasts the change in water availability from climate change, as

projected by Joseph Alcamo and his colleagues.

Water availability is defined as annual river discharge – the combined surface runoff - and groundwater recharge. Across the G-20, the contrast is remarkable. Each Canadian has access to over 90,000m³, while Saudi Arabia has access to less than 100m³ of water per capita per year.

The United Nations defines a country as severely water stressed if its per capita water availability is less than 1,000 m³/capita/yr²⁶. Currently among the G-20, only Saudi Arabia qualifies as a severely water stressed country on this criterion. However South Africa is not far behind: currently its per capita water availability is estimated to be only 1,082 m³/capita /yr. By 2025, our analysis projects a drop of up to 20% in its per capita water availability – placing it in the category of severely water stressed.

²⁶<http://www.escwa.un.org/information/publications/edit/upload/sdpd-07-WP-3-e.pdf> & http://www.africanwater.org/drought_water_scarcity.htm

Table 7: Current and projected water availability in the G-20 ²⁷

Country	Total available water -2000 (bn m3 =km3= trillion litres)	Total available water - 2025 (bn m3 =km3= trillion litres)	% Change in total water availability	Per cap water availability – 2002 (000s litres or m3)	Per cap water availability – 2025 (000s litres or m3)	% Change
Argentina	814.00	803.33	-1.31	21605.00	17420.17	-19.37
Australia	492.00	448.36	-8.87	25034.00	18380.67	-26.58
Brazil	8233.00	7494.89	-8.97	45963.00	32752.66	-28.74
Canada	2902.00	3237.56	11.56	92671.00	85396.59	-7.85
China	2830.00	2903.55	2.60	2188.00	2008.29	-8.21
EU	1968.6	2024.8	2.86	4146.40	4127.00	-0.47
France	203.70	204.55	0.42	3405.00	3110.14	-8.66
Germany	154.00	152.74	-0.82	1873.00	1901.10	1.50
India	1880.00	2149.87	14.35	1744.00	1485.23	-14.84
Indonesia	2838.00	2908.66	2.49	13459.00	10724.09	-20.32
Italy	191.30	189.31	-1.04	3322.00	3259.58	-1.88
Japan	430.00	445.17	3.53	3383.00	3660.48	8.20
Mexico	457.20	389.65	-14.77	4480.00	3124.84	-30.25
Russia	4508.00	5266.28	16.82	31017.00	41080.84	32.45
Saudi Arabia	2.40	2.87	19.41	97.24	82.36	-15.30
South Africa	50.00	45.28	-9.44	1082.00	865.80	-19.98
South Korea	69.70	74.79	7.31	1485.00	1525.80	2.75
Turkey	213.60	197.03	-7.76	3123.00	2200.02	-29.55
United Kingdom	147.00	154.63	5.19	2466.00	2371.95	-3.81
United States	3051.00	3313.04	8.59	10377.00	9334.34	-10.05
G-20 total*	30739.5	31705.1	3.14	7900	7213	-8.86

*Adjusted for double counting of France, Germany, Italy and UK.
Source: HSBC (FAO-AQUASAT & Alcamo et al., 2007);

Climate modelling suggests that climate change could have a major effect on future global water availability. Changes in precipitation are likely to raise or lower the average volume of river runoff. In addition, the expected increase in air temperature intensifies evapo-transpiration almost across the globe, reducing runoff. These two effects interact differently at different locations and produce a net increase in water availability in some locations and net decreases in others.

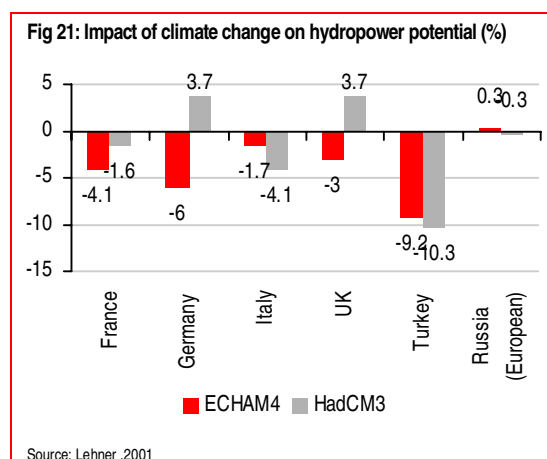
Our analysis suggests that as the world turns slightly wetter, the G-20 could gain around 3% in terms of overall water availability. However, in terms of per capita availability, almost all the G-20 members would likely experience a decline. Notable exceptions are Germany, Japan, South Korea and Russia which have stable or declining population levels. Regionally, Mexico, South Africa, Brazil, Australia and Turkey suffer the biggest losses in total water availability. However since South Africa already has very low per capita water availability, its water situation becomes especially precarious.

National level averages often mask huge regional disparities. Australia is a case in point, with a national average of 25,000 liters of water available to each of its residents every year, but with severe droughts in the Murray-Darling basin (see Country Profile). India's western states also face water shortages. In a changed climate, their water availability will decrease further even though the country average of water availability increases modestly. Similarly, China's north-eastern provinces already face increasing pressures on water resources. This area is also the prime area for wheat production, which peaked nationally at 123 mn tons in 1997. Last year, wheat production had fallen to 109 mn tons. A combination of aquifer depletion and the growing consumption by fast growing cities has reduced water available for irrigation²⁸.

²⁷ See Appendix 2 for more information on methodology
²⁸ Lester Brown, Plan B 4.0

As well as agriculture, the hydropower sector will also be impacted by changing water availability.

A 2001 study²⁹ by Bernhard Lehner estimates Turkey risks losing up to 10% of its developed hydropower potential by 2020. In other countries, the fortunes are more mixed (see Fig 21).



²⁹ <http://www.usf.uni-kassel.de/usf/archiv/dokumente/kwws/kwws.5.en.htm>

An unhealthy climate

- ▶ Currently, climate change is the cause of less than 1% of the global disease burden, or the loss of 5.5 mn Disability Adjusted Life Years. The G-20 accounts for less than half of this.
- ▶ By 2020, we estimate that G-20 health-related productivity losses attributable to climate change could double, with health costs due to floods quintupling.
- ▶ Longer term, climate change could become “the biggest global health threat of the 21st century”, according to the British medical journal, The Lancet.³⁰

Taking the temperature

Traditionally, the impact of climate change has been quantified in terms of mortality and morbidity, with the latest estimates suggesting that 300,000 people now lose their lives annually due to climate change.³¹ Increasingly, another measure is being used - quantifying the impacts in terms of Disability Adjusted Life Years (DALYs). This provides a measure of the productive life years lost due to a certain disability.³²

Using the DALYs method, the direct and indirect impacts of climate change on human health are currently relatively small in terms of the global disease burden. Globally, climate change is currently responsible for the loss of 5.5mn Disability Adjusted Life Years – with the largest share in South and South-East Asia. This ranks as 22 out of 26 leading risk factors for human health

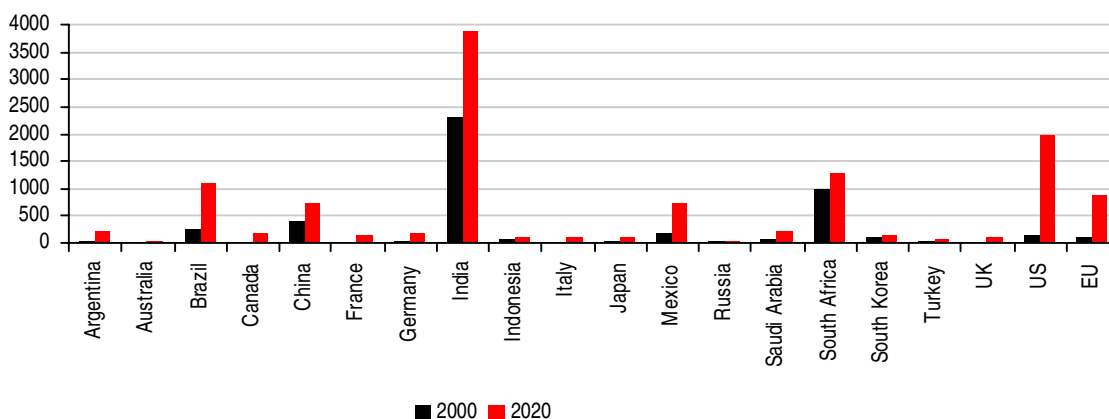
– ahead of noise and airborne particulates, but lagging urban air pollution, and one-tenth of the ill-health caused by tobacco.

Climate change is likely to impact human health directly through changes in the transmission of vector-borne diseases such as malaria and dengue, as well as through changes in heat- and cold-related sickness. The indirect ill-effects are likely to be more profound, notably the implications for water and sanitation, drought induced malnutrition as well as increased loss of lives from climate related disasters such as floods, storms and other such extreme events.

The WHO has identified malaria, malnutrition, and diarrhoea and flood-related disabilities as the key disabilities having strong linkages to climate change. Our estimates based on WHO disability projections suggest that currently the G-20 suffers a minimum of 2.6 mn DALY losses annually – less than half the total burden - resulting in an annual loss of more than USD 4.8 bn at present at 2008 GDP per capita figures.

³⁰ The Lancet, Managing the health effects of climate change, May 2009
³¹ Global Humanitarian Forum, The Anatomy of a Silent Crisis, 2009
³² WHO (2007) Quantifying the health impact at national and local levels, Environmental Burden of Diseases Series, No. 14.

Fig 22: Comparison of current and projected disability related losses in USD mn (attributable to climate change)



Source: HSBC (based on WHO, 2007)

By 2020, WHO estimates that with increasing temperature and rainfall variability, climate induced disabilities such as malaria, diarrhoea, and malnutrition are likely to rise. Our estimate suggests an increment of 1.9 mn climate change induced DALY losses by 2020, causing additional productivity losses of USD 6.9 bn among the G-20 nations (see Table 8).

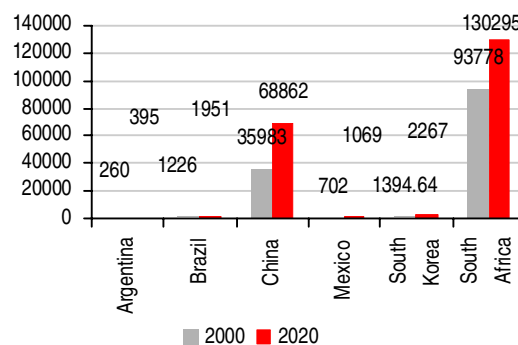
Table 8: Climate induced current and projected disability losses (in USD mn, at 2008 prices)

	2000	2020
Malaria	684.2	1015.1
Malnutrition	2004.8	3325.3
Diarrhoea	1162.6	1604.1
Flood	953.7	5782.1
Total	4805.3	11726.7

Source: HSBC estimates (based on WHO, 2007)

related disabilities in these countries. In addition, it projects malaria to make inroads to new destinations such as Argentina, Brazil, and Mexico.

Fig 23: Current and projected malaria-related DALY losses attributable to climate change in G-20



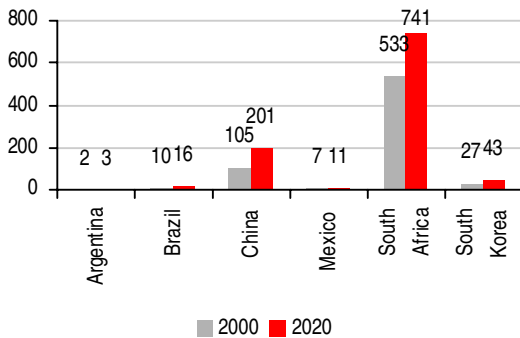
Source: HSBC (calculated from WHO estimates)

Warmer climates bring more malaria

Warmer temperatures will take malaria to new destinations as the survival window for the vector lengthens, and viral infections spread through unsanitary water conditions, which might arise from extreme drought or flood conditions. Malaria-related disabilities currently cause more than USD 684 mn pa in terms of labour productivity losses among G-20 nations. According to the WHO, currently malaria-related disabilities are concentrated mainly in China, South Korea and South Africa. By 2020, the WHO predicts a significant increase in malaria-

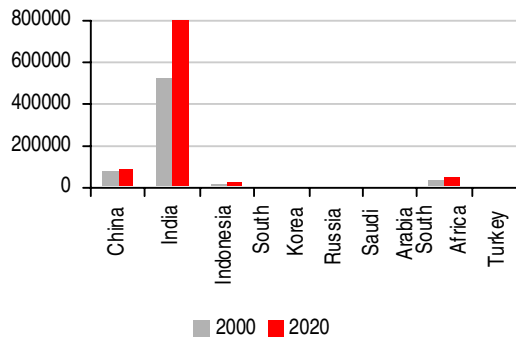
Our analysis suggests that currently South Africa suffers the highest climate-related malaria burden, costing USD 533 mn pa, increasing to USD 741 mn pa by 2020. Overall, our estimates suggest that losses linked to malaria DALYs are poised to reach more than USD 1 bn pa by the year 2020 at 2008 prices (Fig 23).

Fig 24: Malaria induced productivity losses (attributable to climate change) in USD mn



Source: HSBC (based on WHO projections)

Fig 25: Diarrhoea-related DALY losses (attributable to climate change)

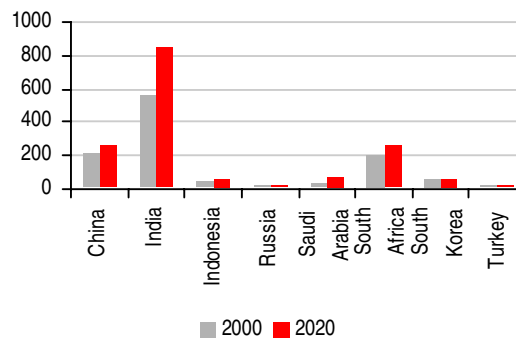


Source: HSBC (based on WHO projections)

Dirty water and diarrhoea

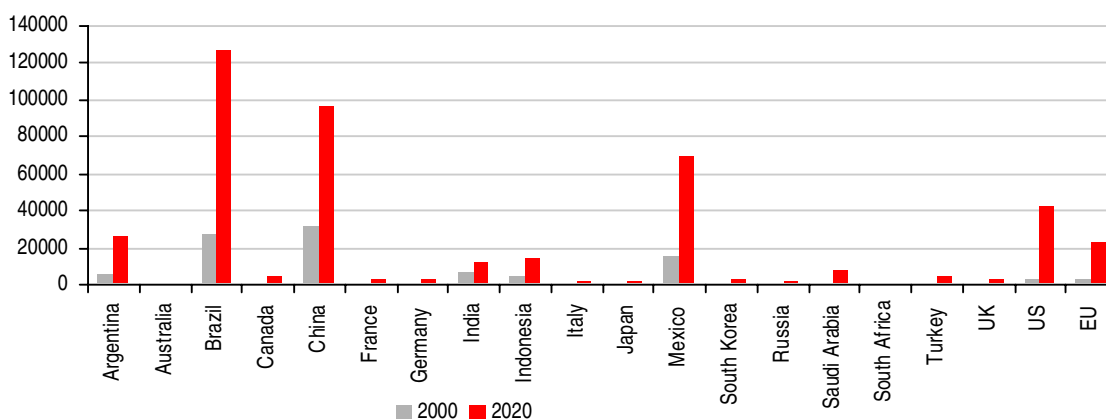
Within the G-20, India, China and South Africa have the largest burdens of diarrhoeal disabilities. This is from viral and bacterial infections, spread through unsanitary conditions, with lack of clean water being the main cause. According to our estimates, diarrhoea-related disabilities currently cause more than USD 1.2 bn pa in terms of labour productivity losses among G-20 nations, primarily the developing countries. By 2020, the WHO predicts significant increases in diarrhoea-related disabilities.

Fig 26: Diarrhoea-related productivity losses (attributable to climate change) in USD mn



Source: HSBC (based on WHO projections)

Fig 27: A comparison of flood induced DALY losses

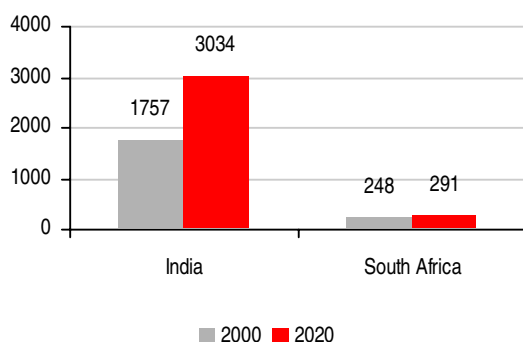


Source: HSBC (based on WHO projections)

The bane of malnourishment

According to WHO, malnutrition is a phenomenon typically confined to South Asia and Africa. Within the G-20, climate change induced malnutrition-related disabilities currently cause more than USD 2 bn pa in terms of labour productivity losses, primarily in India and South Africa, with more than USD 1.75 bn lost in India alone, which could rise to over USD 3 bn in 2020.

Fig 28: Malnutrition induced productivity losses (as attributable to climate change) in USD mn



Source: HSBC (based on WHO projections)

Flooded reality

Unlike diarrhoea and malnutrition, floods are almost a universal health hazard. We estimate that flood-related disabilities currently cause USD 1 bn of productivity losses pa among the

G-20. Currently the US, Brazil and Japan witness the biggest losses. Based on WHO projections, we estimate that flood-related losses in the G-20 are poised to dramatically increase in the next decade with the total G-20 flood-related health losses reaching more than USD 5.7 bn by 2020. The biggest increments are projected for the US for which the flood-related health losses are projected to reach USD 2 bn pa by 2020.

A dangerous future

For the G-20, the health impacts of climate change are still relatively small – except in the case of key emerging economies such as China, India and South Africa. Here, climate change acts as a multiplier of existing inequalities in terms of access to adequate food, water and health-care. Globally, the numbers of people who will lose their lives each year because of climate change is set to rise to 500,000 in the next 20 years, with 99% of the casualties in the developing world – bringing Kofi Annan, the former UN Secretary-General, to describe this as “the greatest emerging humanitarian challenge of our time”.

Linking up the impacts

- ▶ All of the G-20 major exporters of 'virtual water' are expected to have less per capita water availability in 2025
- ▶ The US, the world's leading exporter of cereals could face a decline in cereal production of c11-15% by 2020
- ▶ Recent experience in global commodity markets suggests a prospect of rising and volatile food prices to 2020 and beyond

Trading impacts

The economic and financial repercussions of a changing climate will not be confined within national borders. Globalisation means that the changes in agriculture, water and health that we have estimated will be felt directly and indirectly throughout the trading system.

Table 9: Embedded water in daily products

Products	Embedded water in (litres)
1 Kg paper	2000
1 Kg of tea	2100
1 Kg of apple	500
1 Kg of coffee	2100
Per bottle of beer	150
1 Kg of bread	1200
1 Kg chicken	4000
1 Kg of sugar	1500
1 Kg of cheese	5000
1 Kg of Rice	3400
1 Kg of Beef	15500
Per pair of jeans (1 Kg)	10850

Source: University of Twente/ UNESCO
(http://news.bbc.co.uk/1/hi/shared/spl/hi/sci_nat/09/embedded_water/swt/embedded_water.swf)

Embedding water

Embedded water is the amount used in the entire process of producing, retailing and consuming a product. It is also referred to as virtual water, embodied water or shadow water. Table 9 compares the amount of embedded water in

different day-to-day commodities, ranging from 500 litres for a kilo of apples to 15,500 for a kilo of beef. The amount of embedded water varies between nations due to different climates, irrigation and production techniques. For example, it has been estimated that a kilogramme of oranges from Australia has up to three times the embedded water of a kilogramme of oranges from the US. Additionally, different species of the same plant can differ in water requirements. Most importantly, similar amounts of water used in drought prone countries have a much greater impact than in high rainfall countries³³.

Hundreds of billions of cubic metres of virtual water cross international borders every year embedded in agricultural products. Fig 29 shows the net flows of water above 10 bn m³/yr between 1997 and 2001. For example, North America exports a total of 108 m³/yr of virtual water, of which 75 bn m³/ yr goes to Central/South Asia and 15 bn m³/yr to Western Europe.

³³ <http://www.igd.com/index.asp?id=1&fid=1&sid=5&tid=48&cid=326>

Fig 29: Virtual water balance and flow related to agricultural products (in bn m3/yr) (all flows more than 10bn m3/year are shown)



Source: "GWSP Digital Water Atlas (2008). Map 32: Virtual Water Flows between World-Regions (Dataset) (V1.0). Available online at <http://atlas.gwsp.org>."

These flows will inevitably be affected by climate change. Table 10 highlights the trade balance in virtual water among the G-20; overall, the Group is a net importer of water from the rest of the world. Canada, US, Brazil, Argentina, Australia, per capita by 2025.

Table 10: Current virtual water flows – Regions

Source Region	Destination Region	Flow in bn m3/yr
North America	Central/South Asia	75
South America	Western Europe	52
North Africa	Western Europe	49
Oceania	Central/South Asia	29
South America	Central/South Asia	19
South East Asia	Central/South Asia	18
North America	Central America	16
North America	Western Europe	15
South East Asia	Western Europe	15
Oceania	South East Asia	12
Oceania	North America	10
North America	Middle East	10

Source: GWSP Digital Water Atlas (2008). Map 32: Virtual Water Flows between World-Regions (Dataset) (V1.0). Available online at <http://atlas.gwsp.org> & Alcamo et al., 2007

Trading food

Agricultural exports do not just contain water, but nutrition as well. Most agricultural production within the G-20 is consumed domestically, notably in China and India, the world number one and two in terms of cereal production (see Table 11). The US is the world's leading

trader of cereals, exporting over 100mn tonnes in 2007. But its cereal production is projected to fall by c11-15% by 2020 as a result of climate change.

The impacts of these shocks will not necessarily be reflected in a linear fashion on world commodity markets. The price effect of a 2% loss of production can be more than twice the impact of a 1% loss in production. This is essentially due to the interaction of other factors such as current food stocks in the country (domestic buffer), and bumper crops in other countries (international buffer).

A major global price spike could happen either if a major agricultural producer loses a significant part of its output, or if minor losses occur at the same time in different countries, wiping out the international buffer at the same time.

Recent experience with food prices in 2007-08 shows that prices can surge and volatility intensify as a result of relatively small movements in underlying fundamentals (See Fig 31). Prices still remain above the long-run average for the decade in spite of the worst financial crisis in decades. Even this year, sugar prices have spiked due to

Table 11: World cereal trade risks disruption from climate change

	Total production of cereals (mn tonnes) - 2007	Imports (mn tonnes)-2007	Exports (mn tonnes)-2007	% Change in production by 2020** under no carbon fertilisation	% Change in production by 2020 ** under carbon fertilisation
Argentina	37.03	0.02	27.01	-3.11	1.72
Australia	33.89	0.14	17.30	-0.13	5.29
Brazil	58.36	8.83	11.50	-8.76	-4.44
Canada	51.97	3.13	25.78	-6.23	-1.05
China	429.87	7.97	9.88	-5.55	-1.04
EU Adjusted*	135.07	45.16	22.47	-3.46	1.19
France	65.88	2.10	25.05	-2.84	2.37
Germany	45.31	6.69	8.95	-3.10	1.91
India	249.20	4.75	9.84	-12.00	-7.22
Indonesia	63.65	4.78	0.20	-3.53	0.49
Italy	20.85	10.23	1.10	-3.30	1.44
Japan	12.14	25.62	0.02	1.46	5.62
Mexico	31.85	13.98	0.96	-11.26	-6.88
Russian	71.96	1.10	16.59	-18.00	-12.78
Saudi Arabia	2.76	10.01	0.04	-85.70***	-85.05***
South Africa	11.76	3.48	0.14	-9.66	-6.63
South Korea	7.04	12.17	0.00	-1.16	2.86
Turkey	33.52	3.64	0.50	-18.00	-12.64
United Kingdom	22.36	3.69	2.70	-2.41	3.06
US	352.08	6.12	100.41	-14.87	-10.52
G-20 Total	1736.58	173.60	280.45	-4.06	-8.70

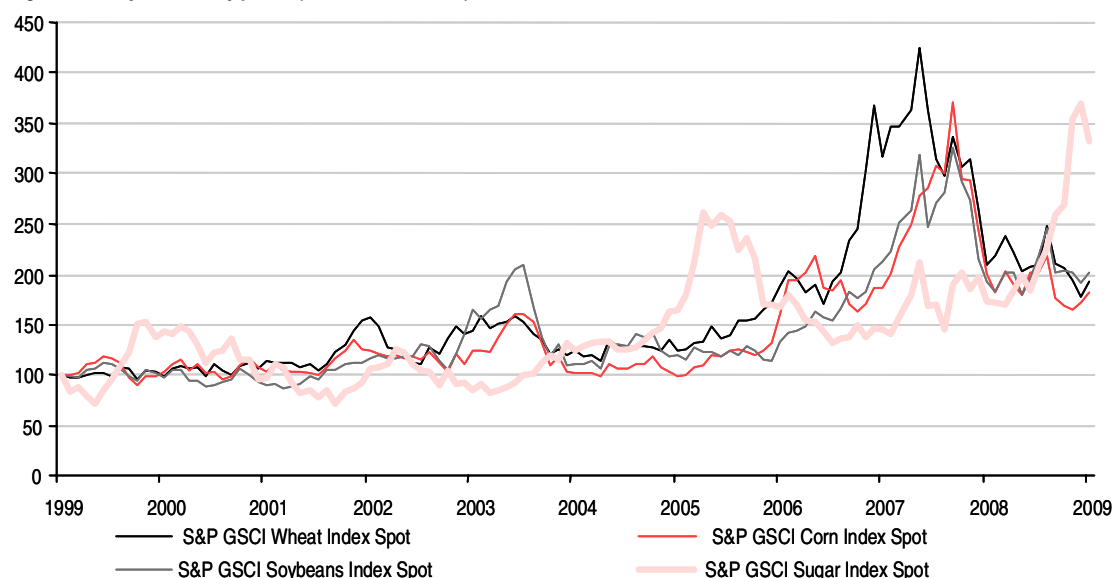
* Adjusted for double counting of France, Germany, Italy and UK; ** At constant Acreage; ***Including impact of Saudi Arabia's policy to exit wheat production by 2016.
Source: HSBC (FAOSTAT & Rosenweig et al., 2003);

shortages caused by events in two key countries- drought in India and flooding in Brazil.

Public policy often tends to exacerbate market reactions by imposing restrictions on food exports. India is usually the third largest exporter of rice after Thailand and Vietnam. But in 2008 it introduced an

export ban on non-basmati rice in April. When Thailand also moved to restrict exports, world rice prices sky-rocketed. The price of Thai medium-quality rice, the global benchmark, reached a record of more than USD 1,100 a tonne in May 2008, significantly higher than the USD 200-USD 300

Fig 31: Monthly commodity prices (Jan 1999- Nov 2009)



Source: Bloomberg

Table 12: Interlinkages between climate change impacts on the Water, Agriculture and Health sectors

	Impact on Water (2025)	Impact on Agriculture (2020)		Impact on Health (2020)
	% Change in per capita water availability	% Change in cereal production with CO2 fertilisation	% Change in cereal production with No CO2 fertilisation	Multiplier in climate induced DALYs (2020/2000)
Argentina	-19.4	1.7	-3.1	4.3
Australia	-26.6	5.3	-0.1	3.0
Brazil	-28.7	-4.4	-8.8	4.5
Canada	-7.8	-1.1	-6.2	12.6
China	-8.2	-1.0	-5.6	1.8
EU*	-0.5	1.2	-3.5	7.1
France	-8.7	2.4	-2.8	7.6
Germany	1.5	1.9	-3.1	6.8
India	-14.8	-7.2	-12.0	1.7
Indonesia	-20.3	0.5	-3.5	1.7
Italy	-1.9	1.4	-3.3	7.0
Japan	8.2	5.6	1.5	2.4
Mexico	-30.2	-6.9	-11.3	4.3
Russia	32.4	-12.8	-18.0	1.6
Saudi Arabia	-15.3	85.1*	85.7*	3.6
South Africa	-20.0	-6.6	-9.7	1.3
South Korea	2.7	2.9	-1.2	1.5
Turkey	-29.6	-12.6	-18.0	2.1
UK	-3.8	3.1	-2.4	7.5
US	-10.0	-10.5	-14.9	12.7
G-20 Average	-8.86	-4.1	-8.7	1.7

(*As a policy, Saudi Arabia is exiting wheat production by 2016); Adjusted for double counting of Germany, France, UK and Italy
Source: HSBC (based on Alcamo et al., 2007; FAO-AQUASAT, Rosenweig et al., 2003; FAOSTAT, & WHO, 2007)

range during 2000-07.³⁴ Prices are now at about USD 520, still much higher than the pre-crisis levels in 2007 (Fig 31). Kazakhstan, one of the world's largest wheat exporters, banned wheat exports during the same period. Other restrictions included Argentina banning soya exports and Russia stopping wheat exports.

In October 2009, after the worst drought in more than 30 years, India lifted its 70% rice import tax. Looking ahead, considerable attention will be placed on the actions of the US authorities in response to projected impacts on agricultural production. In the 1970s, the US restricted exports of grain and soyabeans when domestic food prices spiked³⁵, and there is no guarantee that this will not be repeated if agricultural output is impacted over the coming decade.

Less water, less food, less health

Climate change impacts will not just affect international trade, but will also have profound synergistic effects. Table 12 summarises our overall estimates of the impacts to water availability, cereal production and health from climate change. Severe water stress in Saudi Arabia is projected to increase further in a changed climate over a period when domestic cereal production is being cut back, contributing to a more than 60% increase in health disabilities arising from malnutrition and diarrhoea. India is projected to graduate from being a mid-stressed country to a highly water-stressed one, with agricultural production falling by 7-12% and health disabilities from diarrhoea and malnutrition rising by two-thirds. Water stress climbs also in China, matched by a relatively small fall in cereal production of 1-6% and a 20% increase in malnutrition and diarrhoea-related disabilities.

³⁴FT, *Top food exporters ease restrictions*, Javier Blas, Sep 4, 2008
³⁵ Lester R. Brown, *Plan B 4.0*, 2009

Russia is a curious case where as the climate becomes milder, health problems (primarily from diarrhoea) decrease, while agricultural productivity declines primarily due to increasing droughts in the currently most productive southern regions of Russia. Even though the central and northern-forested regions experience an increase in productivity, it would not be sufficient to compensate for a sharp drop in yields in the southern regions.

Confronting the inevitable

- ▶ Business has so far been slow to react – but the pace of action is now accelerating
- ▶ Risk management practices need to be extended and updated to integrate climate factors
- ▶ A step-change is required to reduce underlying vulnerabilities, increase the capacity to respond and reduce the costs of impact

Adapting to change

This report is about the scale and scope of climate vulnerability - not about what to do about it. Our projections for potential impacts assume a modest amount of immediate adaptation – and do not include more strategic interventions by the private and public sectors to better understand potential impacts, take upfront action to prevent damage and respond rapidly to climate shocks. As a result, the net social, economic and financial costs of climate impacts, for the 3 sectors we have looked into, are likely to be less than we have projected. How much less is the key question.

Once the Cinderella issue of the climate agenda, adaptation is now rapidly gaining a new urgency. Increased attention is being given to the policy frameworks, market incentives and institutional structures that will be needed to reward consumers, businesses and investors for confronting an uncertain but inevitable shock to conventional practice. In particular efforts are being made to give the same amount of economic rigour that has been applied to the task of driving down greenhouse gas emissions to the issue of driving down the burden of adjustment. This is critical as adaptation is not costless – and choices

will need to be made about the relative benefits of different investment options³⁶.

Initiatives such as the Carbon Disclosure Project have highlighted a growing maturity in corporate approaches to adaptation³⁷. To date, however, “the private sector as a whole has been slow to react, held back by lack of awareness and due diligence on climate change risks, insufficient resources, perverse incentives and the weakness of the enabling environment”.³⁸

Closing the adaptation deficit

One of the stark realities about adapting to climate change is that the global economy is already poorly adapted to existing weather and natural variability. What climate change does is magnify this underlying adaptation deficit by making sure that the past is no longer a useful guide to future impacts.

As we highlight in the HSBC Climate Vulnerability Assessment, the threats posed by climate impacts are a compound result of exposure, sensitivity and capacity. As a result,

³⁶ *Economics of Climate Adaptation, Shaping Climate-Resilient Development, 2009*

³⁷ *CDP report, Building Resilience to inevitable climate change, 2009*

³⁸ *AccountAbility & iied, The Business of Adaptation, November 2009*

adaptation strategies by countries, businesses and investors need to address all four elements of the 'continuum of adaptation' identified by the World Resources Institute (see Table 13).

Table 13: The Adaptation Continuum

Addressing the drivers of vulnerability	Building response capacity	Managing climate risks	Confronting climate change
Activities to strengthen the underlying adaptive capacity of regions and institutions through health, education and governance	Activities to build robust systems for problem-solving in a disrupted climate such as better mapping, weather monitoring, environmental management and emergency response systems	Activities to integrate climate factors into regular decision-making on R&D, capital expenditure, insurance and operational management	Activities to address impacts exclusively associated with climate change, such as sea-level rise, glacier melting

Source: WRI, *Weathering the Storm*, 2007

For emerging markets in particular, businesses, investors and governments need to focus on reducing the underlying vulnerabilities in markets and communities such as fundamental gaps in health, education and governance, as well as building up basic response capacities, notably in terms of communications, environmental management and emergency response. If these pillars of adaptive capacity are not in place, then specific action to tackle climate risk is likely to be wasted. Unfortunately, the adaptation agenda has often come to be symbolised by the construction of infrastructure to defend against a new generation of floods and storms. But this is only one aspect of the continuum – and not necessarily the most important.

A question of risk – and opportunity?

Climate risk is the combination of the probability of exposure to the effects of climate change with the potential impacts arising from different levels of exposure. Once this range of outcomes has been defined, businesses and investors can take action to manage, transfer, mitigate, avoid or accept the risks involved³⁹

In generic terms, key sectors face a range of increasingly clear risks. And the flip-side of these risks will be growing opportunities to provide new or enhanced products or services.

Critically, climate risks extend along the value chain such that the most important risks may well lie outside a corporation's direct control, along its supply chain or among its customers.

Furthermore, climate impacts will also alter the macro-economic operating environment, disrupting the functioning of infrastructure and changing the focus and levels of public spending.

³⁹ Pew Centre, *Adapting to Climate Change: a Business Approach*, 2008

Table 14: Business risks and opportunities from climate change impacts

Sector	Risk	Opportunity
Agriculture & food	▶ Loss of competitive advantage for established crops and regions ▶ Interruption of supply due to extreme weather events ▶ Greater volatility in availability and price of commodities ▶ Increasing competition for water, land and other resources ▶ Greater risk of animal infections	▶ Increased yield due to extension of the growing season and temperature increases ▶ Increased demand for more resilient plant and animal varieties
Energy	▶ Loss in seasonal revenues due to reduced demand for heating in winter ▶ Inability to meet peak demand during heat waves or extreme events ▶ Failure to meet contractual obligations due to extreme weather events ▶ Reduced availability of water for hydropower and/or thermal cooling ▶ Coastal facility closure due to flooding and/or sea level rise	▶ Increased demand for energy saving technologies and services ▶ Acceleration of shift from solid fuels to electricity
Water	▶ Increasing pressure to conserve water ▶ Increasing potential for conflicts and risks to licence to operate ▶ Flooding of water supply works resulting in supply disruption ▶ Infrastructure upgrade costs and damage from sewer flooding	▶ Increased demand for water saving technologies and services ▶ Increased demand for infrastructure retrofit to harvest and store water
Insurance	▶ Increased losses could raise the cost of capital and market volatility ▶ Increased need to upgrade catastrophe models to evaluate capital adequacy ▶ Increasing competition for water drives up commercial risks for crop insurance ▶ Increased risks to health insurance ▶ Increasing political intervention to prevent withdrawal of insurance cover	▶ Increased demand for risk management consulting services ▶ Increased demand for weather and climate related insurance products
Healthcare	▶ Increasing operational health and safety risks ▶ Reduced productivity through increased disease and overheating of working environment ▶ Higher health insurance costs	▶ In higher latitudes, reduced healthcare costs in winters ▶ Increased demand for new medicines and services

Source: Pew Center, Adapting to Climate change: a Business Approach, 2008; WBCSD, Adaptation: an issue brief for business, 2009; HSBC

Four key challenges make adaptation a particularly tough issue for corporations and their investors to grapple with:

- ▶ First, climate impacts are place specific, and so general policies and strategies need to be translated into actions that respond to the specific circumstances and capacities of particular locations.
- ▶ Second, actions to adapt to climate change could exacerbate wider risks. For example, efforts to protect a particular community or asset could undermine the prospects for

others. This places a premium on community level co-operation. 40

- ▶ Third, there are still too few direct incentives for strategic action on adaptation. The adaptation agenda lacks a policy tool equivalent to carbon markets which provides entrepreneurs with a financial incentive for delivering a public good – in this case protection from potential harm.
- ▶ And fourth, the timing of both the acute and chronic impacts of climate change lie beyond

40 Acclimatise & Synergy, *Climate Finance, Business & Community: The Benefits of Co-operation on Adaptation*, 2008

the operational frameworks of most corporations, and certainly most investors. Institutional changes will be needed to reward companies and their owners that act as if long-term adaptation really mattered.

How much will it cost?

Assessments of the likely costs of adaptation are beset by a huge degree of uncertainty. Thus, the United Nations Framework Convention on Climate Change (UNFCCC) calculated in 2007 that the total cost could vary between USD 49 bn and USD 171 bn per year by 2030. These estimates are broadly in line with other studies published by Oxfam, the United Nations Development Programme (UNDP) and the World Bank.

However, these projections are likely to underestimate the full costs. For example, the UNFCCC assessment for health adaptation only evaluated diarrhoeal diseases, malaria and malnutrition, which may account for just 30-50% of the global disease burden caused by climate change. As a result, investment needs could be two to three times higher for included sectors – in other words USD 98-342 bn or USD 147-513 bn. In addition, many sectors, such as mining, manufacturing, energy, retail, finance and tourism, were not included in the UNFCCC analysis. Adapting ecosystems to a changing climate could add USD 65-300 bn to the total costs. Finally, there will always be a residual cost of impacts that can't be addressed through adaptation.⁴¹

We are still in the early phases of climate adaptation as a question of strategy for governments, business, society and investors. The scale of assessment remains incomplete – and we do not yet have sufficient experience on the ground to establish whether adaptation will have rising or falling cost rates (i.e. whether adaptation will have economies of scale and thus lower costs as more adaptation takes place, or if it will see higher costs as time progresses, due to the higher cost of adapting to a higher level of climate change) as we learn how to prevent and respond to climate impacts. But the starting point for effective action is a better understanding of potential impacts – and this is what the HSBC Climate Vulnerability Assessment seeks to achieve.

⁴¹ Martin Parry et al, *Assessing the costs of adaptation to climate change*, Imperial College & iied, 2009

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Country Profiles

Country profiles

In this section, we describe the climate vulnerability of each country in brief.

Each profile consists of:

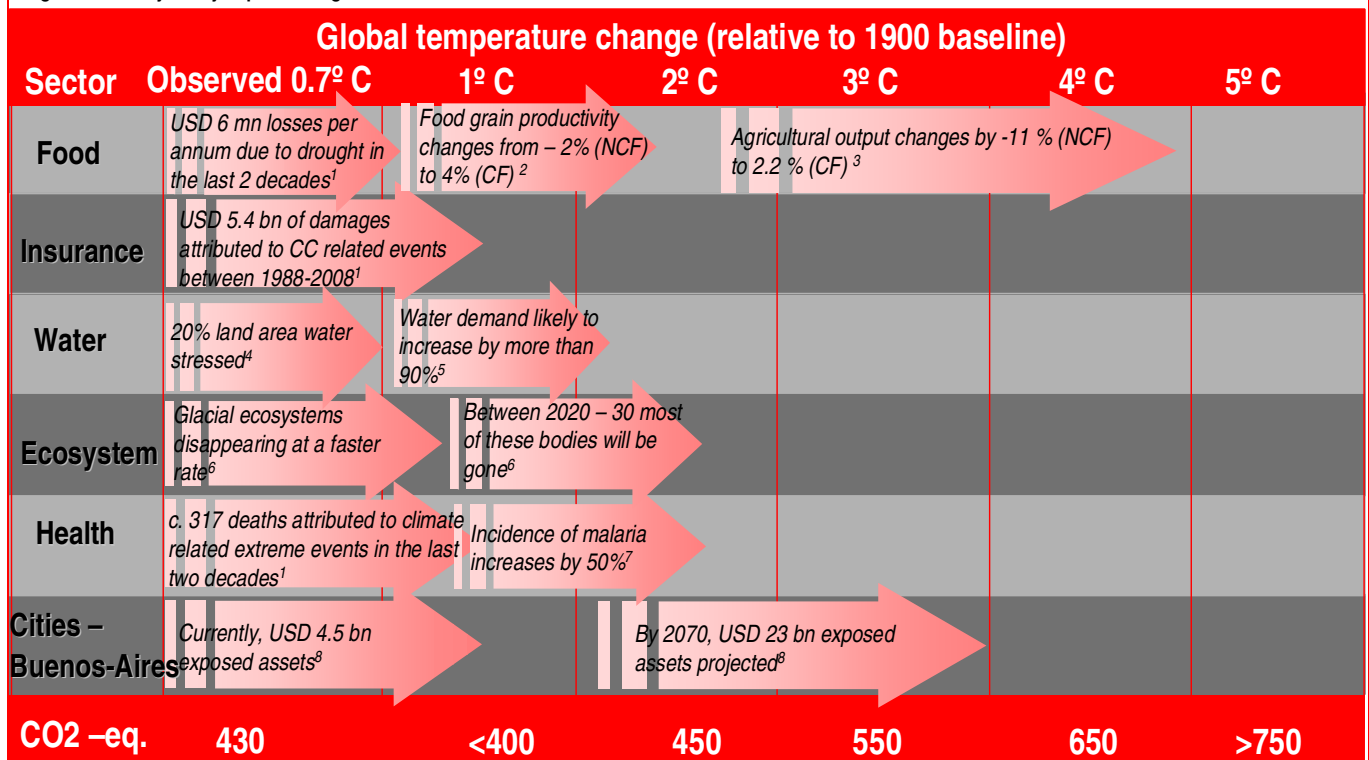
- ▶ HSBC Climate Vulnerability Assessment (HCVA) rank and risk classification.
- ▶ Summary of impacts chart: This maps the observed and projected (2020 and beyond) impacts across a variety of sectors, with the corresponding global mean temperature rise which is the likely threshold for it to occur.
- ▶ Historical temperature charts, or temperature anomalies charts, where available. Anomalies are differences with respect to a reference value. For some countries, this information is not available at the country level.
- ▶ Losses over the last 20 years from climate-related disasters (floods, droughts, landslides, storms, wildfires, etc.).
- ▶ Commentary on country's key climate risks.
- ▶ Projections for temperature and precipitation (rainfall)⁴²: - While interpreting the temperature and rainfall projections the following caveats should be kept in mind:
 - ▶ Although local and regional climate changes (changes in temperature and precipitation) are of much greater interest to people, these regional projections are less reliable than global projections and have more uncertainty (a greater risk of under-estimating or over-estimating the projected changes)
 - ▶ Unlike changes in temperature, rainfall changes are not directly influenced by rising GHGs. However, a warmer atmosphere can hold more water vapour, and hence produce heavier rainfall. Also, changing the temperature patterns across the planet means that the wind patterns as well influence the rains. Regional rainfall variations can be quite sensitive to small differences in the circulation and other processes. Hence, it is very difficult to be able to make definitive statements on the direction of precipitation change in many cases.
- ▶ Impact on Agriculture – HSBC analysis (for details of the methodology see appendix 4)
 - ▶ Changes in agricultural yield, absolute and per capita levels of cereal production loss are discussed. Coarse grains comprise of barley, maize, oats, rye, triticale, sorghum and millet. Pulses comprise of beans, chick peas, lentils, peas, cow peas, etc... In this report, the words cereals and food grains are used interchangeably.
- ▶ Impact on water – HSBC analysis (for details of the methodology see appendix 4)
 - ▶ The profile of water use and changes in water supply and water demand are discussed.
- ▶ Impact on health – HSBC analysis (for details of the methodology see appendix 4)
 - ▶ World Health Organisation (WHO) estimates for Disability Adjusted Life Years (DALYs) are profiled for climate-related disabilities. This analysis shows the impact of floods, diarrhoea, malaria and malnutrition in 2000, and in 2020, factoring in the expected impact of climate change.

⁴² Rainfall and precipitation are often used interchangeably. But key difference is that rainfall suggests only raining liquid water whereas precipitation includes snowfalls. We use this distinction in this report.

Argentina

- ▶ HCVA assessment: 4th quartile; marginally vulnerable
- ▶ Per capita water availability could decrease by 19%.
- ▶ Climate induced health sector losses could increase over four-fold by 2020
- ▶ On balance, the agricultural sector could see some positive impacts assuming a CO₂ fertilisation benefit

Fig 32: Summary of key impacts – Argentina



Source: 1EMDAT database, 2008 & HSBC; 2 Rosenweig, 2003; 3 Bill Clime, 2007 (NCF-without carbon fertilisation and CF- with carbon fertilisation)

4http://sedac.ciesin.columbia.edu/es/esi/2005ESI_DataCoverage.xls?bcsi_scan_B786307563EE7842=0&bcsi_scan_filename=2005ESI_DataCoverage.xls; 5Alcamo et al., 2007; 6<http://www.scidev.net/en/news/climate-change-destroying-glaciers-in-argentina.html>; 7 WHO, 2007; 8OECD, 2008.

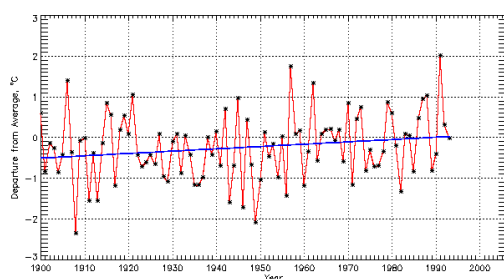
Argentina's average temperature has risen by 0.5°C over 1900-1993. (Fig 33 depicts the average temperature anomaly over this period)

In Argentina, climate change is expected to cause a tendency to higher rainfall, causing flooding particularly in the northeast and centre of the country, including Buenos Aires, a report by Oxford Analytica states⁴³.

The Patagonian glaciers are expected to disappear within 20 years⁴⁴. The Science Research Centre in Argentina states that the Upsala glacier has shrunk by 8 kms in the last 25 years. These melting glaciers will also impact other countries in the region such as Bolivia, Ecuador, Columbia and Peru.

Hydropower may be stressed by lower volumes of water in certain regions. Hydroelectric output in the Comahue area of southern Argentina, which currently produces just over a quarter of the country's hydropower, could show a reduction of almost a third by the 2020s, due to a drop in river levels⁴⁵.

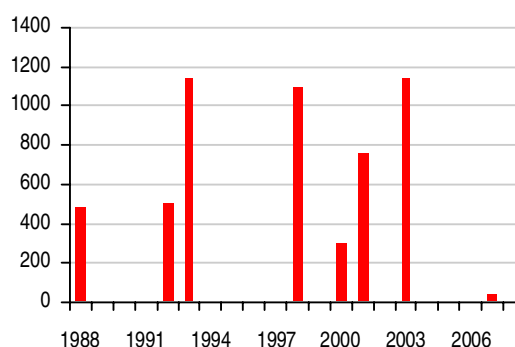
Fig 33: Temperature anomaly in Argentina 1900-1993 (°C)



Source: <http://www.ncdc.noaa.gov>

Argentina has an annual average loss of USD 274 mn from climate disasters (averaged over the period 1988 to 2008). The disaster data shows a low average, with high variability, mainly from flood events (Fig 34).

Fig 34: Losses due to climate related disasters in Argentina (USD mn)



Source: EMDAT database

According to climate change projections, it is likely that Argentina will warm slightly less rapidly in the future than the global average. Projections under different scenarios⁴⁶ suggest that Argentina warms from a low of 0.9 °C to a high of 1.7 °C by 2020, compared to pre-industrial baseline (1850). However, within the country, the north is likely to warm at a considerably higher rate than the south. In terms of precipitation, future changes in precipitation differ between the western and eastern regions of Argentina. Annual precipitation tends to decline over the Andes while the east of the country – the region of the lower Rio de la Plata river basin – experiences increased annual precipitation.

Table 15: Projected temperature (by 2020) change in Argentina⁴⁷

	B1-Low	B2-Mid	A1-Mid	A2-High
Temperature (in °C)	0.9	1.2	1.3	1.7

Source: <http://www.cru.uea.ac.uk/~mikeh/research/wwf.argent.pdf>

Argentina's economy is likely to be positively impacted in a climate change scenario at least in the next decade, though not necessarily in the longer term.

⁴³ <http://www.offnews.info/verArticulo.php?contenidoID=8572>

⁴⁴ <http://www.scidev.net/en/news/climate-change-destroying-glaciers-in-argentina.html>

⁴⁵ Torcuato Di Tella Foundation study (2006)

⁴⁶ <http://www.cru.uea.ac.uk/~mikeh/research/wwf.argent.pdf>

⁴⁷ Relative to 1961-90 baseline

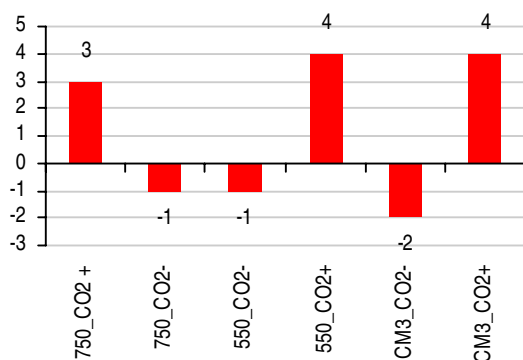
Impact on the agriculture sector

Argentina is a net exporter of food grains. Around 10% of the country's land is arable. While agriculture accounts for only 1% of employment, it is 8.5% of GDP and over 15% of exports. Climate change induced changes in the yield under different scenarios are shown in Fig 28.

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

Under this scenario, food grain productivity in Argentina could increase by up to 4% by 2020.

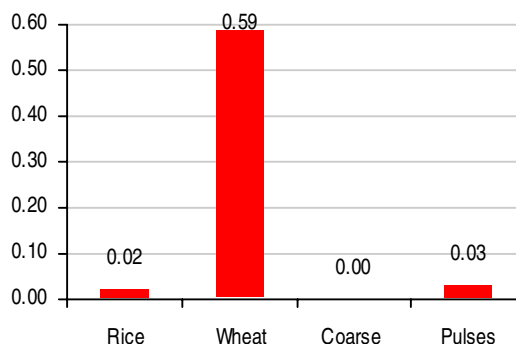
Fig 35: % change in cereal yield in Argentina by 2020e



Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Our analysis suggests that food grain production in Argentina could increase by 0.64 mn tonnes pa by 2020, with the biggest increases in wheat grain production. Currently, Argentina produces 37 mn tonnes of cereals. Per capita food grain production in Argentina is currently estimated at 0.9 tonnes per year which could decrease by 8 % under the carbon fertilisation scenario.

Fig 36: Change in food grain production in Argentina by 2020e (Mt pa)

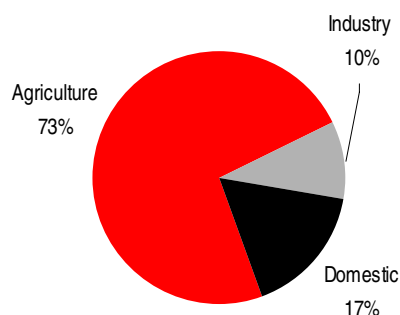


Source: HSBC (SEDAC)

Impact on the water sector

In Argentina, current per capita water availability is approximately 21,605 m3/capita/year which is comfortably higher than the 1,000 m3/capita/year threshold below which a country is defined as water stressed. However there is considerable variation in the distribution of freshwater resources and around 20% of the land area is classified as water stressed.

Fig 37: Water use in Argentina (2007)



Source: World Bank statistics

By 2025, water availability is projected to decrease by 19%. In addition, the per capita water withdrawal is projected to rise by 53% to over 1mn litres (=1,000 m3) per year from the current demand level of 0.8 mn litres per capita per year (see Table 6). This will make Argentina the third most water hungry country among the G-20.

The bulk of Argentina's water is used for agricultural purposes. Livestock production uses a high level of water per unit output, as water is first used for the production of feedstock.

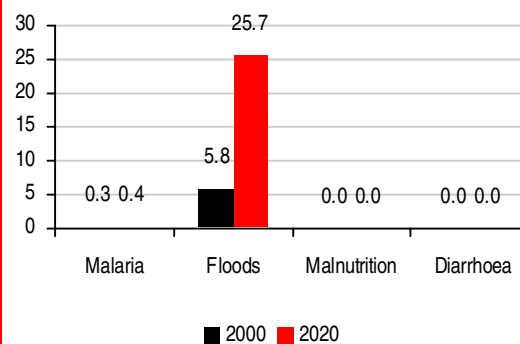
On the other hand, water abundance in specific locations has its downside as well. Currently, Argentina loses more than USD 265 mn pa to flood-related disasters (averaged over the last two decades 1988 to 2008).

Impact on the health sector

Argentina has limited exposure to climate change induced malaria in 2000, which is estimated to increase only modestly by 2020. However, as already discussed, Argentina has considerable flood exposure. Floods also contribute to human disabilities. WHO estimates the current DALY losses arising from climate change induced floods as 5,800. This is projected to rise almost four-fold, to 25,000 by 2020.

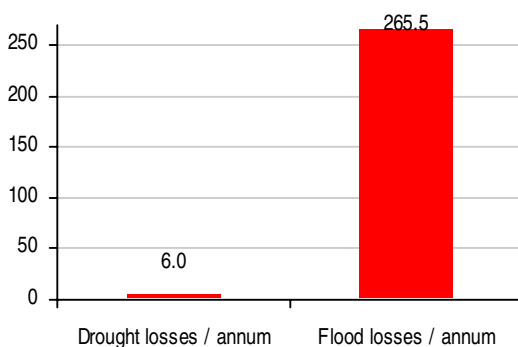
We estimate that currently climate change related disability costs the Argentinean economy USD 50 mn pa which is projected to increase over four-fold to USD 214 mn pa by 2020.

Fig 39: Disability adjusted life year losses attributable to climate change in Argentina for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

Fig 38: Flood and drought related average losses pa (1988-2008) in Argentina (USD mn)

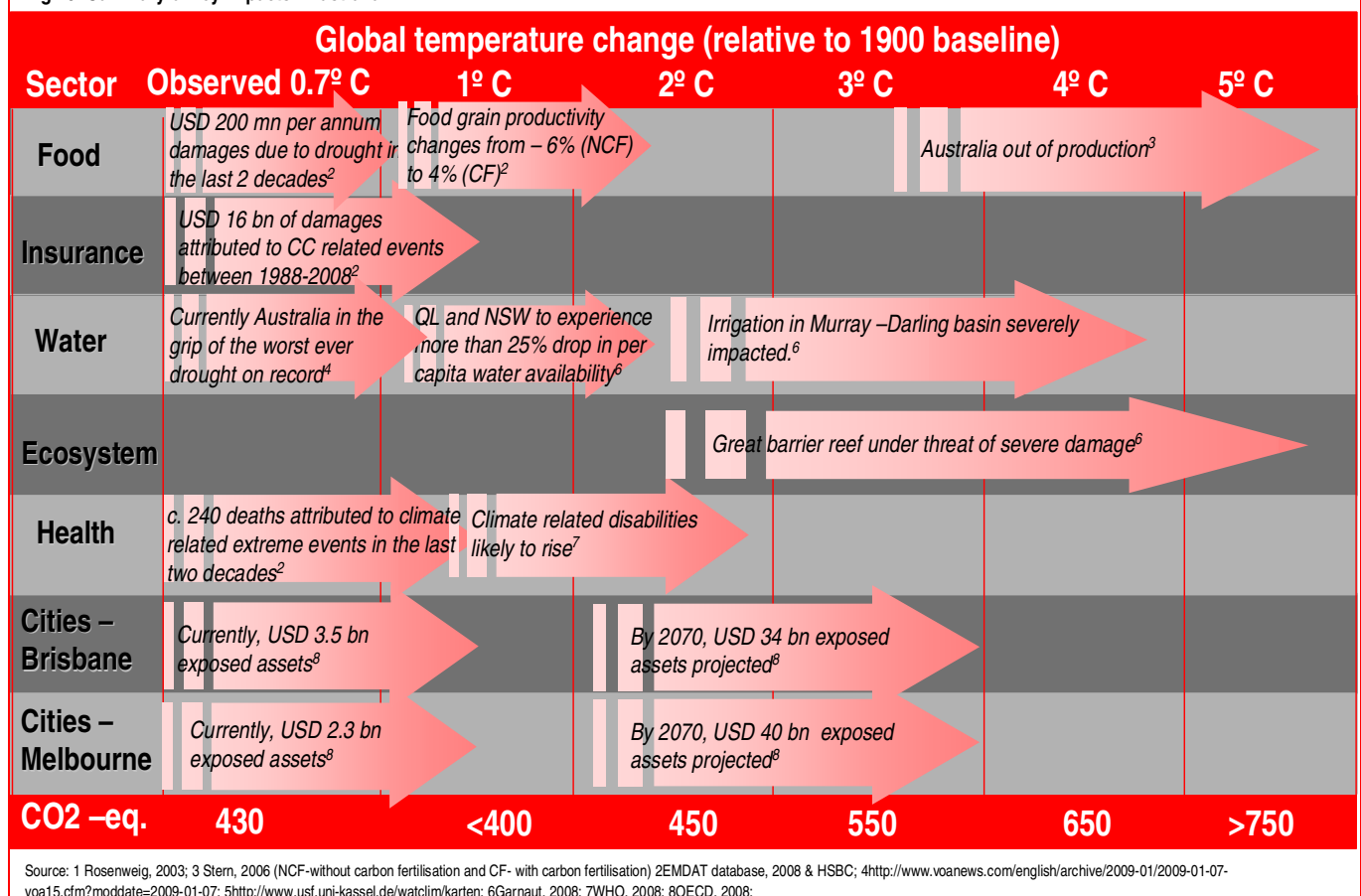


Source: HSBC (Based on EMDAT database)

Australia

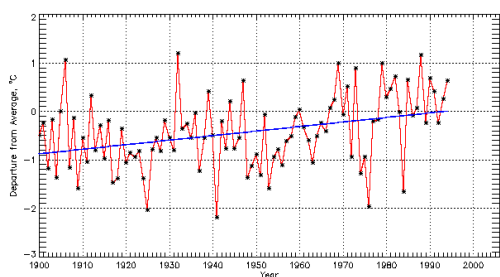
- ▶ HCVA assessment: 2nd quartile; moderately vulnerable
- ▶ Per capita water availability projected to decrease by 27% by 2020
- ▶ Climate change related health losses might double by 2020
- ▶ The agricultural sector might see some positive impacts, especially if a carbon fertilisation benefit is assumed

Fig 40: Summary of key impacts - Australia



Australia has warmed by 1 °C during the last century, according to NOAA statistics. Fig 41 shows the average temperature increments during the 1900-1993 period.

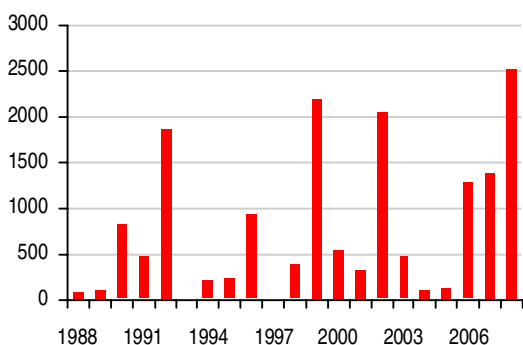
Fig 41: Fig 33: Temperature anomaly in Australia 1900-1993 (°C)



Source: <http://www.ncdc.noaa.gov/gcag/GCAGtsalt?dat=GHCN&SYST=TS&TS=5>

Australia is highly prone to climate related natural disasters such as droughts, floods and wild fires. Even in the current climate, Australia experiences huge losses of lives as well as assets due to climate related disasters. Between the years 1988 and 2008, Australia has lost more than USD 16 bn of assets to climate related disasters.

Fig 42: Losses due to climate related disasters in Australia (USD mn)



Source: EMDAT database

Regional climate models for Australia project a mean temperature increment of 1.3° – 1.5 °C in coastal regions by 2030,⁴⁸ while inland temperatures are projected to increase between 1.6 – 1.8 °C, relative to pre-industrial (1850).

⁴⁸ <http://www.climatechangeinaustralia.gov.au/>

Simulations from 23 IPCC models suggest little change in precipitation patterns in the far north and a decrease of 2 to 5% in the rest of the country by 2030. Model estimates further suggest that decreases of around 5% prevail in winter and spring, reaching 10% in the south west. We note that there is a wide range of estimates for Australia, as there is not enough agreement amongst the different climate models.

Table 16: Projected temperature (by 2030) change in Australia⁴⁹

	2030 ⁵⁰	
Temperature (°C)	Coastal – 1.3 to 1.5	Inland – 1.6 to 1.8

Source: Climate Change in Australia – Technical Report, 2007

Australia is already experiencing significant economic losses every year (Fig 42) due to climate related events. The Garnaut Review⁵¹, published in 2008, indicated that in the absence of a global effort to reduce GHG emissions, climate change would have severe adverse effects on Australian agriculture and on the natural environment. Irrigation in the Murray-Darling Basin would be severely affected, and in the most adverse scenarios, would cease altogether. Severe damage and even destruction of the Great Barrier Reef is also a likely impact of rapid climate change.

Impact on the agriculture sector

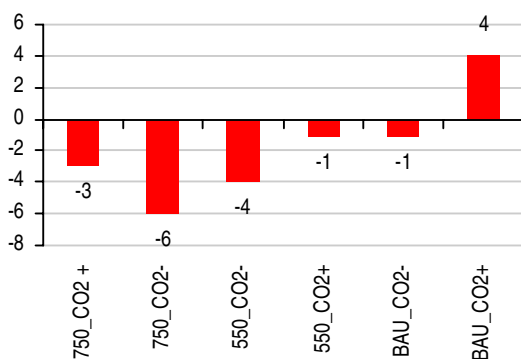
Climate modelling results suggest that under different scenarios of climate change, food grain productivity in Australia could vary from a decrease of 6 % to an increase of 4%.

⁴⁹ Although local and regional climate changes are of much greater interest to people, these regional projections are less reliable than global projections and have more uncertainty (a greater risk of under-estimating or over-estimating the projected changes)

⁵⁰ Relative to pre-industrial baseline (1850)

⁵¹ http://www.garnautreview.org.au/domino/Web_Notes/Garnaut/garnautweb.nsf

Fig 43: % change in cereal yield in Australia by 2020e



Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

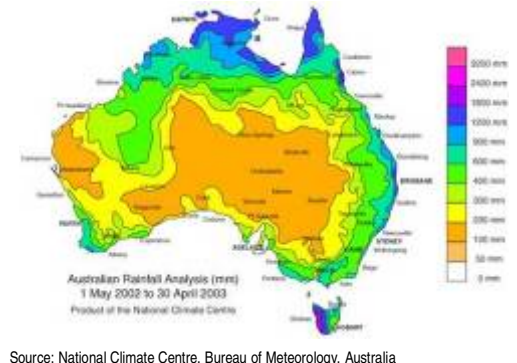
We estimate that Australia under this particular scenario would experience an increase in cereal yield of 4%, resulting in an increased production of 1.8 mn tonnes cereals pa by 2020. Currently, Australia produces 34 mn tonnes of cereals pa. Per capita food grain production in Australia is currently estimated at 1.45 tonnes per year, which could decrease by up to 6%.

Water use by the Agriculture sector has gone up between the years 2005 and 2007 and any shortage of water could cause further adverse impacts on per capita food production by 2020.

Impact on the water sector

Australia has reasonably high per capita water availability at more than 25000 m3/ capita/ year. However, the geographic distribution of this water wealth is highly skewed. Australia has a very diverse geography which makes national level aggregates almost meaningless.

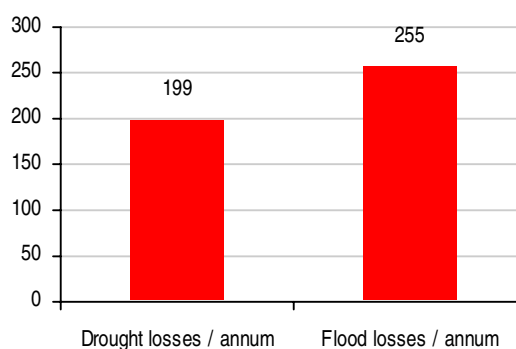
Fig 44: Rainfall variability in Australia



The northern as well as eastern coastal parts of Australia receive abundant rainfall whereas the interior of the continent suffers desert-like conditions. Australia has already suffered from a number of severe droughts in the past.

Secondly, at 1,218 m3/capita/year, current per capita water withdrawal rates are very high in Australia, second only to Canada among the G-20 member states. Thus, Australia, in spite of having abundant per capita water, periodically suffers from water stress.

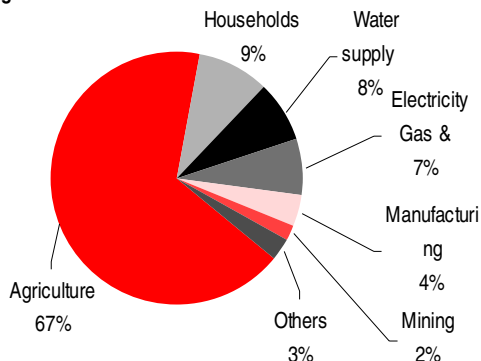
Fig 45: Flood and drought related average losses pa (1988-2008) in Australia (USD mn)



Source: HSBC (based on EMDAT database)

Our estimate suggests that on average floods and droughts annually cost Australia more than USD 450 mn pa (averaged over 1988 to 2008). Unlike other industrialized countries, the bulk of the water resources in Australia are used for agricultural purposes.

Fig 46: Water use in Australia 2005

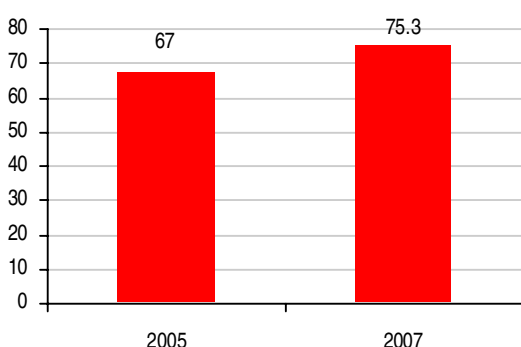


Source: http://www.connectedwater.gov.au/water_policy/water_security.html

Recent years have seen an increase in the agricultural water use (Fig 47).

Australian agriculture, especially around the Murray-Darling basin, has suffered from major drought in recent years. The amount of water flowing in Murray-Darling (M-D) has come down significantly. M-D currently accounts for 41% of Australia's agriculture, 90% of the country's irrigated crops and about USD 22bn of agricultural exports.

Fig 47: Water use in agriculture in %



Source: HSBC

According to the Garnaut Review (2008), all major cities and many regional centres are already feeling the strain of declining rainfall and runoff into streams. For the next two decades, it projects climate change to further stress the water supply for urban areas as well as for agriculture. It notes that most major cities are beginning to develop high-cost

infrastructure for new water sources. And it concludes that in the absence of effective global mitigation, continued investment in expensive new sources of water becomes a necessity.

By mid-century, the Garnaut Review contends that irrigated agriculture in the Murray-Darling Basin would lose half of its annual output. This would lead to changes in Australia's capacity to export food and a growing reliance on food imports.

Worst drought on record in Australia

A new drought, one of the worst on record, started in 2003. The drought has changed the way Australia treats its water resources. Australia in the past 100 years relied solely on water from dams for agriculture and consumption. Now schemes like grey water recycling and tougher restrictions on industries have come in to effect. There has been a greater push on desalination. A desalination project has been initiated on the Gold Coast, Queensland. In November 2006, Perth completed a seawater desalination plant that will supply the city with 17% of its needs⁵². Likewise, the state of Victoria is also in the process of building one of the world's largest desalination plants. When complete, it will be capable of producing up to a third of Melbourne's water needs⁵³.

Dairy producers have been hit particularly hard by the drought that has swept much of Australia. In 2004, a drought induced drop in production caused industry revenue to go down by 4.5%⁵⁴.

Queensland and South Wales, Victoria and parts of Western Australia have historically been impacted by droughts. Climate change scenario projections⁵⁵ from the centre for Environmental Systems Research of the University of Kassel suggest that overall Australia loses more than

⁵² <http://www.watercorporation.com.au/D/desalination.cfm>

⁵³ <http://www.ourwater.vic.gov.au/programs/desalination>

⁵⁴ <http://www.smartcompany.com.au/Premium-Articles/Industry-Trends/Dairy-farmers-face-tough-times071025.html>

⁵⁵ http://www.usf.uni-kassel.de/watclim/karten/avl_var_95_2_had_a2_2020.jpg

26% in terms of per capita water availability by 2025 under the A2 scenario of climate change, while per capita water demand could also decrease by more than 20%. Victoria currently has the highest water withdrawal to available ratio, indicating high pressure on the available water. In a changed climate, Victoria remains the most water stressed province in the federation⁵⁶.

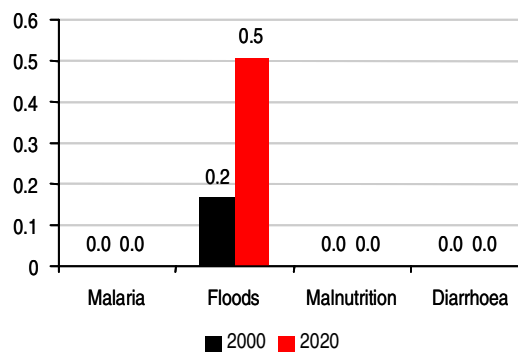
Impact on the health sector

The WHO estimates suggest that flood induced diseases are currently the biggest source of climate-related DALY losses in Australia. For example, 166 DALYs were lost due to flood induced disability in 2000 alone (attributable to observed climate change).

With climate change, such losses are likely to reach over 500 DALYs per year by 2020.

We estimate that currently climate change related disabilities cause annual disability losses worth USD 7.9 mn which could increase to up to USD 24 mn per year by 2020

Fig 48: Disability adjusted life year losses attributable to climate change in Australia for 2000 and 2020e (000)



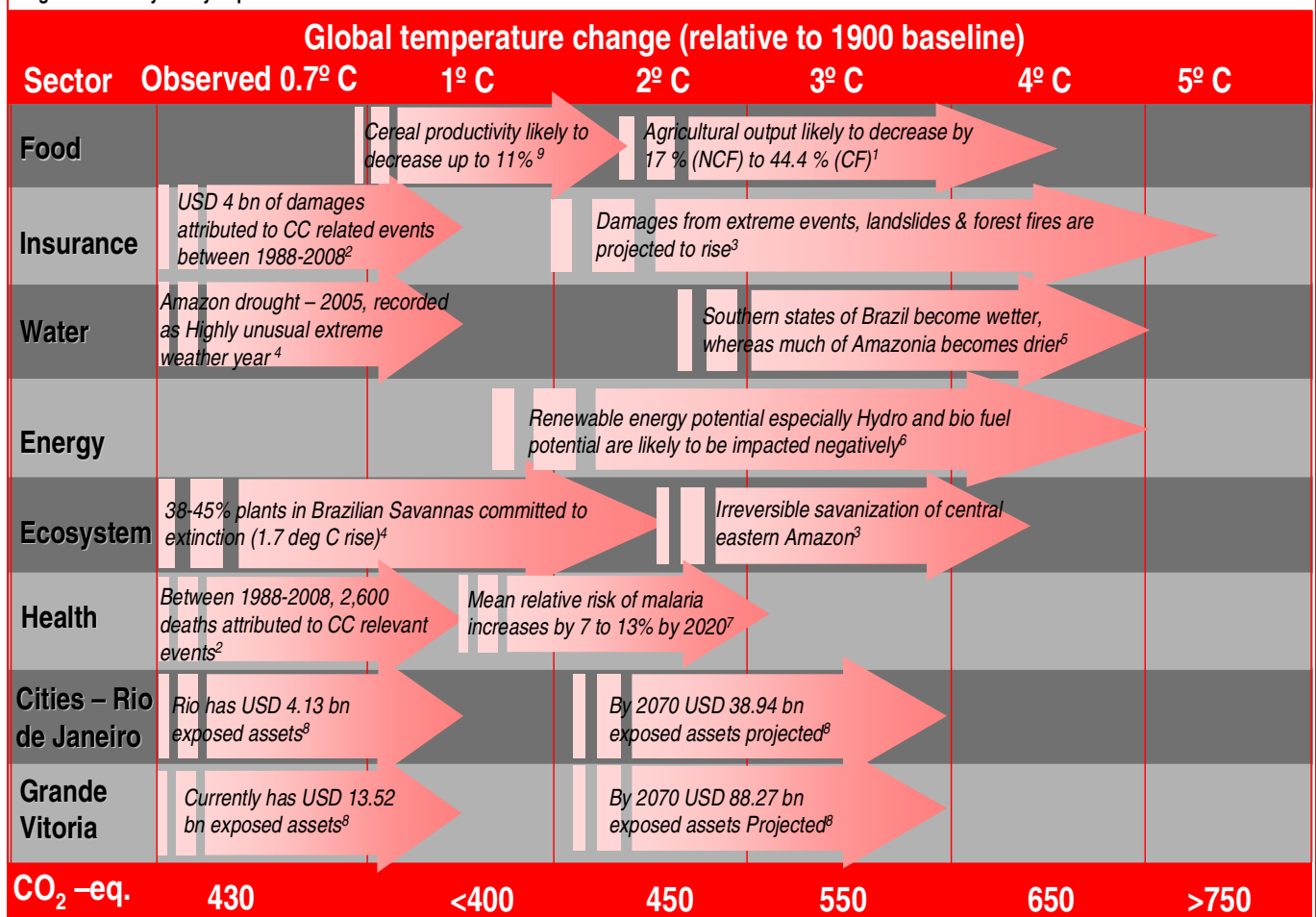
Source: HSBC (WHO, 2007)

⁵⁶ <http://www.usf.uni-kassel.de/watchim/karten.htm>

Brazil

- ▶ HCVA assessment: 1st quartile; highly vulnerable
- ▶ Per capita water availability could decrease by 29%
- ▶ Cereal production could decrease by 4% to 9% by 2020
- ▶ Climate change induced health disabilities could increase by more than 3-fold over the same period

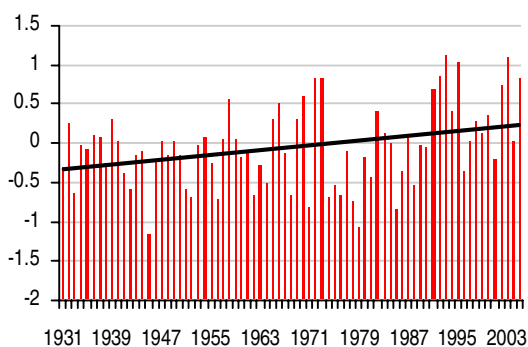
Fig 49: Summary of key impacts – Brazil



Source: 1Bill Cline, 2007 (NCF – No CO₂ fertilisation effect and CF – with CO₂ fertilisation effect); 2EMDAT database, 2008 & HSBC; 3IPCC, 2007; 4WWF, 2007 & IPCC, 2007; 5CRU (WWF); 6Lucena et al., 2008; 7WHO, 2007; 8OECD, 2008; Rozenweig et al., 2003

Brazil's warming trajectory is shown in Fig 50. Between the period 1931 to 2003, the temperature increase is about 0.6°C.

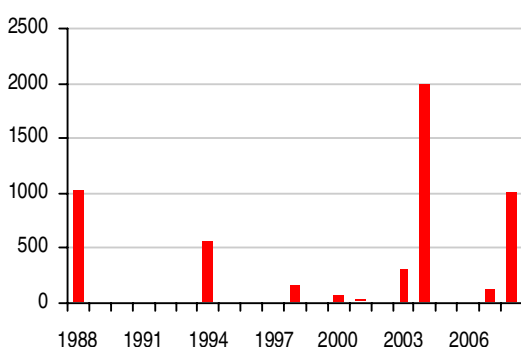
Fig 50: Temperature anomaly in Brazil 1931-2003 (°C)



Source: NOAA (1980 data unavailable)

We estimate that on an average (over 1988 to 2008) Brazil lost more than USD 260 mn pa to climate related disasters. However, the losses are not evenly distributed: some years see huge losses while others have witnessed modest losses. For example, in 2004, Brazil lost USD 2bn to climate related disasters.

Fig 51: Losses due to climate related disasters in Brazil (USD mn)



Source: EMDAT database

According to regional climate projections, Brazil is set to warm by 0.9° to 1.7 °C by 2020, compared to the pre-industrial baseline (1850). Warming is projected to be greatest over the Amazonian rainforest but rather smaller in the south-eastern coastal states along the Atlantic

Ocean. In terms of precipitation, the southern states of Brazil become wetter in the future whereas much of Amazonia becomes drier.

Table 17: Projected temperature (by 2020) change in Brazil ⁵⁷

	B1-Low	B2-Mid	A1-Mid	A2-High
Temperature (in °C)	0.9	1.2	1.3	1.7

Source: <http://www.cru.uea.ac.uk/~mikeh/research/wwf.brazil.pdf>

Fig 49 summarizes the key impacts of climate change in Brazil. One of the major likely impacts is on agriculture which loses up to 44% in productivity in the long run⁵⁸. Another major impact is the projected decrease in precipitation over Amazonia and the consequent threat of its savanisation. Amazonia produces between a third and a half of its own rainfall by recycling precipitation through evapo-transpiration. As deforestation decreases evapo-transpiration, it decreases regional rainfall as well. It may also set in motion a self-perpetuating feedback loop of deforestation causing drought, in turn causing fire, thereby causing more deforestation, prompting more drought, etc... Scrub vegetation could ultimately displace rain forest across a third or more of the Amazon. It is believed that between 70 and 80 percent of the region's forest cover must stay intact to maintain adequate rainfall.

Drought revisits the Amazon

The Amazon is already witnessing drying conditions. The worst drought in four decades hit the western part of Amazonia in 2005. The months-long drought ignited huge forest fires, dried up major waterways, killed off fish, wildlife and crops, prompting "a state of public calamity" in 2005⁵⁹. In 2009, drought returned to the Amazon for the second successive year. New

⁵⁷ Relative to Pre-Industrial baseline (1850)

⁵⁸ Study by Bill Cline, 2007

⁵⁹ <http://www.nwf.org/nationalwildlife/article.cfm?issueID=109&articleID=1365>

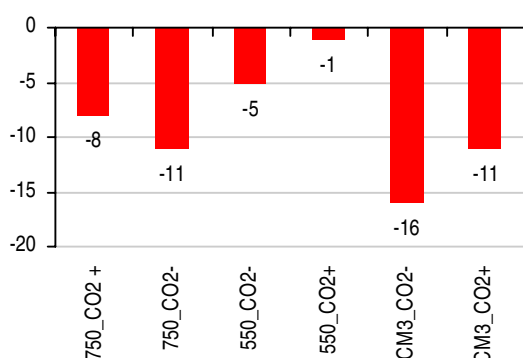
research suggests⁶⁰ that one more dry year could tip the whole forest into a cycle of decline.

Impact on the agriculture sector

Brazil is a net exporter of food grains. Only 7% of the country's land is arable. While agriculture constitutes 21% of employment, it accounts for 5.2 % of GDP and over 10.5% of exports.

Crop impact modelling suggests Brazil to be among the worst impacted in terms of projected agricultural losses. We note that under different climate change scenarios (Fig 52) food grain productivity in Brazil could decrease between 1% and 16% by 2020.

Fig 52: % change in cereal yield in Brazil by 2020e



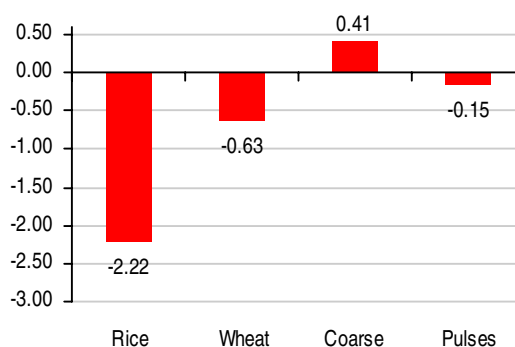
Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

Our analysis suggests that even when the CO2 fertilisation effect has been taken into account, food grain production in Brazil could decrease significantly, by about 2.6 mn tonnes pa, while currently Brazil produces about 58 mn tonnes of food grains annually. The biggest decrease is estimated to be in rice production followed by wheat and pulses (Fig 53). Currently (2007), per capita

food grain production in Brazil is 0.30 tonnes pa which could decrease to 0.24 tonnes pa under the no CO2 fertilisation scenario and to 0.25 tonnes pa under CO2 fertilisation assumption by 2020.

Fig 53: Change in food grain production in Brazil by 2020e (Mt pa)



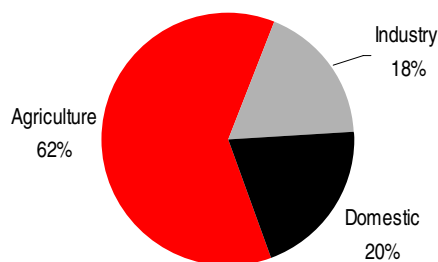
Source: HSBC (SEDAC)

Impact on the water sector

Brazil has huge per capita water availability at more than 45,000 m3/capita/ year (2002) and 91% of the population has access to tap water. Currently, Brazil uses 59 trillion litres of water pa which comes to a use of about 340,000 litres per capita per year. By 2025, under the A2 scenario, water use is likely to go up to 160 trn litres, with per capita water consumption doubling.

The bulk of Brazil's water resources are utilised in the agriculture sector (Fig 54).

Fig 54: Water use in Brazil - 2007

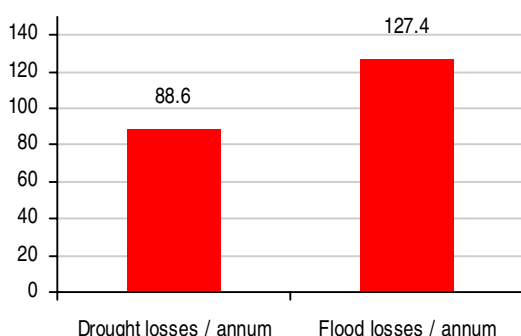


Source: World Bank statistics

⁶⁰
http://www.nzherald.co.nz/world/news/article.cfm?c_id=2&objectid=10392615

Though Brazil is well endowed with water resources, parts of Brazil do experience drought spells. But the major losses for Brazil emanate from floods. We estimate that on average floods and droughts cost USD 216 mn annually over the last two decades (1988 to 2008).

Fig 55: Flood and drought related average losses pa (1988-2008) in Brazil (USD mn)

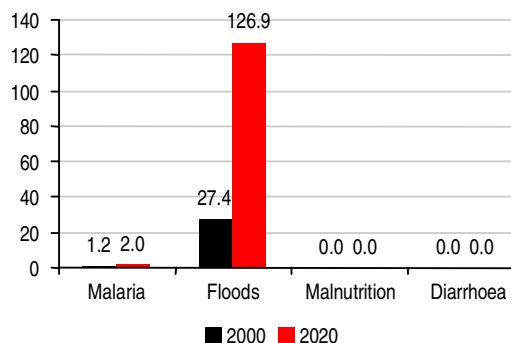


Source: HSBC (Based on EMDAT database)

Energy supply in Brazil relies heavily on renewable energy sources, especially on hydropower which accounts for 90% of its electricity production⁶¹. Hydropower potential is projected to suffer negatively from climate change⁶².

Impact on the health sector

Fig 56: Disability adjusted life year losses attributable to climate change in Brazil for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

WHO estimates suggest that flood induced diseases and malaria are the major source of climate-related DALY losses in Brazil. Around 1,200 DALYs are lost pa (2000 estimates) due to malaria and floods cause even bigger losses at about 27,000 DALYs pa.

In a changed climate, these disabilities are projected to rise substantially with flood induced DALY losses expected to climb more than four-fold by 2020.

We estimate that climate change induced disabilities caused an estimated loss of USD 240 mn in 2000, and this loss is estimated to rise to more than USD 1 bn pa by 2020.

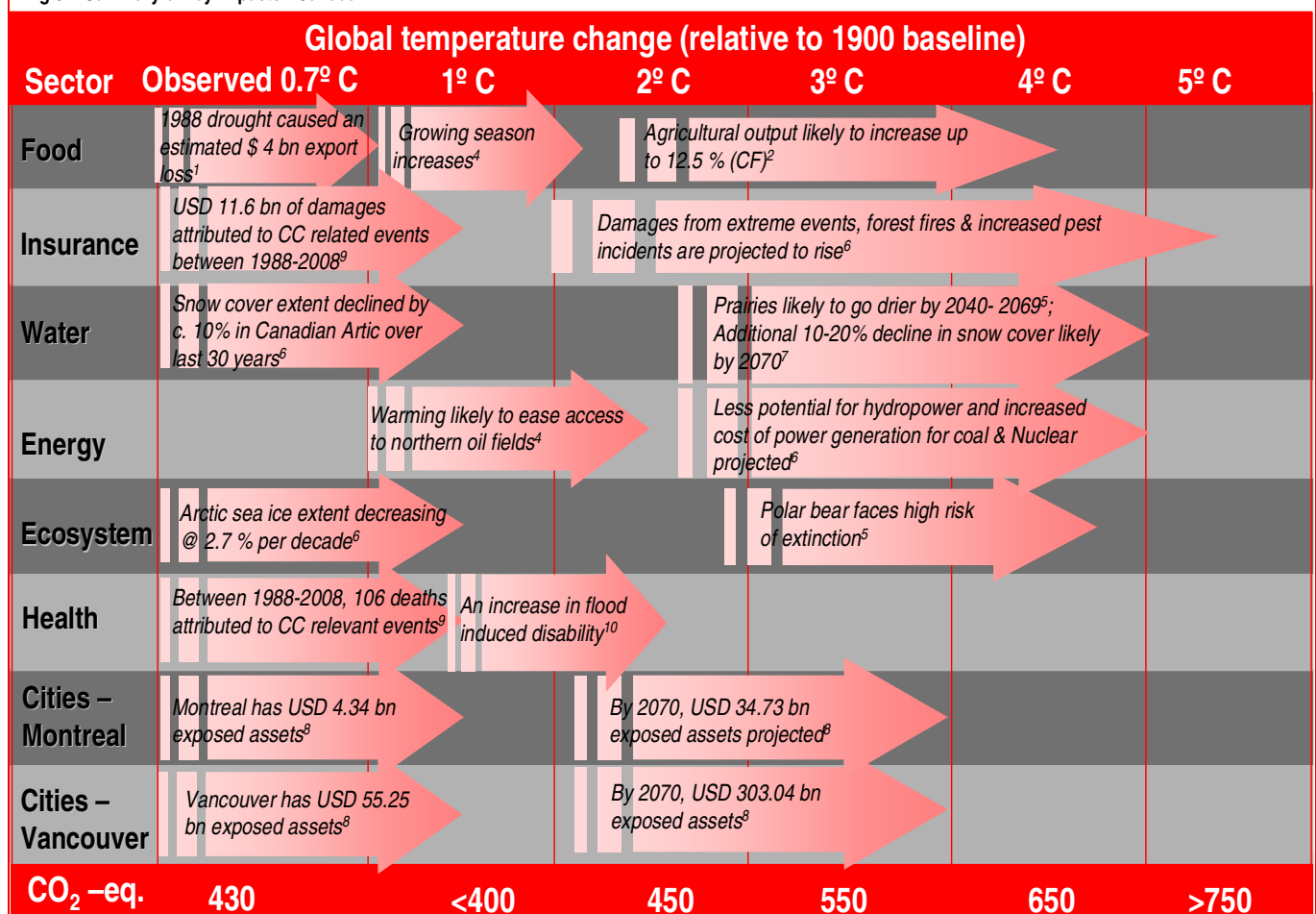
⁶¹ http://www.pewclimate.org/global-warming-in-depth/all_reports/brazil/pol_brazil_execsumm.cfm

⁶² http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V2W-4V34RP8-2&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=1084443573&_rerunOrigin=google&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=ac198fffb3840483706cb317e040892a

Canada

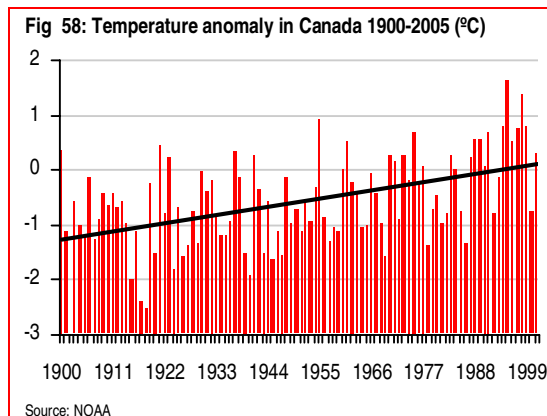
- ▶ HCVA assessment: 3rd quartile; less vulnerable
- ▶ Although currently endowed by ample water wealth, per capita water availability could decrease by 8% by 2020
- ▶ Agricultural productivity could decrease marginally
- ▶ Possible increases in climate change induced health losses

Fig 57: Summary of key impacts - Canada

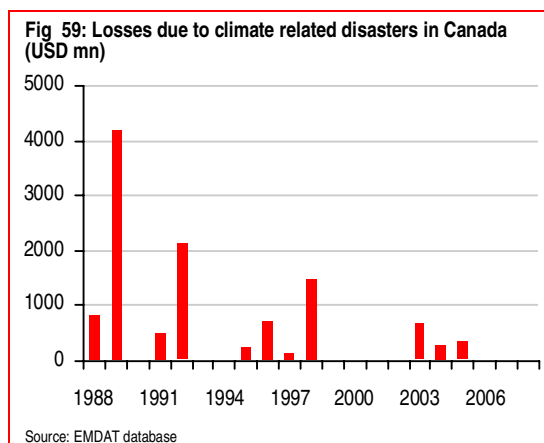


Source: 1Govt of Canda, 2004; 2Bill Cline, 2007 (NCF – No CO2 fertilisation effect and CF – with CO2 fertilisation effect); 3Nyirira, W.N et al., 2002; 4US report, 2008; 5IPCC, 2007; 6Govt of Canada 2007; 7Arctic Climate Assessment, 2004; 8OECD, 2008; 9EMDAT database, 2008 & HSBC; 10 WHO, 2008

Canada has warmed by more than 1°C in the last century. (Fig 58)



Although Canada is one of the least vulnerable countries among the G-20, it suffers average losses of about USD 582 mn pa from climate related disasters (averaged over the last two decades 1988 to 2008). However Fig 59 seems to indicate lower climate-related disaster losses in recent years.



North America is expected to warm more than the global average. Projections made with a Canadian Coupled Climate Model show average temperatures rising by 1-2°C by 2020, increasing to 2-4°C by 2050 and 5-10°C by 2090 over most areas relative to 1975-1995 baseline. The greatest warming occurs over the high Arctic, with projections of increases as high as 15°C or more by 2090⁶³.

⁶³ <http://www.greenlearning.ca/climate/science/climate-and-weather/7>

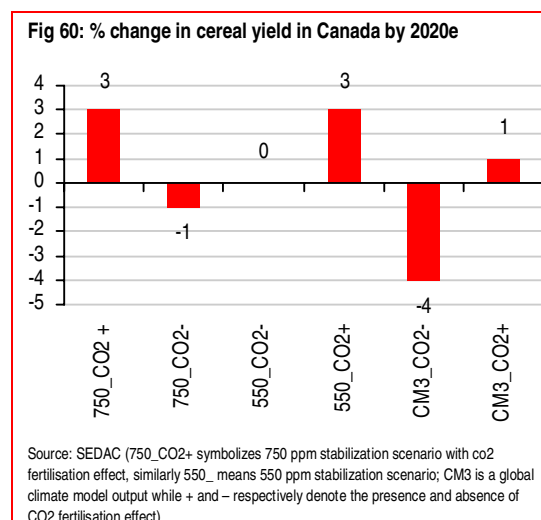
Regional models for the prairies suggest that climate change could result in increased air temperatures and decreased soil moisture, with predictions that the semi-arid regions of the prairies can expect more frequent and longer droughts.

Climate impact studies suggest Canada will generally benefit from a warming climate, especially in the short term, although there are likely to be some negative impacts as well.

Impact on the agriculture sector

Canada is a net exporter of food grains, and it was the second largest wheat exporter in 2007⁶⁴.

Currently, only 5% of the country's land is arable, accounting for 2.3% of GDP and 3% of employment. Crop impact modelling suggests climate change could have both positive and negative effects on food grain productivity in Canada, which under different scenarios could range from a decrease of 4% to an increase of 3% (Fig 60).

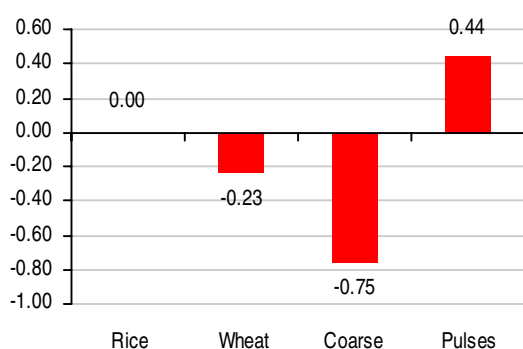


Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

⁶⁴ US Dept of Agriculture, Foreign Agricultural Service, Grain: World Markets and Trade (Jan 2008)

Under this scenario, overall food grain production in Canada could decrease modestly by 500,000 tonnes pa. Production of pulses is projected to rise, while wheat, rice and coarse grain production is projected to decline marginally.

Fig 61: Change in food grain production in Canada by 2020e (Mt pa)



Source: HSBC (SEDAC)

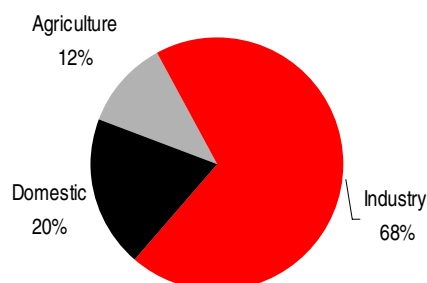
Currently, Canada produces 52 mn tonnes of cereals, with per capita food grain production estimated at 1.54 tonnes pa, which is considerably higher than the G-20 average of 0.37 tonnes per capita pa. Per capita food grain production could decrease by 8.6% by 2020, even when carbon fertilisation is taken into account, mainly due to the increasing population.

Impact on the water sector

Canada has immense natural water resources and a very small population. Its per capita water availability is more than 90,000 m³/capita/year, and with universal access to safe water, it is probably one of the least water stressed countries in the world, and it is certainly the least stressed among the G-20.

Currently, Canada uses 46 trillion litres of water p.a which works out to be 1,500 m³ per capita p.a. This is the highest per capita water use among the G-20 member states. Water use is projected to increase by 13% by 2025. However due to increases in population and water use efficiency, the per capita demand comes down by 6%. The bulk of Canada's water is currently used in industry.

Fig 62: Water use in Canada (2007)

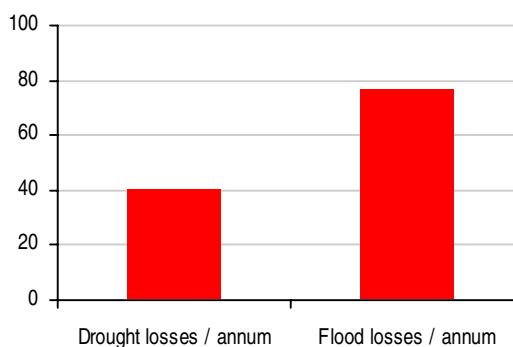


Source: World Bank statistics

Although Canada is endowed with plenty of water resources, its distribution is highly skewed across the country. In spite of having such high levels of water resources, Canada does suffer from drought in some areas.

Based on the EMDAT data base, we estimate that on average floods and droughts caused USD 117 mn of annual losses over the last two decades (1988 to 2008), primarily in the agriculture sector.

Fig 63: Flood and drought related average losses pa (1988-2008) in Canada (USD mn)



Source: HSBC (Based on EMDAT database)

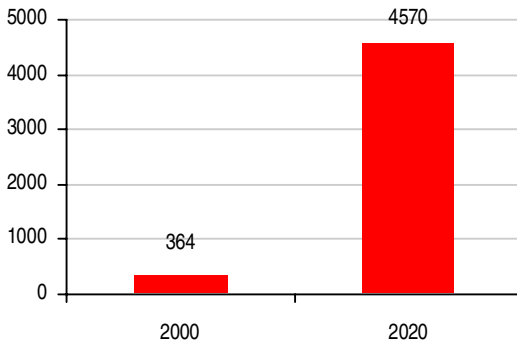
Canada does have some water stress in its prairie region (up to 1% of the (vast) land area of Canada is currently described as water stressed⁶⁵) which is projected to increase with climate change.

65

http://sedac.ciesin.columbia.edu/es/esi/2005ESI_DataCoverage.xls?bcs

Impact on the health sector

Fig 64: Disability adjusted life year losses attributable to climate change in Canada for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

WHO estimates suggest that in 2000 more than 360 DALYs pa attributable to climate change were lost in Canada, which is likely to rise to more than 4,500 by 2020.

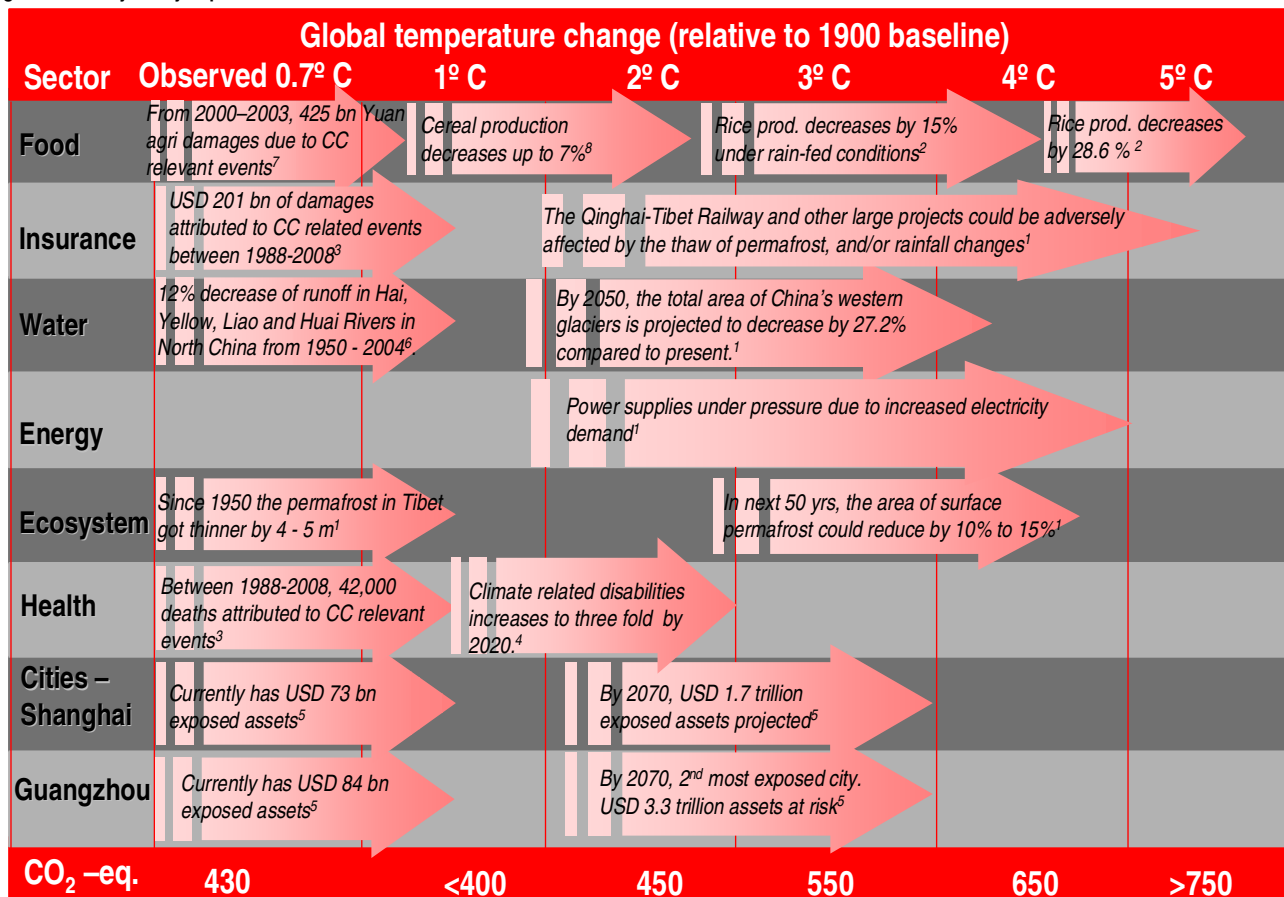
We estimate that currently climate change related disabilities cost Canada a modest USD 15 mn pa which could increase to USD 192 mn by 2020.

Canada is currently immune to climate-related diseases such as malaria, malnutrition, diarrhoea etc... WHO estimates suggest that Canada is likely to remain immune to such disabilities in the near future as well (up to 2020). However, it has considerable flood hazard, which causes numerous disabilities and such disabilities are likely to rise in the future.

China

- ▶ HCVA assessment: 1st quartile; highly vulnerable
- ▶ Parts of China already face water stress; per capita water availability could decrease by 8%
- ▶ Production of cereals could decrease by 1.6% assuming a carbon fertilisation benefit and by 8% in the absence of carbon fertilisation
- ▶ Current losses of more than USD 411 mn from climate-related health disabilities rise to USD 744 mn (+81%) by 2020

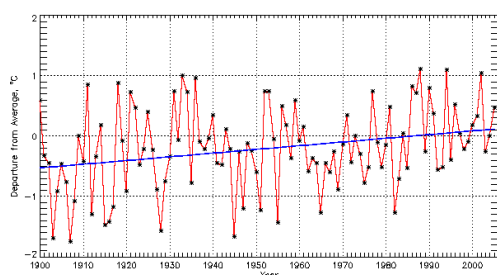
Fig 65: Summary of key impacts – China



Source: 1Erda et al., 2007 (China's National Communication); 2Xiong et al., 2008 (DFID); 3EMDAT database, 2008 & HSBC; 4WHO, 2007; 5OECD, 2008; 6UNDP, 2007; 7Wang et al., 2006 (UNDP, 2007); Rozenwig et al., 2003

China has warmed by over 0.6 °C over the period 1900-2005.

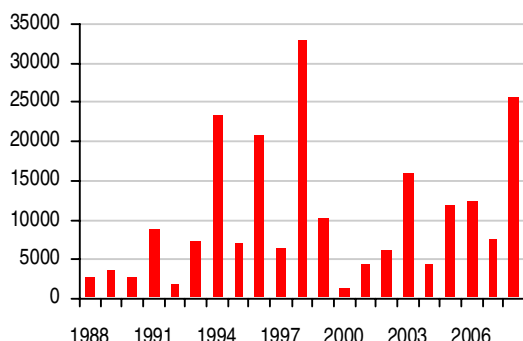
Fig 66: Temperature anomaly in China 1900-2005 (°C)



Source : Source : <http://www.ncdc.noaa.gov/>

Currently, China loses more than USD 10 bn pa to climate-related disasters. Over the last two decades (1988 to 2008), it has lost a total of USD 218 bn to climate-related disasters.

Fig 67: Losses due to climate related disasters in China (USD mn)



Source: EMDAT database

According to a recent study⁶⁶ by the University of East Anglia, China is likely to warm by an average of 1.5 °C by 2020, relative to the pre-industrial baseline (1850). Rainfall is likely to increase marginally throughout the country.

Table 18: Projected temperature (by 2020) and precipitation (by 2020) changes in China

Regions	Temperature change ⁶⁷ (°C)		Rainfall Change (%) ⁶⁸	
	A2	B1	A2	B1
West	1.8	1.8	4	5
North East	1.7	1.6	3	4
East	1.3	1.3	-2	1
North	1.6	1.6	3	7
South	1.1	1.2	-3	1
Whole of China	1.5	1.5	1	2

Source: Xiong Wei et al., 2008 ⁶⁶ "The Impact of CC on China's Agriculture- Phase II"

China faces the impact of climate change on many fronts including food production, water resources, sea level rise and health.

Impact on the agriculture sector

China is almost entirely self sufficient in food grains at present. Imports are less than 2% of its production levels, while exports and imports are almost equal (Table 11). 15% of the country's land is arable, and 43% of the labour force is employed in agriculture, although it makes up only 11.7% of GDP.

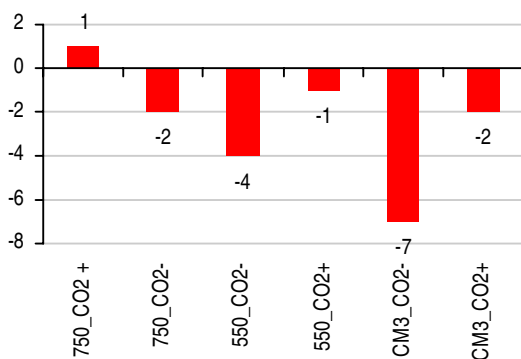
Impact modelling estimates suggest that under different scenarios of climate change, changes to food grain productivity in China could vary from a decrease of 7 % to a small increase of 1% (Fig 68).

⁶⁶ Xiong Wei et al., 2008 ⁶⁶ "The Impact of climate change on Chinese Agriculture- Phase II"

⁶⁷ Relative to pre-industrial

⁶⁸ Relative to 1960-1990 baseline

Fig 68: % change in cereal yield in China by 2020e

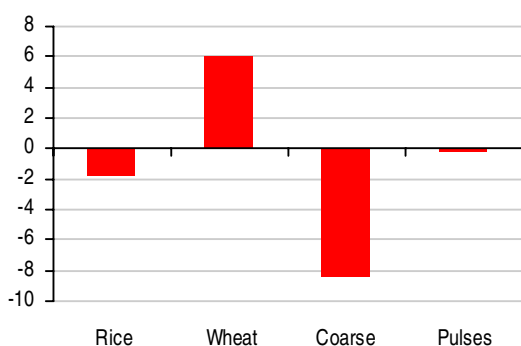


Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with CO₂ fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO₂ fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

In this scenario, food grain production could decrease by over 4.5 mn tonnes pa by 2020. The biggest decrease is estimated to be in coarse grain production followed by rice; wheat production is expected to increase – possibly due to an increased length of growing period in the northern wheat belt.

Fig 69: Change in food grain production in China by 2020e (Mt pa)



Source: HSBC (SEDAC)

China has moved over the last 10 years from being self sufficient in soybeans to importing nearly 70% of its soybeans. The US and Brazil are the largest suppliers. Negative impacts on agricultural production in the supplier countries could affect Chinese food price inflation. (See the Interlinkages

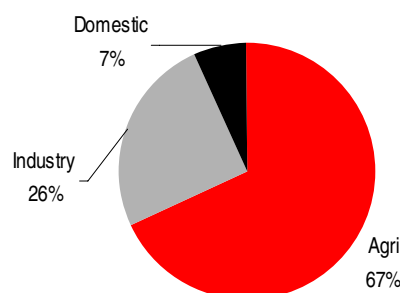
chapter for more on global food exports and imports. Also, please see HSBC Global Research report *Food Fight*, Stuart Green et al, 2008)

Currently, China produces 430 mn tonnes of cereals. In terms of per capita food grain production, this is 0.32 tonnes per year which could decrease by 7% by 2020, even when carbon fertilisation is taken into account.

Impact on the water sector

In China, current per capita water availability is 2,100 m³/capita/year which is comfortably higher than the water stress threshold of 1,000 m³/capita/year. Regional disparities exist – China has more than 40%⁶⁹ of its land area categorised as water stressed which is likely to rise further, especially in the north-eastern, as well as north-western parts of the country. China uses 630 trn litres of water pa which works out to 487,000 litres per capita pa. By 2025, under the A2 scenario, water use is likely to go up to 812 trn litres and per capita water consumption is likely to increase by 15 %. Currently, the bulk of China's water resources are used for agricultural and industrial purposes.

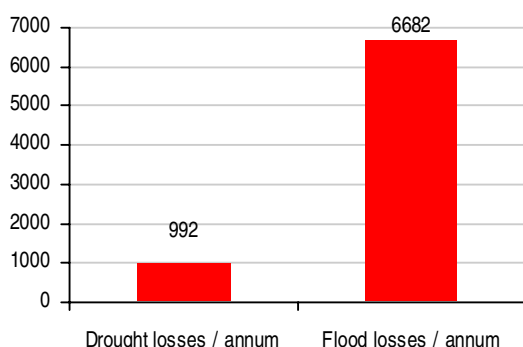
Fig 70: Water use in China (2007)



Source: World Bank statistics

69 <http://www.usf.uni-kassel.de/watclim/results.htm>
http://sedac.ciesin.columbia.edu/es/esi/2005ESI_DataCoverage.xls?bcsi_scan_B786307563EE7842=0&bcsi_scan_filename=2005ESI_DataCoverage.xls

Fig 71: Flood and drought related average losses pa (1988-2008) in China (USD mn)



Source: EMDAT database

While parts of China face the consequences of water abundance, WHO estimates indicate that 19% of the rural population does not have sustainable access to safe drinking water.⁷⁰

Most water disaster prone

Parts of southern China are water abundant and in fact are plagued by periodic floods, while parts of northern China are water stressed and intermittently hit by droughts.

According to our estimates, based on data from EMDAT, over 1988 to 2008, China seems to be the country most prone to water disasters among the G-20, with more than USD 7.5 bn of annual losses from flood and drought events. Floods caused about 88% of these losses.

Current flood vulnerabilities lie mainly in Guangdong, Guanxi, Guizhou, Hunan, Jiangxi, Fujian, Zhijiang, Jiangsu and Anhui provinces in south-eastern China⁷¹. In a warmer climate, the same provinces are likely to become even more vulnerable to floods. Our analysis suggests that Guangdong, Guanxi, Hunan, Fujian and Zhijiang

are especially prone to increased rainfall risk.⁷²

Flood losses in China will be impacted by the Three Gorges dam – which is designed to prevent flooding in the Yangtze river basin.

In addition, to help reduce the risk of flood in southern China and to alleviate the water shortages in the north, China has undertaken a river interlinking project, connecting the Yangtze and Yellow rivers, which is expected to be completed by 2013-14, at the earliest⁷³.

Melting Himalayan water towers

Over 80% of the glaciers in western China have retreated in the past 50 years, with the greatest percentage of retreat occurring on the northern slopes of the Himalayas. The Tibetan Plateau has been warming at an annual rate of 0.16 °C per decade with winter temperatures rising by 0.32 °C per decade. Himalayan glaciers have been retreating more rapidly than glaciers elsewhere in the world⁷⁴. This is well documented through remote sensing. Satellite imagery reveals average annual decreases in glacier surface area of 0.17, 0.19 and 0.77 km² per year for the time periods 1976–90, 1990–1999, and 1999–2003, respectively. Not only are the majority of Tibetan glaciers retreating, but this retreat is accelerating across much of the plateau as well. Declining snow cover and earlier melts decrease the regional albedo (reflectivity of the surface) and may enhance the rapidity and geographic scale of Himalayan glacier retreat. The Tibetan Plateau ice fields are a critical resource for at least one-sixth of the world's population because they provide dry season runoff for major rivers in China and South Asia⁷⁵.

⁷⁰

http://apps.who.int/whosis/database/core/core_select_process.cfm?countries=chn&indicators=PopAccessImprovedWaterUrban&indicators=PopAccessImprovedWaterRural&indicators=PopAccessImprovedSanitationUrban&indicators=PopAccessImprovedSanitationRural

⁷¹ Socioeconomic data and application center & Shi Peijun (ed) (2003) *Atlas of Natural disaster systems of China*. Beijing: Science Press, P. 83

⁷² Model UKMO-HadCM3 (IPCC, 2007)

⁷³ <http://uk.reuters.com/article/idUKPEK91076> (27 Feb, 2009)

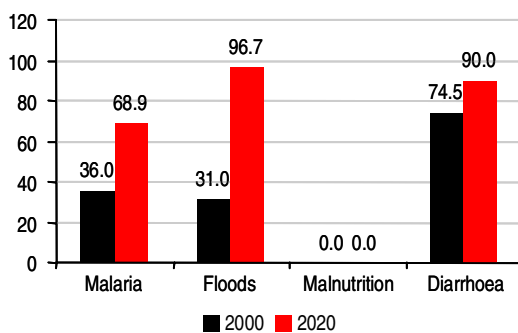
⁷⁴ Cruz et al., 2007

⁷⁵ Ibid & <http://www.agu.org/pubs/crossref/2008/2008GL035556.shtml>

The Qinghai - Tibet railway line cost over USD 4 bn⁷⁶. Some experts predict that it could come in harm's way as the underlying permafrost melts - however there is no agreed timeline as to when this is expected⁷⁷. Over the last two decades, China has spent more than 1 billion Yuan (USD 146.6 mn) reinforcing the main highway to Tibet. The government believes that the railway will be safe to use for the next 40 years if the thaw continues at its present speed⁷⁸.

Impact on the health sector

Fig 72: Disability adjusted life year losses attributable to climate change in China for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

WHO estimates suggest that flood, malaria and diarrhoea-related disabilities are currently the biggest source of climate change induced DALY losses in China. About 30, 000 DALYs were lost due to flood induced disabilities in 2000, with 74,000 DALYs lost from diarrhoea in the same year. By 2020, flood induced disabilities are likely to reach 96,000 DALYs pa whereas diarrhoea-related DALY losses are likely to reach 90,000 pa by the year 2020.

Current climate change related disabilities in the form of malaria- and flood-related disabilities and diarrhoea cause an estimated loss of more than USD 411 mn pa which is estimated to rise to USD 744 mn pa by 2020.

⁷⁶ <http://www.reuters.com/article/environmentNews/idUSTRE54511M20090506>

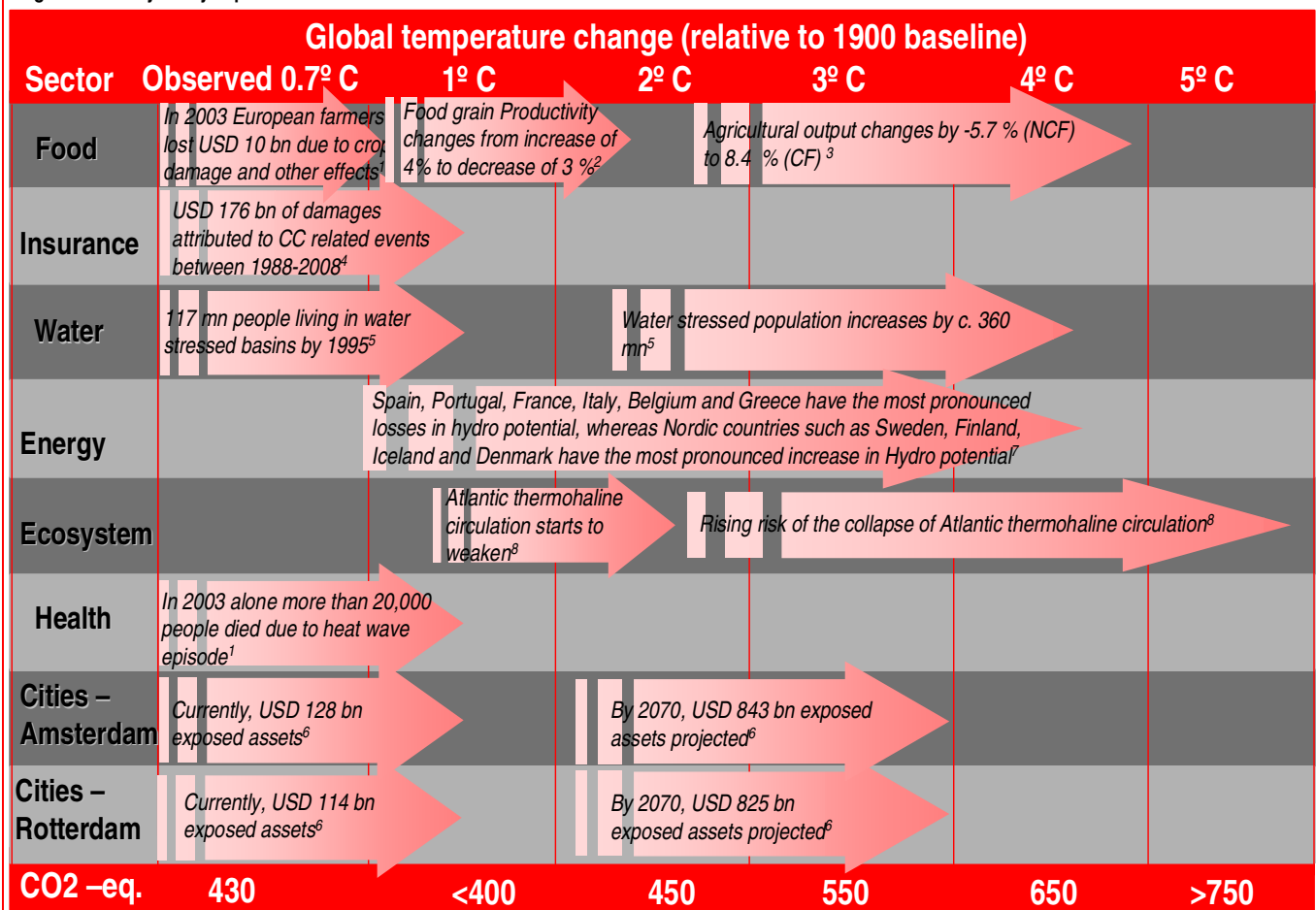
⁷⁷ Erda et al., 2007, China's National Communication

⁷⁸ <http://www.reuters.com/article/environmentNews/idUSTRE54511M20090506>

European Union

- ▶ HCVA assessment: 2nd quartile; moderately vulnerable
- ▶ Water availability should remain stable while water demand could increase by 9% by 2020
- ▶ On balance, the agricultural sector could see some positive impacts
- ▶ Climate change induced disabilities likely to increase

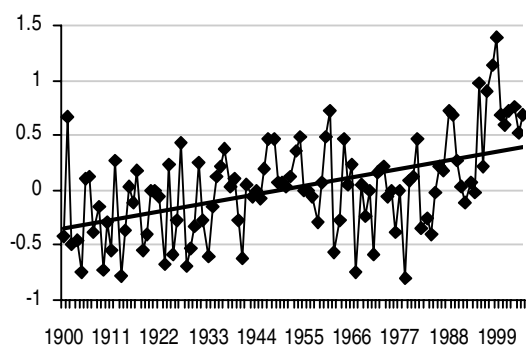
Fig 73: Summary of key impacts - the EU



Source: 1 <http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/07/17>; 2 Rosenzweig, 2003; 3 Bill Clime, 2007 (NCF-without carbon fertilisation and CF- with carbon fertilisation) 4 EMDAT database, 2008 & HSBC; 5 Anrell, 2004; 6 OECD, 2008; 7 Lehner, 2001; 8 Stern, 2006

The European Union (EU) has warmed by about 0.8°C in the last century (Fig 74)

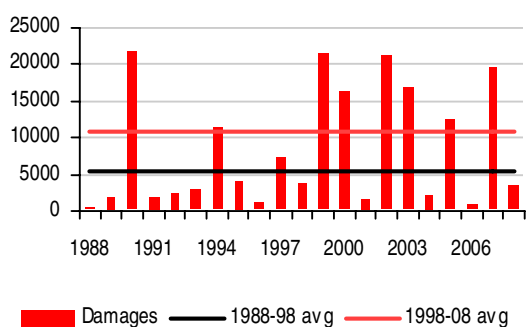
Fig 74: Temperature anomaly in Europe 1900-2005 (°C)



Source: NOAA

According to our estimates, currently the EU loses approximately USD 8.8 bn pa due to climate-related disasters (averaged over 1988 to 2008). A study of the past 20 year data suggests that the mean loss of USD 5 bn pa over 1988-1998 increased to USD 11 bn pa for the period 1998-2008. The increase is driven by population growth, rising prosperity (hence higher asset values) and increasing frequency and intensity of extreme events.

Fig 75: Losses due to climate related disasters in EU (USD mn)



Source: EMDAT database

According to the multi-model regional climate projection from IPCC AR4 (IPCC, 2007), northern Europe experiences a mean warming of 3.5 °C while southern Europe warms by 3.8 °C by 2080- 2099

relative to pre-industrial baseline.⁷⁹ While northern Europe gains in precipitation, southern Europe loses a considerable 12% of its average rainfall.

Table 19: Projected climate change over Europe by 2080-2099⁸⁰

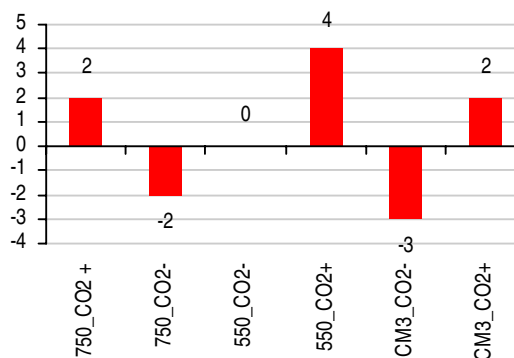
	Temperature anomaly (°C) ⁸¹	Precipitation anomaly (%) ⁸²
Northern Europe	3.5	9
Southern Europe	3.8	-12

Source: http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_Ch11.pdf

Impact on the agriculture sector

The EU is a net importer of cereals, with net imports at 16% of production. 26% of the EU's land is arable and 6 % of the labour force is employed on agriculture, although it constitutes only 2% of GDP. The eastern half of the EU is more dependent on agriculture, i.e. it has a higher share of both employment and GDP.

Fig 76: % change in cereal yield in EU by 2020e



Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

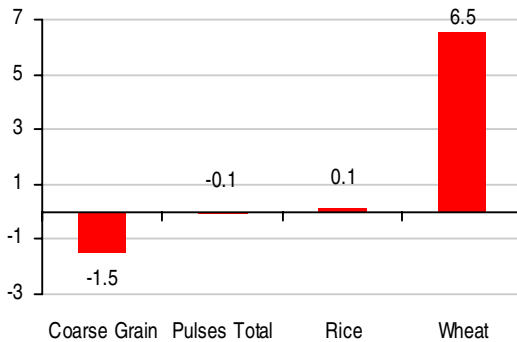
⁷⁹ We use long term estimates for the EU as recent 2020 estimates are not readily available.

⁸⁰ NEU is northern Europe and SEM is Southern Europe

⁸¹ Relative to pre-Industrial (1850)

⁸² Relative to 1990 baseline

Fig 77: Change in food grain production in EU by 2020e (Mt pa)



Source: HSBC (SEDAC)

Various climate change impact models (see Fig 76) suggest that under the carbon fertilisation assumption, cereal productivity increases by as much as 4%, and without this effect, it could decrease by about 3%.

Of the various scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

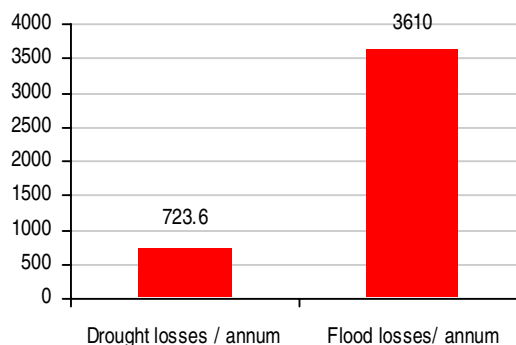
Our analysis suggests that currently the EU produces on an average 290 mn tonnes of cereals pa. Under our chosen climate change scenario, the overall production of cereals increases by 5 mn tonnes pa. The biggest increase is witnessed in wheat production, while rice and pulses remain stable and production of coarse grain falls slightly.

Currently, the EU (excluding France, Germany, Italy and the UK) produces 135 mn tonnes pa of cereals. Per capita food grain production in the EU (excluding France, Germany, Italy and UK) is currently estimated at 0.27 tonnes pa which could increase by 2.4 % if carbon fertilisation were taken into account.

Impact on the water sector

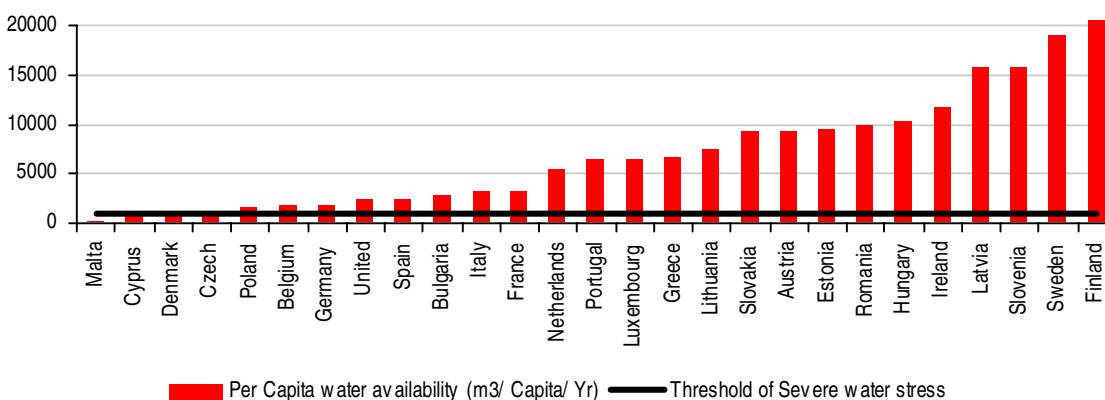
Water availability varies drastically among the member states, from less than 125 m3/ capita/ year in Malta to more than 20,000 m3/ per capita per year in Finland. The EU lives with droughts and floods simultaneously.

Fig 79: Flood and drought related average losses pa (1988-2008) in EU (USD mn)



Source: HSBC (Based on EMDAT database)

Fig 78: Per capita water availability across the EU (2008)



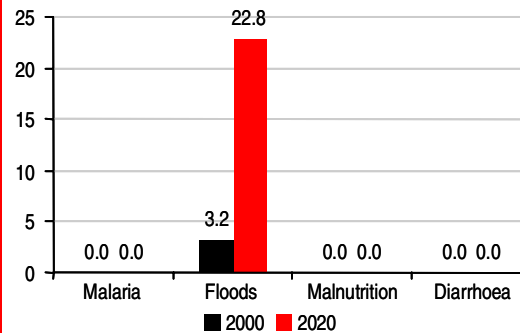
Source: FAO- AQUASTAT

We estimate that the EU loses about USD 4.3 bn pa to droughts and floods.

Impact on the health sector

The EU is seemingly free from most of the climate-related disabilities and WHO estimates suggest that it will continue to be, at least until 2020. However, floods are recurring phenomena across the EU, and these bring a number of disabilities and health hazards with them. WHO estimates from 2000 suggest that the EU suffers a loss of 3,200 DALYs⁸³ pa, mainly due to flood-related events, which is projected to increase to nearly 23,000 DALYs⁸⁴ pa by 2020. We estimate that currently the EU loses USD 122 mn pa due to climate-related disabilities which we expect to rise to USD 870 mn pa by 2020⁸⁵.

Fig 80: Disability adjusted life year losses attributable to climate change in EU for 2000 and 2020e (000)



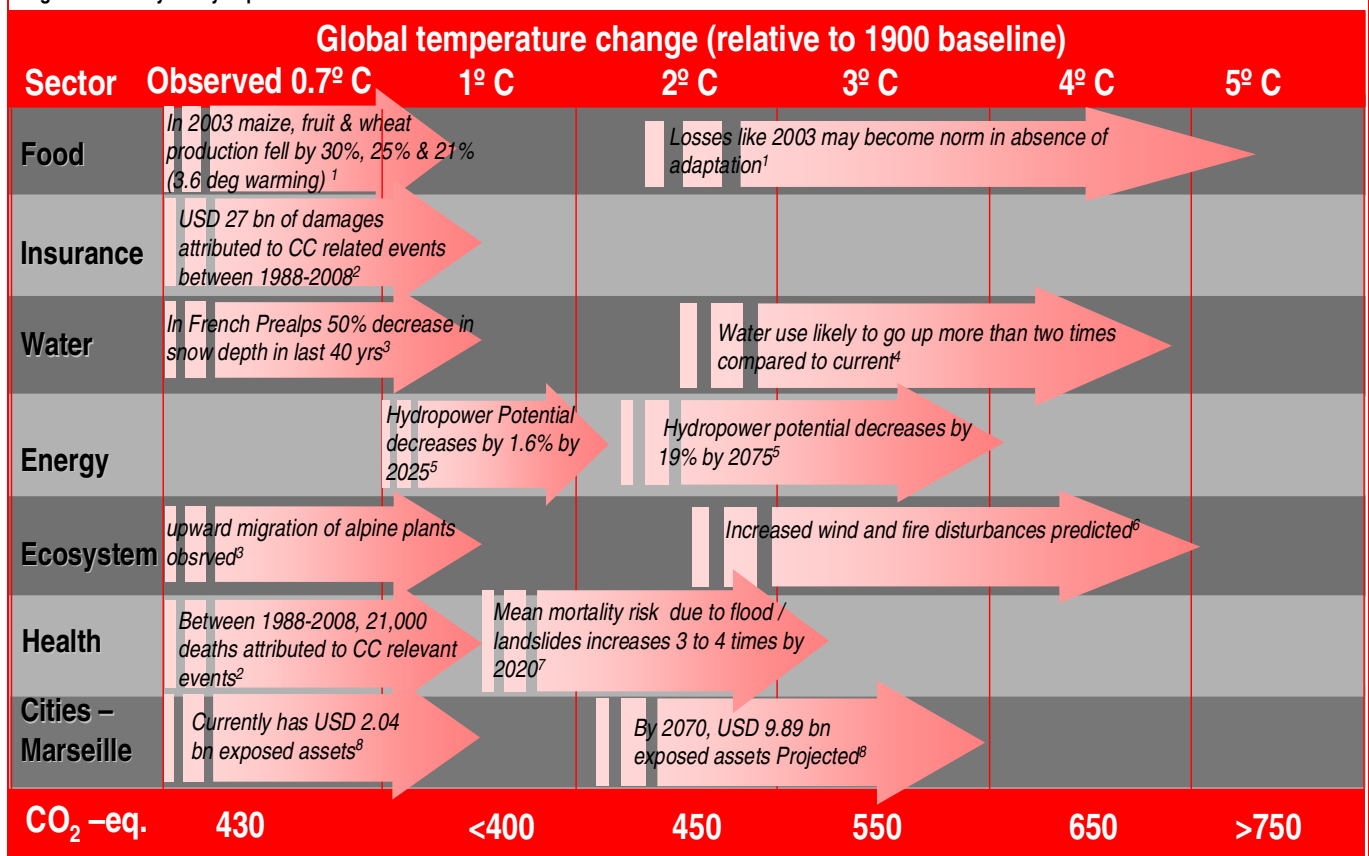
Source: HSBC (WHO, 2007)

⁸³ Includes 1,720 DALYs in France, Germany, Italy and UK
⁸⁴ Includes 12,400 DALYs in France, Germany, Italy and UK
⁸⁵ Includes losses in France, Germany, Italy and UK

France

- ▶ HCVA assessment: 2nd quartile; moderately vulnerable
- ▶ Per capita water availability could decrease by 9%
- ▶ While the agricultural sector could see some positive impacts

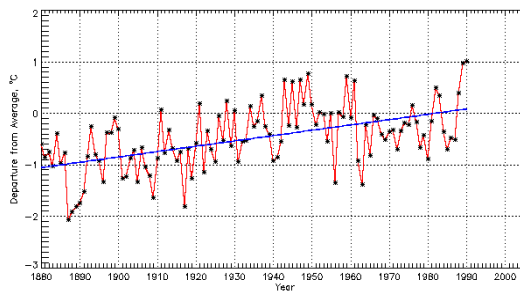
Fig 81: Summary of key impacts – France



Source: 1Battisti et al. 2009 (Science Mag); 2EDMAT database, 2008 & HSBC; 3WWF, 2007 & IPCC, 2007; 4EU, 2008; 5Lehner et al. 2001; 6Linder, 2008; 7WHO, 2007; 8OECD, 2008.

France has warmed by over 1°C (over 1890-1990) (Fig 82).

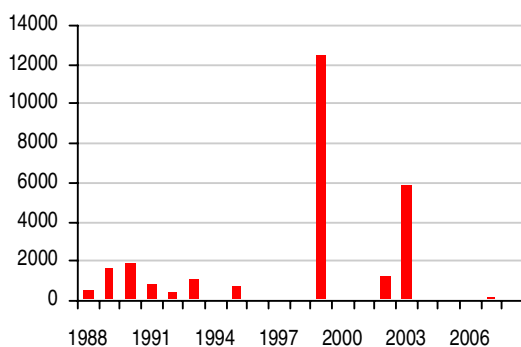
Fig 82: Temperature anomaly in France 1900-1990 (°C)



Source: NOAA

Even in the current climate, France experiences huge losses of lives as well as assets with the year 2003 being a case in point, when more than 15,000 people,⁸⁶ mostly senior citizens, lost their lives due to dehydration caused by a heat wave. The death toll across Europe was 40,000. Our analysis based on climate disaster loss data for the past two decades (1988 to 2008) suggests that currently France loses more than USD 1.3 bn pa on average to climate-related disasters. But a high level of variability is observed in annual disaster losses.

Fig 83: Losses due to climate related disasters in France (USD mn)



Source: EMDAT database

Impact on the agriculture sector

France is one of the best-endowed countries when it comes to agriculture, with some of the most

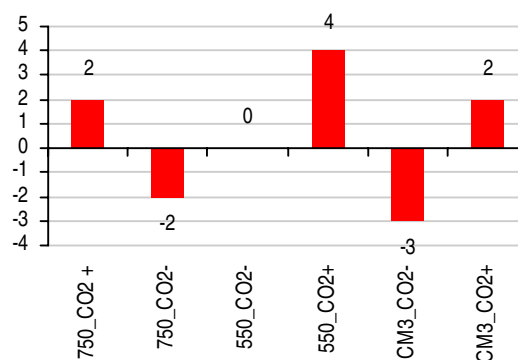
fertile lands in the world. 34% of its land is arable and although agriculture is small as a percentage of both GDP and employment, at 2% for each, it has a strong role in exports: 8.5% of France's exports come from food and drink - French wine is of course quite popular throughout the world.

Wine is France's biggest produce, after cereals. A recent report by Greenpeace⁸⁷ profiled some of the changes occurring in France's wine industry, from early harvests in Burgundy to excess sugar and acidity levels. Warmer weather might improve the quality of wine in some areas where it is less than ideal now. But this means that areas with good quality wine now might see the quality of their output change for the worse.

Heat waves have a big impact on grape harvests. More frequent heat waves would be disastrous for the wine industry. The 2003 heat wave led to a fall in production of 30%.⁸⁸

Crop impact modelling analysis suggests that changes to total cereal production in France might vary between an increase of 4% and a decrease of 3%.

Fig 84: % change in cereal yield in France by 2020e



Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

⁸⁶ <http://www.insu.cnrs.fr/f912pdf,climate-change-research-in-france-2007.pdf>

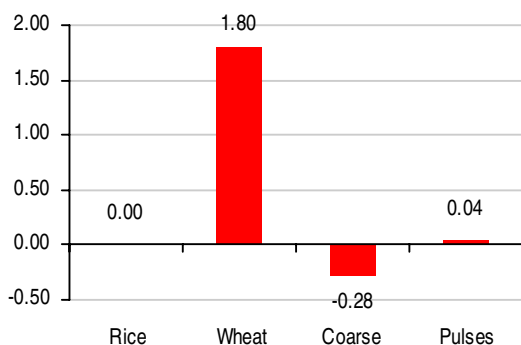
⁸⁷ *Changements climatiques et impacts sur la viticulture en France* (Sep 2009)

⁸⁸ *Ibid.*

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

Currently, France produces 65 mn tonnes of cereals. Per capita food grain production in France is currently estimated at 1.01 tonnes pa. We estimate that food grain production in France will increase by around 1.5 mn tonnes pa by 2020, a rise of about 2.8% in per capita terms. The biggest increase is estimated to be in wheat grains, with coarse grain production falling marginally, and the production of rice and pulses unaffected.

Fig 85: Change in food grain production in France by 2020 (Mt pa)



Source: HSBC (SEDAC)

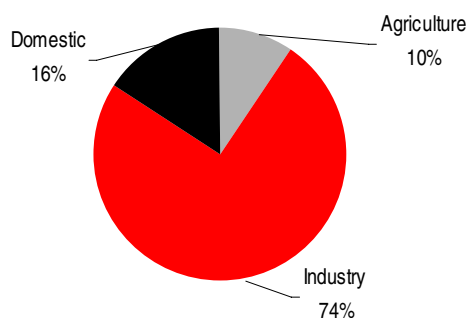
Impact on the water sector

France is well endowed with water resources with more than 3,000 m³ of water available per capita pa. By 2025, with climate change impacts, the per capita water availability is projected to decrease by 8.7%. Current per capita water demand is 676 m³ per capita pa, and this increases to 700 m³ by 2020. Per capita water use increases by 4.8% as the population stabilizes. France boasts of universal access to safe water.

However, France has a varied geography, with northern parts of France having ample water resources while the south has extensive water shortages.

As the Fig 86 suggests that more than two-thirds of water resources are currently being used mainly for industrial purposes.

Fig 86: Water use in France (2007)



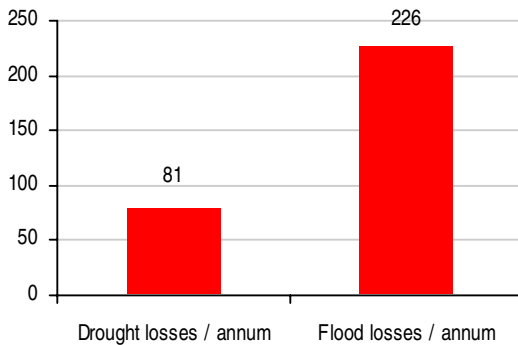
Source: World Bank Statistics

Climate induced water stress for industry is likely to be the major concern for France. For example in 2003 during the European heat wave, a leading French utility had to shut down a quarter of its 58 nuclear plants due to a shortage of water for cooling. The closures triggered price spikes of 1,300 percent and about EUR 300 mn in losses for the French utility⁸⁹, which was not allowed to pass on higher wholesale prices to end consumers.

Average flood losses are about USD 226 mn pa. Drought losses are also significant, running at an average level of USD 81 mn pa.

⁸⁹ Mitch Weiss, "Drought Could Force Nuke-Plant Shutdowns," Associated Press, January 24, 2008

Fig 87: Flood and drought related average losses pa (1988-2008) in France (USD mn)



Source: HSBC (based on EMDAT database)

Impact on the health sector

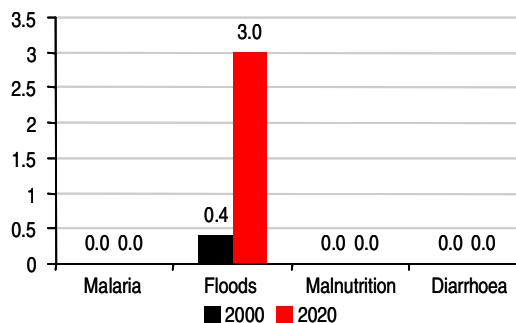
The 2003 heat wave is estimated to have caused an excess mortality⁹⁰ of 15,000 in France.⁹¹

Climate change might make heat waves like the 2003 one more common, with resultant losses.

Given that the general public is now more aware of the importance of rehydration during a heatwave, future mortality rates might be lower, but the trend towards an increasing number of heatwaves across Europe is probably going to result in a net increase in mortalities.

France suffers relatively minor health costs from climate change. Flood induced productivity loss was about 300 DALYs in 2000 and this is projected to reach around 3,000 DALYs pa by the year 2020.

Fig 88: Disability adjusted life year losses attributable to climate change in France for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

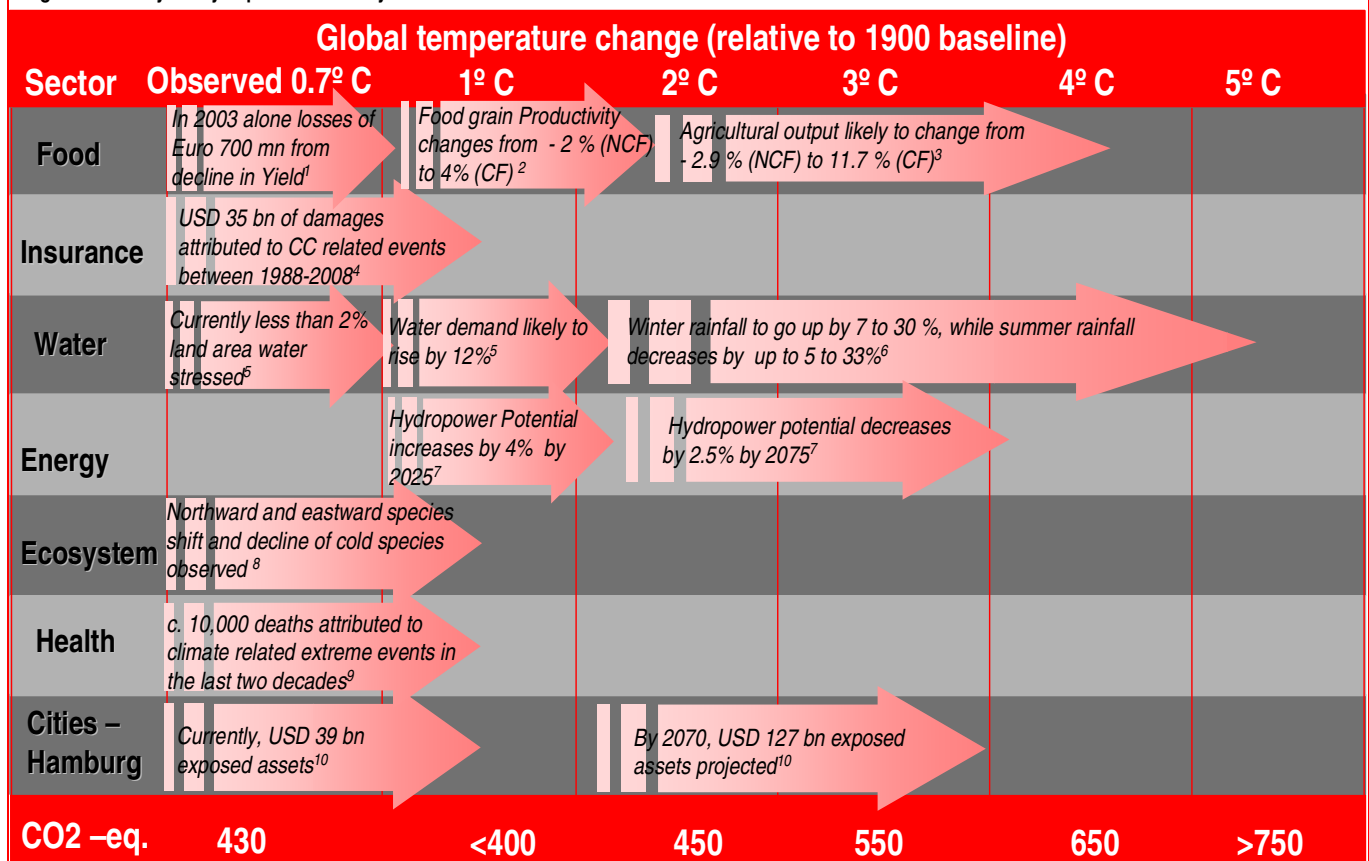
⁹⁰ Observed mortality over long term average mortality rate

⁹¹ <http://www.insu.cnrs.fr/f912pdf,climate-change-research-in-france-2007.pdf>

Germany

- ▶ HCVA assessment: 4th quartile; marginally vulnerable
- ▶ Possible gains in water availability while water demand could increase by more than 12%
- ▶ Agriculture sector could see some positive impacts, especially under the assumption of CO₂ fertilisation

Fig 89: Summary of key impacts – Germany



Source: 1EMDAT database, 2008 & HSBC; 2 Rosenweig, 2003; 3 Bill Cline, 2007 (NCF-without carbon fertilisation and CF- with carbon fertilisation)

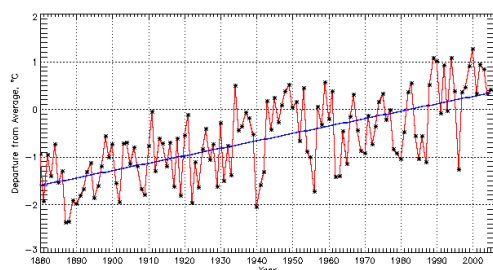
4http://sedac.ciesin.columbia.edu/es/esi/2005ESI_DataCoverage.xls?bcsi_scan_B786307563EE7842=0&bcsi_scan_filename=2005ESI_DataCoverage.xls; 5Alcamo et al., 2007; 6<http://www.scidev.net/en/news/climate-change-destroying-glaciers-in-argentina.html>; 7 WHO, 2007; 7OECD.

Germany has warmed by around 1.9 °C since 1880. (Fig 90)

The zones most vulnerable to future climate change are the north-eastern German lowland and the south-eastern basin and hills, according to an environmental report by the Potsdam Institute for Climate Impact Research.⁹²

Germany was also affected by the 2003 European heat wave. An increasing number of European heatwaves will affect much of the continent, including Germany, although France remains more susceptible. (See the France country profile in this report for details)

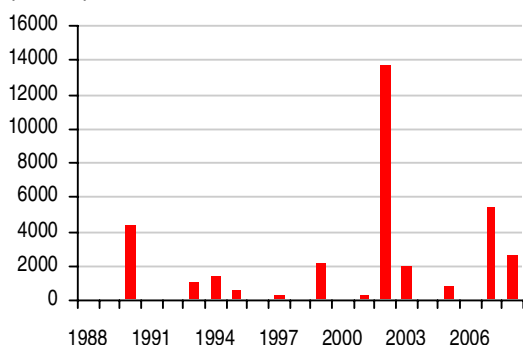
Fig 90: Temperature anomaly in Germany 1880-2005 (°C)



Source: <http://www.ncdc.noaa.gov/>

Germany has incurred only modest losses from climate-related disasters over the past two decades. The average annual loss from climate disasters is about USD 1.7 bn (Fig 91).

Fig 91: Losses due to climate related disasters in Germany (USD mn)



Source: EMDAT database

According to climate change projections,⁹³ Germany is likely to experience an increase in temperature of 0.9 to 1.8 °C by 2020. Overall rainfall is likely to decrease by 5% (national average) under an A1 scenario as illustrated in Table 20.

Table 20: Projected temperature (by 2020) and precipitation (by 2020) changes in Germany

	B1-Low	B2-Mid	A1-Mid	A2-High
Temperature ⁹⁴	0.9 to 1.0	1.2 to 1.3	1.3 to 1.4	1.6 to 1.8
Rainfall (%) ⁹⁵	-	-	-5	-

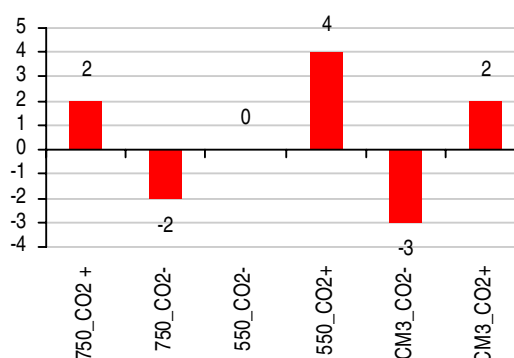
Source: Hulme, M. and Sheard, N. (1999) Climate Change Scenarios for Germany

Impact on the agriculture sector

Germany has about the same percentage of arable land as France, at 34%. It accounts for about 2% of employment, and constitutes only 0.9% of GDP; food is not a prominent export.

Crop impact modelling suggests that under a carbon fertilisation assumption food grain productivity could increase by up to 4%, while in the absence of carbon fertilisation productivity could decrease by up to 3% (Fig 92).

Fig 92: % change in cereal yield in Germany by 2020e



Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit

⁹² Climate Change in Germany, 2005

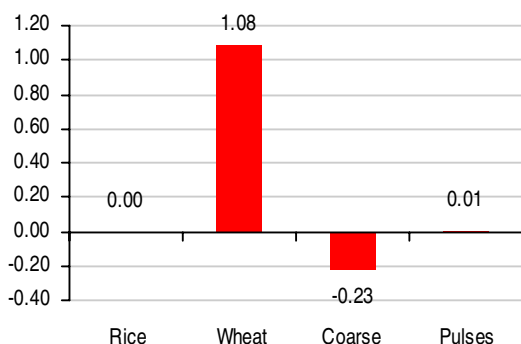
⁹³ Hulme, M. and Sheard, N. (1999) Climate Change Scenarios for Germany

⁹⁴ Relative to Pre-Industrial baseline (1850)

⁹⁵ Relative to 1961-90 baseline

of carbon fertilisation, for further analysis. Currently, Germany produces approximately 45 mt of cereals pa. We estimate that food grain production in Germany could increase by about 0.9 mn tonnes pa by 2020, a net gain of about 3% in per capita terms. The biggest increase is estimated to be in wheat production, with a minor decrease in coarse grain production.

Fig 93: Change in food grain production in Germany by 2020e (Mt pa)

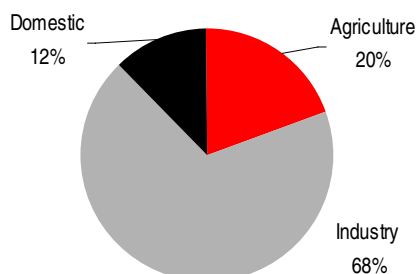


Source: HSBC (SEDAC)

Impact on the water sector

Germany has comfortable per capita water availability at around 1,900 m³/capita/ year, with universal access to safe water. Water stress is not a major concern in Germany⁹⁶ and is likely to decrease further in the next two decades as per capita water availability increases by 1.5%. However, per capita water demand is likely to increase in Germany from the current 472 m³/capita/ year to 660 m³/capita/ year in 2025. Currently, more than 68% of Germany's water withdrawal is used for industrial purposes.

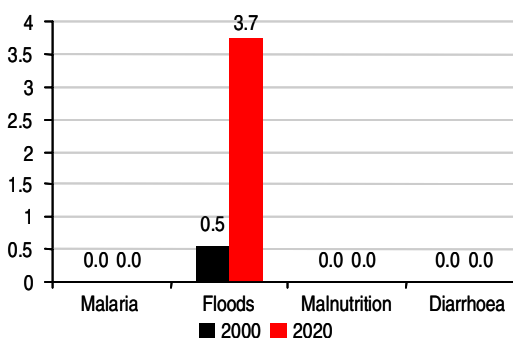
Fig 94: Water use in Germany (2007)



Source: World bank Statistics

Impact on the health sector

Fig 95: Disability adjusted life year losses attributable to climate change in Germany for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

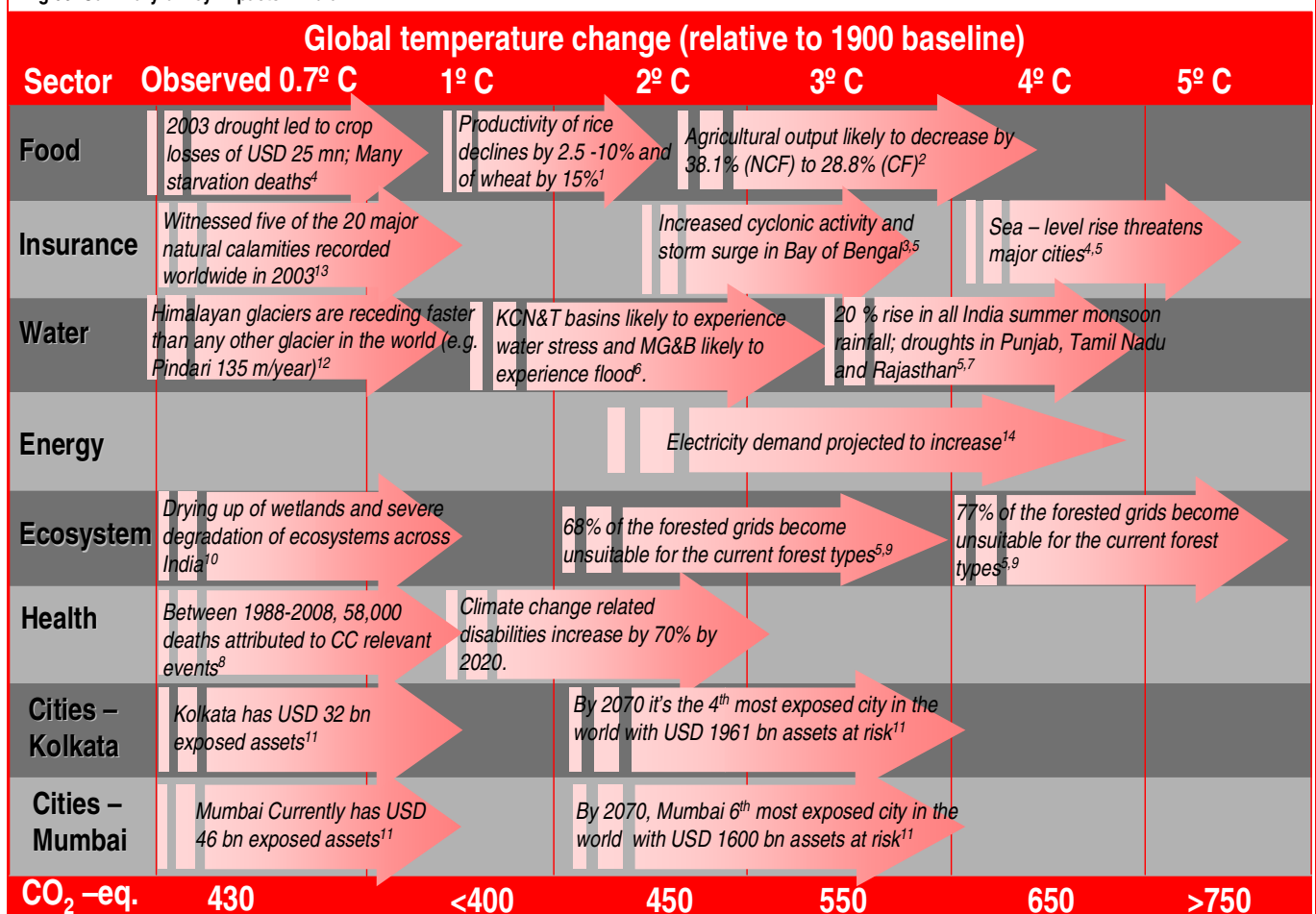
Our estimate suggests that currently floods cause more than USD 680mn worth of losses each year in Germany (averaged over the period 1988 to 2008). Floods also cause a variety of disabilities. Based on WHO projections, we estimate that in 2000, floods caused a loss of about 550 DALYs, which is about USD 24 mn pa in monetary terms. By 2020 WHO estimates suggest that more than 3,700 DALYs are likely to be lost, as a result of increased flood events, causing losses of USD 166 mn pa.

⁹⁶ http://sedac.ciesin.columbia.edu/es/esi/2005ESI_DataCoverage.xls?bcsi_scan_B786307563EE7842=0&bcsi_scan_filename=2005ESI_DataCoverage.xls

India

- ▶ HCVA assessment: 1st quartile; highly vulnerable
- ▶ By 2020 per capita water availability could decrease by 15%.
- ▶ Climate change induced disabilities could increase by 70%
- ▶ Per capita cereal production could decrease by 21 to 25%

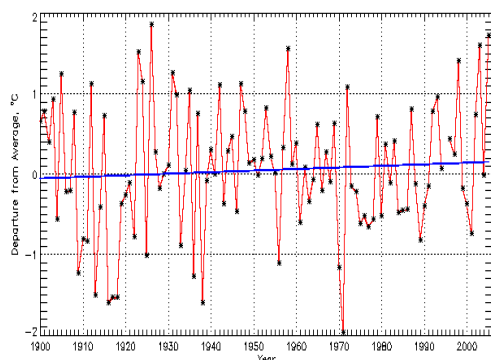
Fig 96: Summary of key impacts – India



Source: 1Lobell et al., 2008; 2 Cline, 2007 (NCF – No CO2 fertilisation effect and CF – with CO2 fertilisation effect); 3Unnikrishnan et al., 2006; 4IPCC, 2007; 5NATCOM; 6Gosain et al., 2006 (K-Krishna, C-Cauvery, N-Narmada, T – Tapi; M-Mahanadi, G-Godavari, B-Brahmani); 7Rupa kumar et al., 2006; 8EMDAT database, 2008 & HSBC; 9Ravindranath et al., 2006; 10WHO, 2007; 11OECD, 2008; 12Greenpeace, 13Development First.

India has warmed by about 0.2°C since 1900. Fig 97 shows a high degree of variability around the mean, compared to other G-20 countries.

Fig 97: Temperature anomaly in India 1900-2005 (°C)

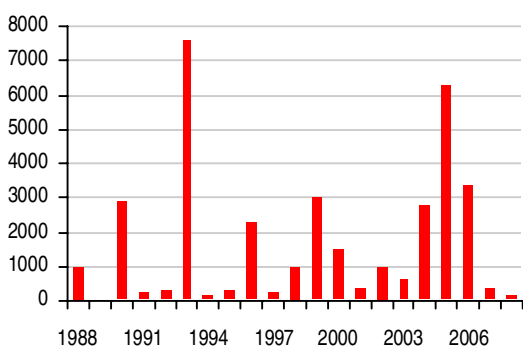


Source: NOAA

Even in the current climate India experiences huge loss of lives as well as assets due to climate-related disasters (Fig 98). Our analysis based on disaster loss estimates for the last two decades (1988 to 2008) suggest that India loses USD 1.76 bn pa due to climate change related disasters.

In this highly populated and diverse country, in the event of climate change, the losses are expected to rise further. Fig 96 summarises some of the key impacts India could face.

Fig 98: Losses due to climate related disasters in India (USD mn)



Source: EM-DAT database

According to climate change projections from the regional climate model of the Hadley Centre (HadRM3), India is likely to experience a 3.3 to

5.3 °C rise in temperature by 2085. Overall rainfall is likely to increase by 20%. However, Tamil Nadu, Rajasthan and Haryana are likely to experience a decrease in rainfall under the B2 as well as the A2 scenarios (Table 21).

Table 21: Projected temperature (by 2085) and precipitation (by 2085) changes in India

	2085	
	A2	B2
Temperature ⁹⁷ (°C)	3.3 to 5.3	2.8 to 4.3
Rainfall ⁹⁸	20 % rise	20 % rise

Source: Rupa kumar et al., 2006

We estimate India to be the most vulnerable to the impacts of climate change among the G-20 nations.

Fig 96 describes the impact of climate change on India with increasing temperature and GHG concentrations in the atmosphere. Major concerns⁹⁹ include the possible disappearance of large glaciers in the Himalayas and a rise in summer monsoon rainfall, leading to increased flooding in flood-prone areas. Drought-prone regions of Rajasthan, Punjab, and Tamil Nadu are likely to experience shortages of rainfall, leading to a worsening of their condition.

Frequency and intensity of tropical cyclones, especially in the Bay of Bengal, are projected to increase particularly in the post-monsoon period.¹⁰⁰ With a large population living in low lying coastal areas India is particularly vulnerable. However, there is a lot of uncertainty over the impact of climate change on the economy.

A recent World Bank report¹⁰¹ concluded that a global warming of 2°C above pre-industrial temperatures — the minimum the world is likely to experience — could result in permanent reductions in GDP of 4 to 5% for South Asia.

⁹⁷ Relative to pre-industrial baseline (1850)

⁹⁸ Relative to 1960-1990 baseline

⁹⁹ NATCOM, 2004; Current Science Special issue, 2006, Stern Review, 2006 and IPCC, 2007

¹⁰⁰ Unnikrishnan et al., 2006

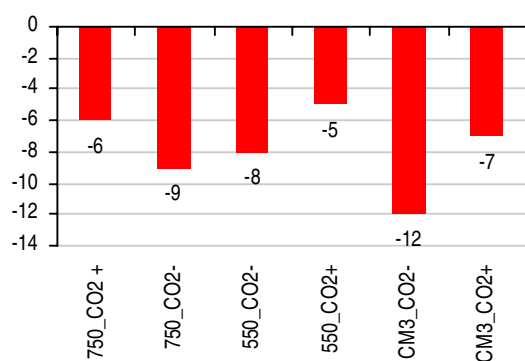
¹⁰¹ World Bank "The World Development Report 2010: Development and Climate Change"

Further, according to the projections from the PAGE v.4.1 model, India loses USD 63bn by 2020, which comes close to 6.3% of India's current GDP.

Impact on the agriculture sector

Currently, India produces 250 mn tonnes of cereals pa. India is a net exporter of food grains. 54% of the country's land is arable. While agriculture accounts for about 58% of employment, it represents 18.3% of GDP (year ending Mar 2007) and over 11.3% of exports. Climate change impact modelling suggests a negative impact from climate change on India under both the carbon fertilisation and no carbon fertilisation scenarios. Under the carbon fertilisation assumption, the cereal yield decreases by up to 12% while under the carbon fertilisation assumption the yield decreases by only up to 5%.

Fig 99: % change in cereal yield in India by 2020e

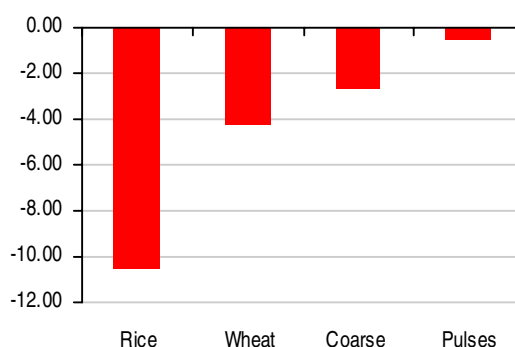


Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

Under this scenario, food grain production in India could decrease significantly, by about 18 mn tonnes pa. The biggest decrease is estimated to be in rice production followed by wheat and coarse grains.

Fig 100: Change in food grain production in India by 2020e (Mt pa)



Source: HSBC (SEDAC)

Per capita food grain production in India is currently estimated at 0.21 tonnes pa, which is estimated to decrease by 21 % even when carbon fertilisation is taken into account and by 25% when the effect of carbon fertilisation is ignored.

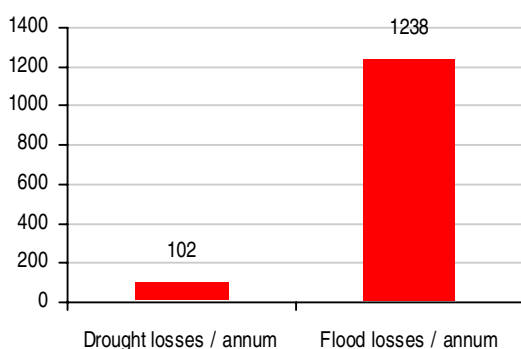
Impact on the water sector

In India, current per capita water availability is approximately 1,632 m3/capita/year (2007) which is comfortably above the 1,000 m3/ capita/year threshold below which a country is defined as water stressed¹⁰². However, water resources in India are unevenly distributed. Parts of eastern India are water abundant, but north-western and south-central parts of the country face acute water shortages. Floods and drought co-exist in India. According to the disaster database maintained by EMDAT, India lost on average more than a billion USD each year to flood-related disasters and another USD 102 mn pa to drought during the last two decades.

102

http://earthtrends.wri.org/maps_spatial/maps_detail_static.php?map_select=265&theme=2

Fig 101: Flood and drought related average losses pa (1988-2008) in India (USD mn)



Source: HSBC (Based on EMDAT database)

Current per capita water availability is projected to decrease by 15% bringing increased water stress by 2025. India already has a huge water stressed population¹⁰³, which is likely to further increase by 2025¹⁰⁴.

Melting water towers in the Himalayas

The Himalayan glaciers have been retreating more rapidly than glaciers elsewhere in the world. This retreat is well documented through remote sensing. Satellite imagery reveals average annual decreases in glacier surface area over the Tibetan plateau of 0.17, 0.19 and 0.77 km² per year for the time periods 1976–90, 1990–1999, and 1999–2003, respectively.

New research suggests that some large geographic regions, like Northern India, where the water supply depends on melting snow or ice for most of the year, are predicted to suffer severe consequences as a result of warming. Negative impacts including seasonal shifts in water supply, flood risks, and increased variability in precipitation will eventually offset benefits incurred by short-term increases in runoff from glacier melt¹⁰⁵.

The Himalayan ice fields are a critical resource for one sixth of the world's population because they provide dry season runoff for major rivers. More specifically, the region forms the headwaters of the Indus, Ganges, and Brahmaputra Rivers in the south-western Himalayas. The Indus and Ganges Rivers currently have little outflow to the sea during the dry season and are in danger of becoming seasonal rivers due to climate change and increased water demand. The surface area of glaciers across the Tibetan Plateau is projected to decrease from 500,000 km² measured in 1995 to 100,000 km² in 2030, thereby threatening regional rivers and water resources¹⁰⁶.

Impact on hydropower

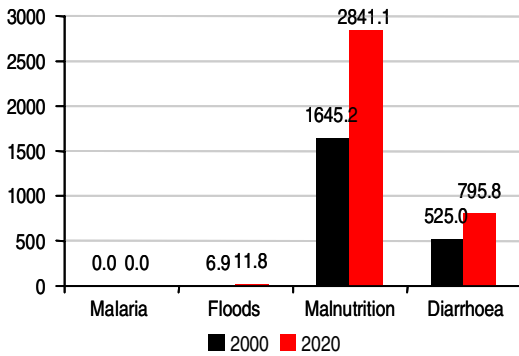
No national level estimates are available as to how the projected climate change might impact hydropower generation in India. However, a case-study carried out by the World Bank in 2007 suggests that at a hydropower station named as Vishnugad Pipalkoti¹⁰⁷ annual hydro electricity generation would increase from 1,768 GWh to 1,898 GWh by 2025 in the event of climate change. The study further suggests that the average monthly available capacity could increase from 212 MW to 280 MW in 2025¹⁰⁸. This increased hydro potential in the short term (until 2025) arises as a result of increased runoff due to greater glacial melting. This is by definition not sustainable into the future, and is likely to see a precipitous drop once the glacier melt stops.

¹⁰³ Esty, Daniel C., Marc Levy, Tanja Srebotnjak, and Alexander de Sherbinin (2005). *2005 Environmental Sustainability Index: Benchmarking National Environmental Stewardship*. New Haven: Yale Center for Environmental Law and Policy
¹⁰⁴ <http://www.usf.uni-kassel.de/watclim/results.htm>
¹⁰⁵ Cruz et al., 2007

¹⁰⁶ <http://www.agu.org/pubs/crossref/2008/2008GL035556.shtml>
¹⁰⁷ On the Alaknanda river in Uttarakhand
¹⁰⁸ The World Bank "Estimating Global Climate Change Impacts on Hydropower Projects: Applications in India, Sri Lanka and Vietnam" Policy Research Working Paper, 2344

Impact on the health sector

Fig 102: Disability adjusted life year losses attributable to climate change in India for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

WHO estimates that about 7,000 DALYs were lost in India due to flood induced disability in 2000. Malnutrition and diarrhoea caused much bigger losses at 1.6 mn and 0.52 mn DALYs respectively in the same year.

In a warmer climate, these disabilities are projected to rise further, with flood induced losses likely to reach 11,000 DALYs per year and malnutrition- and diarrhoea-related DALY losses likely to reach 2.8 mn and 0.8 mn respectively by the year 2020.

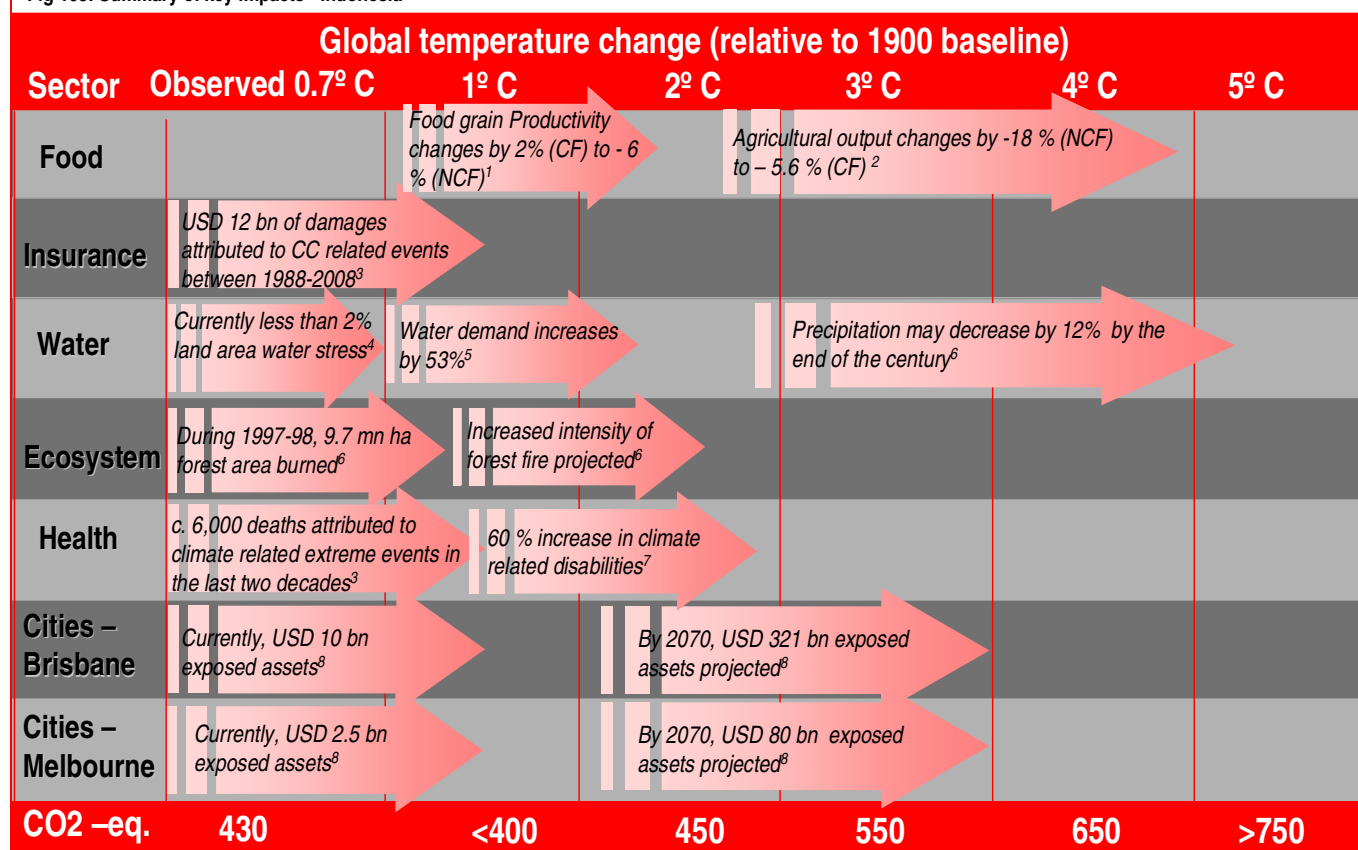
We estimate that currently climate change related disabilities in the form of flood disabilities, malnutrition and diarrhoea, caused an estimated loss of USD 2.3 bn in 2000 and this loss is estimated to rise to USD 3.9 billion in 2020.¹⁰⁹

¹⁰⁹ Per capita income assumed at USD 1068, which is the current GDP.

Indonesia

- ▶ HCVA assessment: 1st quartile; highly vulnerable
- ▶ Per capita water availability could decrease by 20% while per capita water demand could increase by 19%.
- ▶ Climate change related disabilities could increase by 70%
- ▶ On balance, the agricultural sector could see some positive impacts especially under the carbon fertilisation scenario

Fig 103: Summary of key impacts - Indonesia

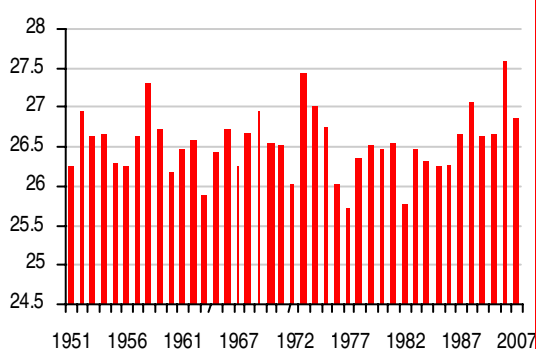


Source: 1 Rosenweig, 2003; 2 Bill Clime, 2007 (NCF-without carbon fertilisation and CF- with carbon fertilisation) 3 EMDAT database, 2008 & HSBC; 4 <http://sedac.ciesin.columbia.edu/es/downloads.html#data>; 5 <http://www.usf.uni-kassel.de/watchlin/>; 6 http://assets.panda.org/downloads/inodesian_climate_change_impacts_report_14nov07.pdf; 7 WHO, 2007; 8 OECD, 2008.

Indonesia is the 3rd largest emitter of GHGs, when land use change (rainforest converted to farmland) and emissions from peat land degradation are considered, behind the US and China.¹¹⁰ In Indonesia, the observed temperature has increased by 0.3°C since 1900.¹¹¹ Fig 104 shows the annual average temperature at Kupang met station.

Currently, Indonesia loses USD 590 mn pa to climate related disasters (average over 1998-2008). However, there is a huge fluctuation in the quantum of loss pa. In 1997, Indonesia lost more than USD 8 bn to climate-related events - the 1997-98 El Niño meant that a large part of the country suffered from severe drought, resulting “in a huge shortfall in rice production that necessitated the import of over five mn metric tons of rice to ensure food availability to the economically weaker sections of the society”¹¹². Dry weather could increase the incidence of forest fires, as dry leaves could ignite and burn more easily. The effects of large-scale forest fires during 1997-98 were unprecedented, damaging more than 9.7 mn ha of forest area.¹¹³ However, since then there has no major event of similar magnitude.

Fig 104: Annual avg temperature (°C) in Indonesia (Kupang station)



Source: <http://data.giss.nasa.gov/work/csci/STATIONS/>

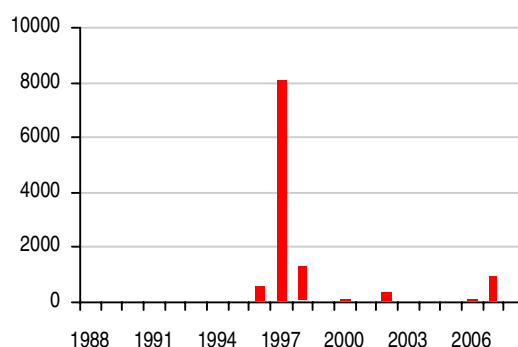
¹¹⁰ *Indonesia and Climate Change: Current Status and Policies*, by PT Pelangi Energi Abadi Citra Enviro (PEACE).

¹¹¹ *Ibid.*

¹¹² <http://www.ccb.uicar.edu/un/indonesia.html>

¹¹³ Asian Development Bank (ADB) and National Development Planning Agency (APPENAS), 1999: *Causes, Extent, Impact and Cost of 1997-98 Fires and Drought*.

Fig 105: Losses due to climate related disasters in Indonesia (USD mn)



Source: EMDAT database

The air temperature in Indonesia is projected¹¹⁴ to increase at a rate between 0.1 °C/ decade for the B1-low scenario and 0.3 °C/decade for the A2-high scenario. Annual average precipitation is expected to increase across most of Indonesia.

Table 22: Projected temperature (by 2020) and precipitation (by 2080) changes in Indonesia

	B1-Low	B2-Mid	A2
Temperature by 2020 ¹¹⁵ (°C)	0.9	1.2	1.7
Rainfall (%) for 2080 ¹¹⁶	4 to 9	6 to 14	7 to 16

Source: Hulme, M. and Sheard, N. (1999) *Climate Change Scenarios for Indonesia*

Impact on the agriculture sector

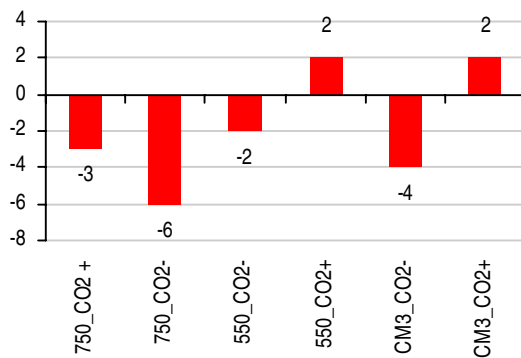
Currently, Indonesia produces 64 mn tonnes of cereals annually. Indonesia has about 13% arable land, similar to the other Asian island nation in the G-20, Japan. However the economy is much more agrarian, with agriculture making up 13% (vs. 1.5% for Japan) of GDP and 42% (4%) of employment. Crop impact modelling studies suggest that under different scenarios of climate change, changes in food grain productivity in Indonesia could vary from a decrease of 6 % to an increase of 2%.

¹¹⁴ Study by Mike Hulme and Nicola Sheard

¹¹⁵ Relative to Pre-Industrial baseline (1850)

¹¹⁶ Relative to 1960-90 baseline

Fig 106: % change in cereal yield in Indonesia by 2020e



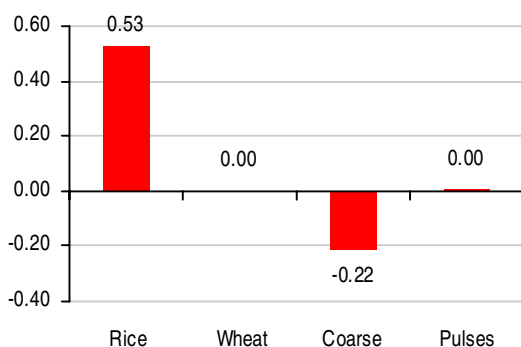
Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

Under this particular scenario, the overall yield of cereals could increase by 2% by 2020.

We estimate that under this particular scenario food grain production in Indonesia could increase by 0.31 mt pa. The biggest increases take place in rice production mainly due to increased precipitation while coarse grain production could decrease modestly. Per capita food grain production in Indonesia is currently estimated at 0.28 tonnes per year which could decrease by 11.7% even when carbon fertilisation is taken into account.

Fig 107: Change in food grain production in Indonesia by 2020e (Mt pa)



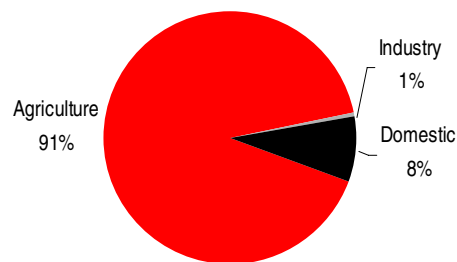
Source: HSBC (SEDAC)

Impact on the water sector

Indonesia has huge per capita water availability at 12,000 m3/capita/year (2007). Per capita water availability is projected to decrease by 20% by 2025. Currently, per capita water demand is only 391 m3/capita/year. About 80% of the population has access to safe water. Indonesia uses water resources mainly in agriculture.

Currently, Indonesia has little water stress¹¹⁷. As precipitation is likely to increase across Indonesia, water availability stands to increase¹¹⁸.

Fig 108: Water use in Indonesia (2007)



Source: World Bank statistics

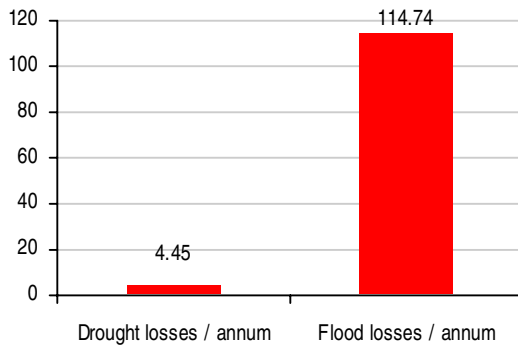
By 2020, the population is projected to rise by about 10%, to reach an estimated 254mn¹¹⁹. However water use is set to go up by 18.8%.

¹¹⁷ <http://www.usf.uni-kassel.de/watclim/results.htm>
¹¹⁸

http://sedac.ciesin.columbia.edu/es/esi/2005ESI_DataCoverage.xls?bcsi_scan_B786307563EE7842=0&bcsi_scan_filename=2005ESI_DataCoverage.xls

¹¹⁹ UN Economic and Social Affairs estimate

Fig 109: Flood and drought related average losses pa (1988-2008) in Indonesia (USD mn)



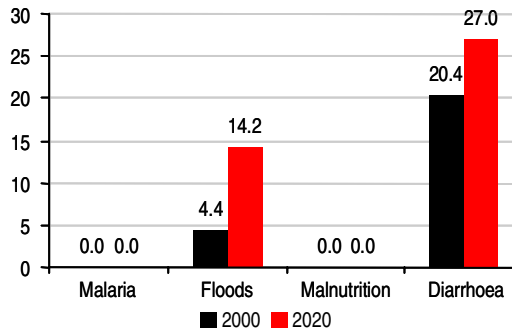
Source: HSBC (based on EMDAT database)

An excess of water brings its own miseries. For example, floods are a major hazard in Indonesia causing more than USD 114 mn in estimated annual losses (averaged over the last two decades 1988 to 2008).

Impact on the health sector

WHO estimates suggest that currently diarrhoea is the biggest climate related disability faced by Indonesia, followed by floods. WHO reports that that 25,000 DALYs were lost in 2000 due to climate related disabilities causing a loss of USD 56 mn pa to Indonesia. Flood and diarrhoea related disability losses are projected to increase in a changed climate, being estimated to reach up to 41,000 DALYs by 2020, taking the cost to USD 93 mn pa by 2020 at 2008 prices.

Fig 110: Disability adjusted life year losses attributable to climate change in Indonesia for 2000 and 2020e (000)

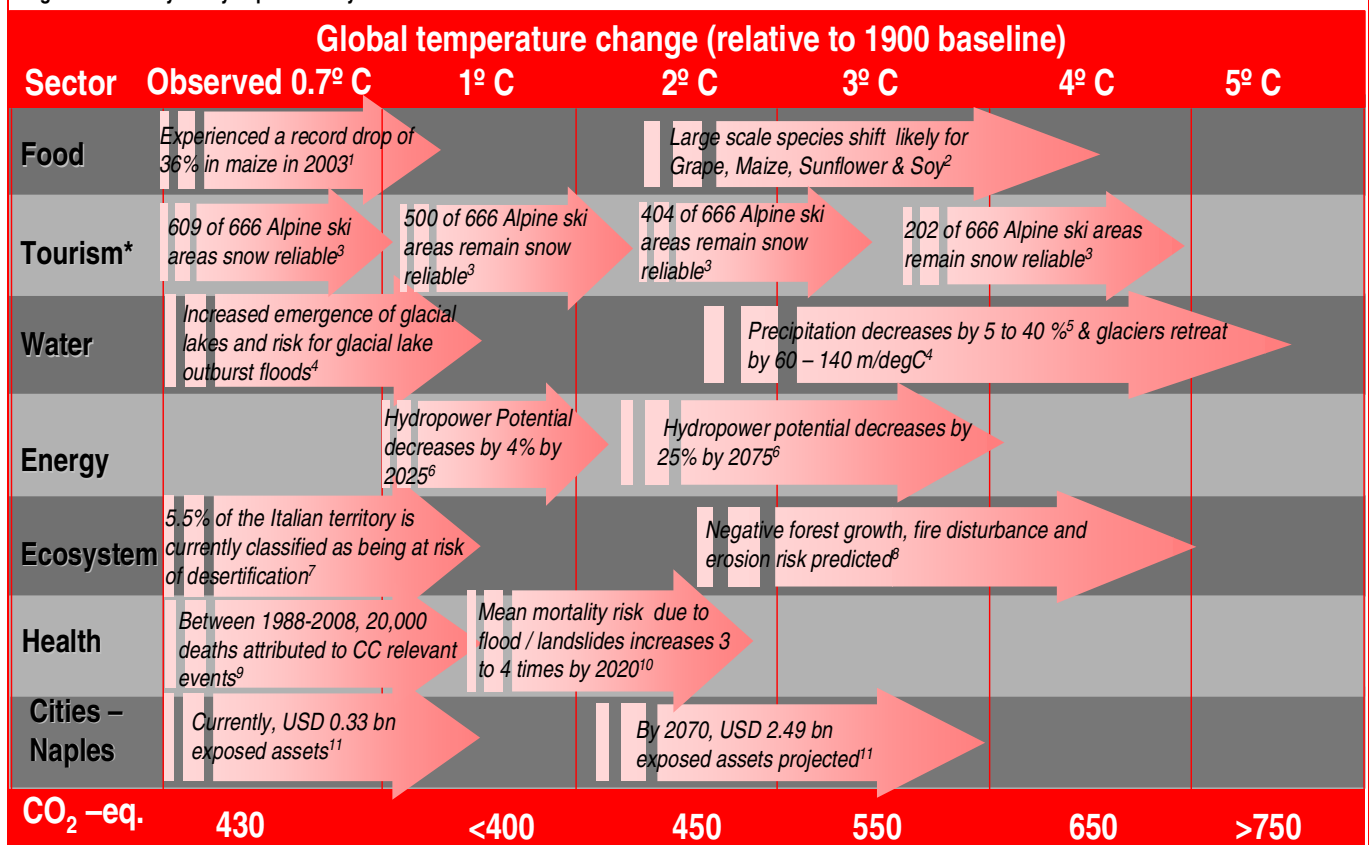


Source: HSBC (WHO, 2007)

Italy

- ▶ HCVA assessment: 3rd quartile; less vulnerable
- ▶ Water availability as well as demand should remain stable
- ▶ Potential manifold increase in climate change induced health losses
- ▶ While the agricultural sector could see some positive impacts

Fig 111: Summary of key impacts – Italy

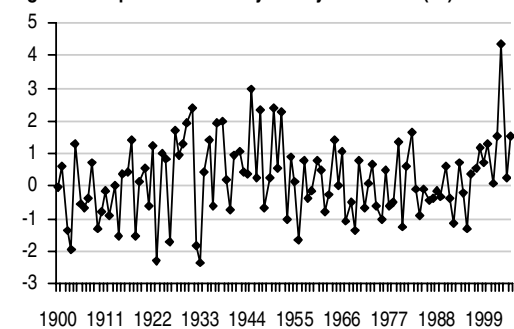


Source: 1Battisti et al. 2009 (Science Mag); 2http://www.ibimet.cnr.it/Staff/baldi/presentation-at-conferences/Baldi_01Agosto2008.pdf; 3OECD, 2007; 4WWF, 2007 & IPCC, 2007; 5EU, 2007; 6Lehner et al., 2001; 7Fondazione Eni Enrico Mattei, 2008; 8Linder, 2008; 9EDMAT database, 2008 & HSBC; 10WHO, 2007; 11OECD, 2008. * Estimates include ski areas in Austria, France, Germany, Italy and Switzerland.

Italy warmed by about 1.5°C in the last century. (Fig 112). A spike in temperature can be seen in 2003, due to the European heat wave.

With climate change (Fig 111), Italy is susceptible to Alpine glacier melting at temperatures above 1.5°C, while also see lower precipitation.

Fig 112: Temperature anomaly in Italy 1900-2005 (°C)

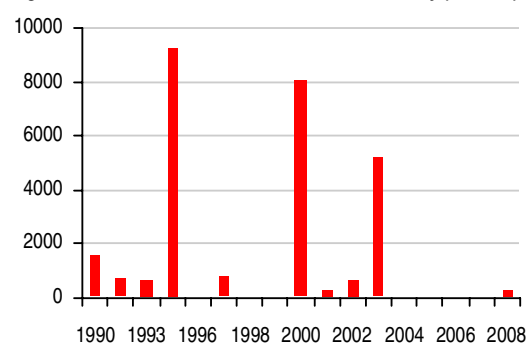


Source: NOAA

For Italy, disaster data is not consistently available for all years. However it is clear from Fig 113 that Italy is vulnerable to climate related events, but no trend is identified.

In Nov 1994, Italy lost more USD 9 bn worth of assets to floods, and again in Oct 2000, floods cost USD 8 bn of losses. The 2003 heatwave caused a loss of USD 4.4 bn. A WHO¹²⁰ study estimates that mean mortality risk due to floods and landslides could increase by 3-4x by 2020.

Fig 113: Losses due to climate related disasters in Italy (USD mn)

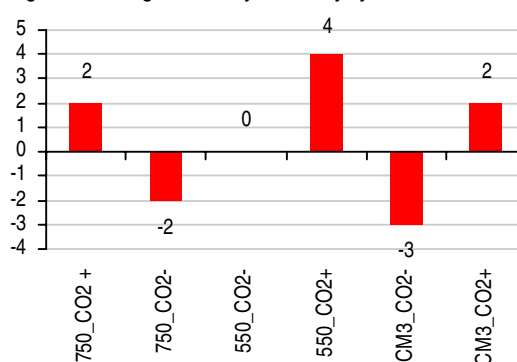


Source: EMDAT database

Impact on the agriculture sector

Italy has 26% arable land, in line with the EU27 average. The size of the agricultural sector is similar to France at 2% of GDP, though it employs twice as high a percentage of the workforce, i.e. 4%. In the short term (2020), Italy gains modestly in terms of productivity. Crop impact modelling suggests that changes in food grain productivity in Italy could vary from a decrease of 2 % to an increase of 4%. Note, however, that these are the results of a Europe wide study; country specific estimates for Italy are not available.

Fig 114: % change in cereal yield in Italy by 2020e



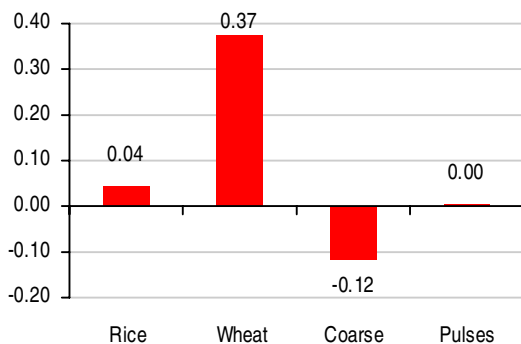
Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with co2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

This scenario suggests that food grain production in Italy could increase by a modest 0.3 mn tonnes pa.

¹²⁰ WHO, 2007

Fig 115: Change in food grain production in Italy by 2020e (Mt pa)



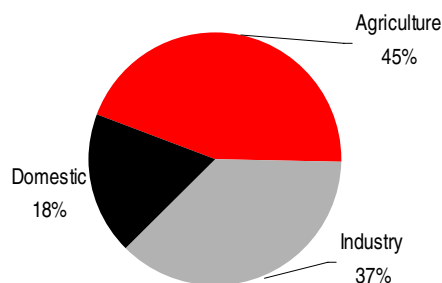
Source: HSBC (SEDAC)

Currently, Italy produces 21 mn tonnes of cereals pa. Per capita food grain production in Italy is currently estimated at 0.35 mn tonnes pa which could increase by 4.2%, when carbon fertilisation is taken into account.

Impact on the water sector

Italy has adequate water supply with current per capita water availability at approximately 3,240 m³/capita/year (2007) with universal access to safe water. Per capita water availability is projected to decrease by 1.9% by 2025. Currently, per capita water demand is 770 m³/capita/year (2000¹²¹), which is likely to remain relatively unchanged by 2025. Italy is an interesting case among the developed world, with the bulk of its water supply going to agriculture. Compared to other Western European countries with similar levels of water availability, the higher proportion of agriculture puts a bigger demand on water supplies, as agriculture is a voracious user of water.

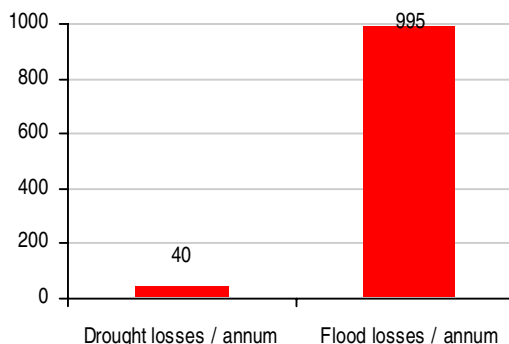
Fig 116: Water use in Italy (2007)



Source: World Bank statistics

Italy is currently faced with both drought and flood hazards - currently more than USD 40 mn are lost pa due to drought hazards, whereas floods cause much more severe losses of about USD 1 bn pa (averaged over 1988 to 2008).

Fig 117: Flood and drought related average losses pa (1988-2008) in Italy (USD mn)



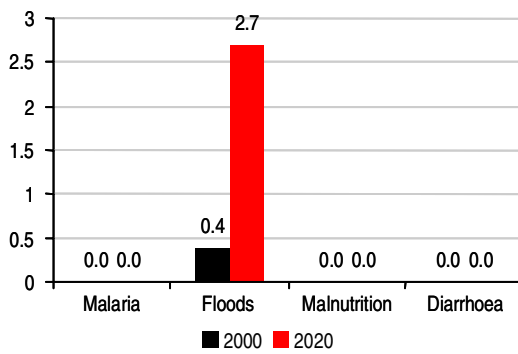
Source: HSBC (Based on EMDAT database)

Impact on the health sector

Italy, like other developed countries, is not much exposed to sanitation-related illnesses such as diarrhoea, or development-related issues such as malnutrition. However, floods are a recurring hazard. Flood induced disabilities account for a loss of 384 DALYs pa by 2000 WHO estimates, and this may increase to more than 2,700 DALYs pa by 2020.

¹²¹ Latest year for which this estimate is available

Fig 118: Disability adjusted life year losses attributable to climate change in Italy for 2000 and 2020e (000)



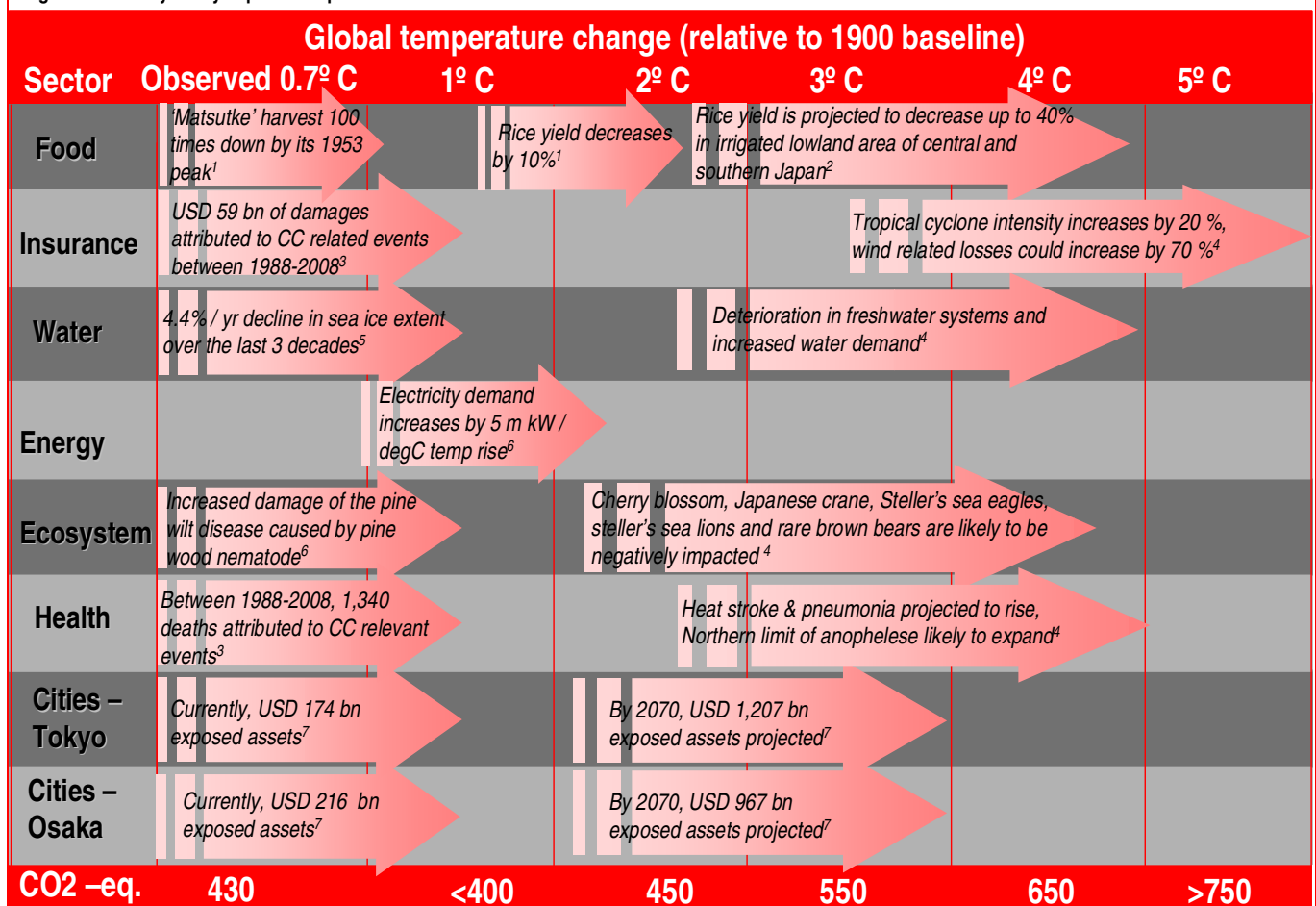
Source: HSBC (WHO, 2007)

We estimate that currently climate change related disabilities cause a loss of USD 15 mn pa which could increase to USD 104 mn pa by 2020.

Japan

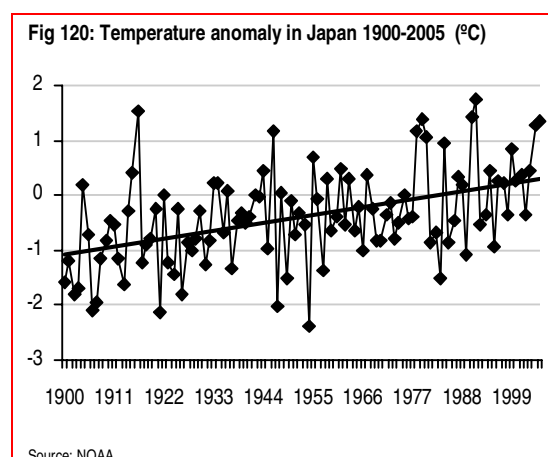
- ▶ HCVA assessment: 2nd quartile; moderately vulnerable
- ▶ Per capita water availability could increase by 8% while at the same time water demand could go down by 12%.
- ▶ With increased water the agricultural sector could see some positive impacts

Fig 119: Summary of key impacts – Japan



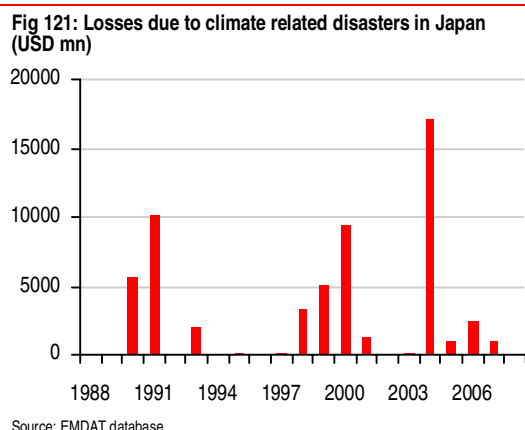
Source: 1http://www.impacts.jp/en/agriculture.html; 2WWF, 2007 (IPCC, 2007); 3EMDAT database, 2008 & HSBC; 4WWF, 2008 (Nippon Changes); 5EORC, 2008 (http://www.eorc.jaxa.jp/en/imgdata/topics/2008/tp080220.html); 6NATCOM (Japan), 2006; 7OECD, 2008; 8Rosenweig et al., 2003

Japan has warmed by more than 1.2°C¹²² in the last century (Fig 120). Climate change impacts Japan in a variety of ways, and the key impacts are illustrated in Fig 119.



We estimate that on an average Japan loses about USD 3 bn pa to climate related disasters. However averages do not reveal the complete story.

In 2004, Japan lost more than USD 17 bn to climate related events - it was hit by ten tropical cyclones, “a record number that was unequalled throughout the previous century”¹²³. If temperatures rise over 3.5°C, tropical storm intensity is estimated to increase by 20%, with wind-related losses rising by over 70%, according to a 2008 WWF report.¹²⁴



According to regional climate change projections, Japan could warm by up to 1.7 °C by the 2020s.

Table 23: Projected temperature (by 2020) changes in Japan¹²⁵

	B1-Low	B2-Mid	A1-Mid	A2-High
Temperature (°C)	0.9	1.2	1.3	1.7

Source: <http://www.cru.uea.ac.uk/~mikehl/research/wwf.japan.pdf>

The islands of Japan get wetter under all scenarios. However, for all seasons and for all time periods considered, the increases are relatively modest.

Impact on the agriculture sector

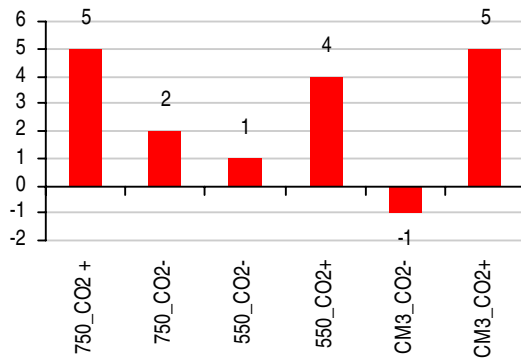
12% of Japan’s land is arable, and intensive terrace farming is widely practised. Agriculture employs 4% of the workforce and makes up 1.5% of GDP. We note, however, that Japan usually imports more than 70% of its annual grain consumption¹²⁶, so domestic prices are more likely to be affected by the global supply-demand situation, and the level of government subsidies, than by domestic production levels.

Crop modelling from SEDAC suggests that in the short term, climate change generally benefits Japanese agriculture and the cereal productivity change could vary from a negative of 1% to a positive of 5% under different scenarios.

¹²² <http://www.cru.uea.ac.uk/~mikehl/research/wwf.japan.pdf>
¹²³ http://www.munichre.com/publications/302-04321_en.pdf
¹²⁴ WWF 2008, *Nippon Changes*

¹²⁵ Relative to Pre-Industrial (1850)
¹²⁶ Earth Policy Institute, 2007, compiled from US Department of Agriculture

Fig 122: % change in cereal yield in Japan by 2020e

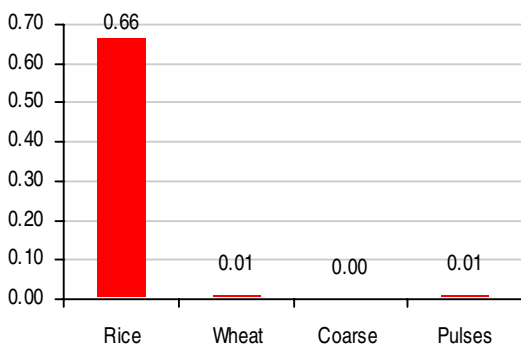


Source: SEDAC(750_CO2+ symbolizes 750 ppm stabilization scenario with co2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

Our analysis suggests that food grain production in Japan could increase by about 0.68 mn tonnes pa by 2020. Currently, Japan produces approximately 12 mn tonnes of food grains annually. The biggest increase by 2020 could come from rice production, while production of other cereals might remain mostly unchanged. Per capita food grain production is currently estimated at 0.10 tonnes pa which could increase by 8%, when carbon fertilisation is taken into account.

Fig 123: Change in food grain production in Japan by 2020e (Mt pa)



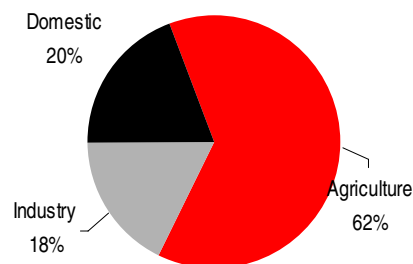
Source: HSBC (SEDAC)

Impact on the water sector

Japan has a per capita availability of water resources of 3,360 m3/capita/year (2007). It also provides universal access of safe water to its citizens. Its per capita water availability is projected to increase by 8% by 2025. Per capita water demand in Japan is currently estimated at 696 m3/capita/year, which could decrease by about 8% by 2020 as the population declines and water use efficiency increases.

The bulk (62%) of water supply goes to irrigation. In a warmer world, as irrigation demand increases, water use might increase also.

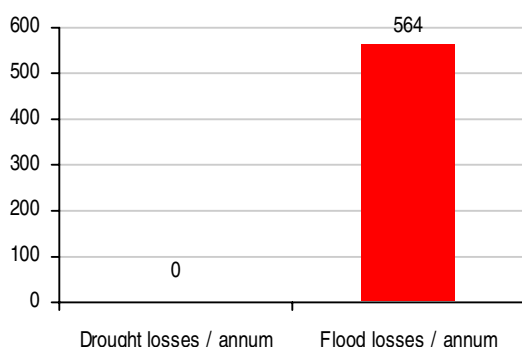
Fig 124: Water use in Japan (2007)



Source: World Bank statistics

Japan loses more than USD 560 mn pa to flood-related hazards. However, it has no exposure to drought losses.

Fig 125: Flood and drought related average losses pa (1988-2008) in Japan (USD mn)



Source: HSBC (Based on EMDAT database)

Impact on the health sector

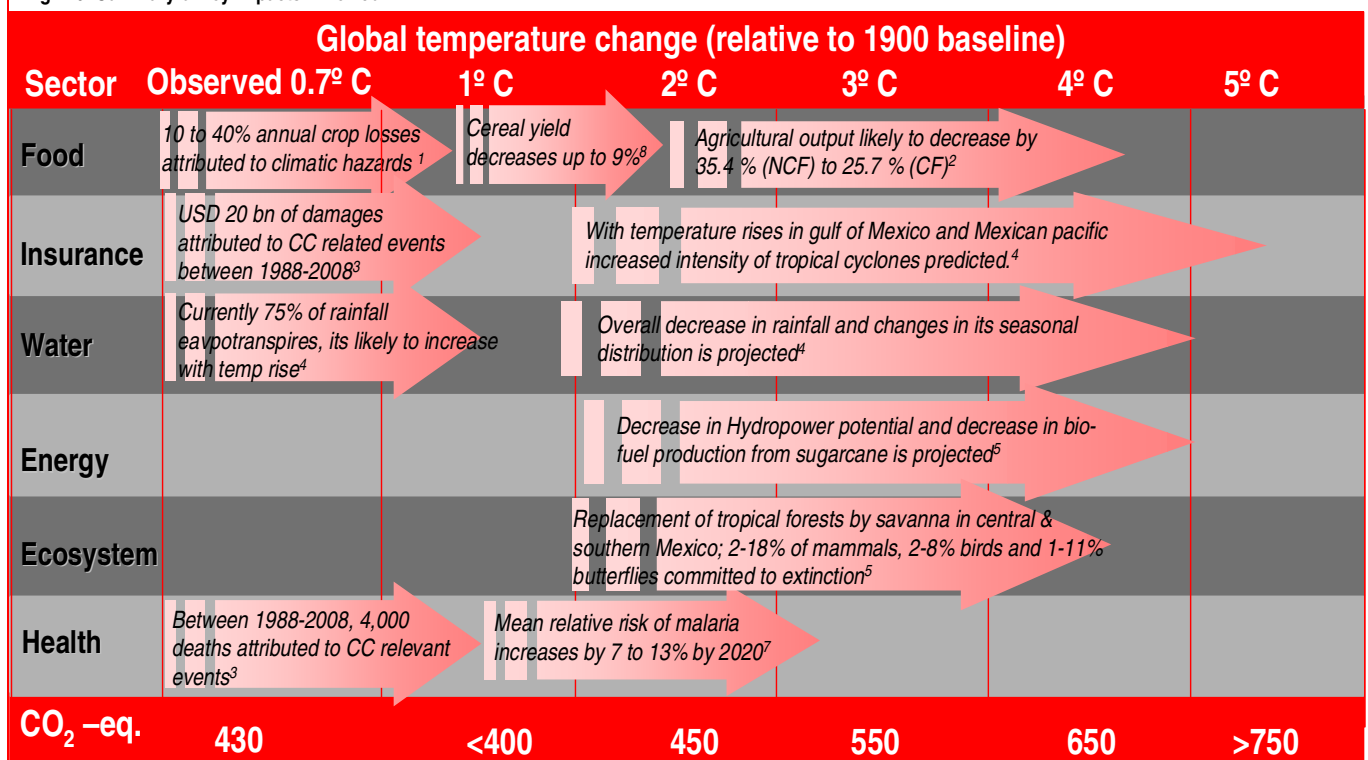
Japan is currently free from climate related diseases such as malaria, malnutrition, diarrhoea etc. However, it has considerable flood-related disabilities. WHO estimates suggest that floods cause more than 1,000 DALY losses pa (2000 estimates) in Japan which is estimated to increase to more than 2,500 DALYs by 2020.

We estimate that currently flood-related disabilities cause USD 42 mn worth of productivity losses pa which we estimate could rise to USD 104 mn pa by 2020.

Mexico

- ▶ HCVA assessment: 3rd quartile; less vulnerable
- ▶ Per capita water availability could decrease by 30%, while per capita water demand could increase by 48%
- ▶ Cereal production could decrease by 7-11%
- ▶ While climate change induced disabilities could increase threefold

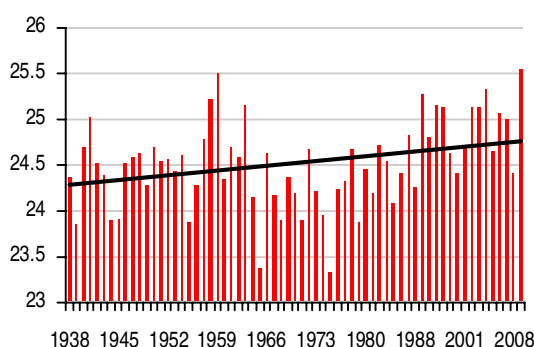
Fig 126: Summary of key impacts – Mexico



Source: 1Phillips, 2006; 2Bill Cline, 2007 (NCF – No CO₂ fertilisation effect and CF – with CO₂ fertilisation effect); 3EMDAT database, 2008 & HSBC; 4NATCOM (Mexico), 2007; 5Contreras-Lisperguer, 2008; 6IPCC, 2007 & WWF, 2007; 7WHO, 2007

A country level temperature record for Mexico is not available, but the temperature at one of the Mexican meteorological stations with the longest data record is shown in Fig 127. The warming observed over 1938-2008 is about 0.8°C.

Fig 127: Annual avg temperature (°C) as recorded at Mazatlan station in Mexico



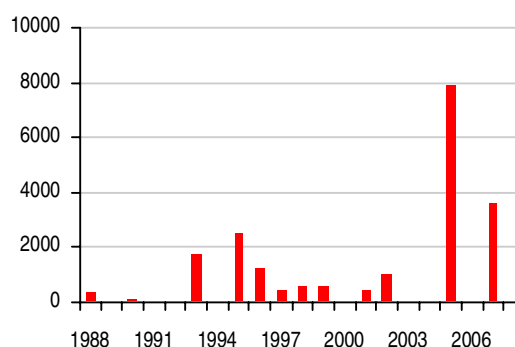
Source: <http://data.giss.nasa.gov/work/csc/stations/tmp.csc/414764580000.2/station.txt>

As the climate changes (Fig 126), temperature increases of over 2°C could cause lower rainfall, and lower agricultural output by 25%-35%. This might be crucial for Mexico as 15% of the workforce is involved in agriculture.

Even in the current climate, Mexico experiences considerable loss of lives as well as assets due to climate related disasters. We estimate that Mexico loses more than USD 1 bn pa to climate related disasters (averaged over 1988 to 2008). In 2005, it lost a record of USD 8 bn to climate related disasters.

According to climate change projections from HadCM3, Mexico is likely to experience a maximum temperature rise of 1.6 °C by 2020.

Fig 128: Losses due to climate related disasters in Mexico (USD mn)



Source: EMDAT database

Precipitation projections are more uncertain, but the indication is that large changes are possible (Table 24).

Table 24: Projected temperature (by 2020) and precipitation (by 2020) changes in Mexico

	A2	B2
Temperature ¹²⁷ (°C)	1.15 to 1.6	1.5 to 1.9
Rainfall ¹²⁸	-20%	-30%

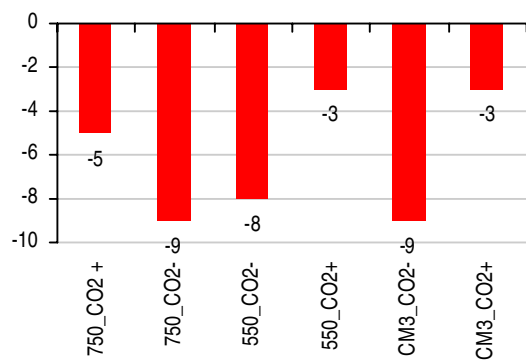
Source:
http://www.aiaccproject.org/meetings/Buenos_Aires_04/Day2/Aug_25Vinocur.ppt#284,15,M
EXICO. Temperature Climate Change Scenarios. A2, B2. 2020, 2050. 3 GCMs. July

Impact on the agriculture sector

About 13% of the land is arable, and it employs a large part of the workforce (15%) and makes up 3.3% of GDP. Crop impact modelling suggests that under different scenarios of climate change food grain productivity in Mexico could decrease by up to 9% by 2020.

¹²⁷ Relative to Pre-Industrial baseline (1850)
¹²⁸ Relative to 1961-90 baseline

Fig 129: % change in cereal yield in Mexico by 2020e



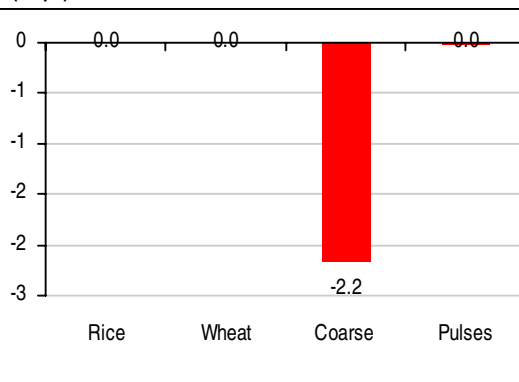
Source: SEDAC(750_CO2+ symbolizes 750 ppm stabilization scenario with co2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

On average, Mexico produces 32 mn tonnes of food grains pa with a maximum of 27 mn tonnes coming from coarse grains. We estimate that even when incorporating the CO2 fertilisation effect, food grain production in Mexico could fall by about 2.2 mn tonnes pa. The biggest decrease is estimated to be in coarse grain production, which would lose 2.16 mn tonnes of production pa while the productivity of other food grains would remain largely unchanged.

Per capita food grain production in Mexico is estimated at 0.30 tonnes pa which could decrease by 17% by 2020, even when carbon fertilisation is taken into account.

Fig 130: Change in food grain production in Mexico by 2020e (Mt pa)



Source: HSBC (SEDAC)

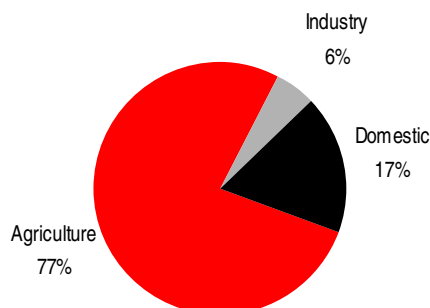
Impact on the water sector

At the national level, Mexico is comfortably placed with regard to per capita water availability at 4292 m3/capita/year (2007). However, there is considerable geographical variation in water availability. Per capita water availability is likely to reduce by 30% by 2025.

Per capita water demand is currently estimated at 784 m3/capita/year. As the economy grows, water demand is projected to increase to 1,135 m3/capita/year by 2025.

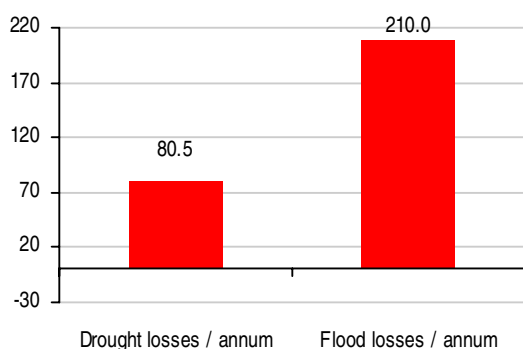
The bulk of Mexico's water resources are currently used in irrigation.

Fig 131: Water use in Mexico (2007)



Source: World Bank statistics

Fig 132: Flood and drought related average losses pa (1988-2008) in Mexico (USD mn)



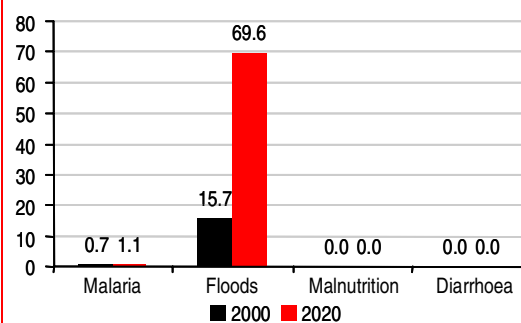
Source: HSBC (Based on EMDAT database)

Though Mexico is well endowed with water resources, floods and droughts co-exist in the country. According to our estimates, Mexico loses more than USD 80 mn pa to drought and another USD 210 mn pa to floods.

Impact on the health sector

Climate change is likely to have grave impacts on human health. In Mexico, there are primarily two climate related health hazards, one being malaria and the other being flood induced disability. In 2000, malaria caused more than 700 DALY losses pa while floods contributed to 16,000 DALY losses.

Fig 133: Disability adjusted life year losses attributable to climate change in Mexico for 2000 and 2020e (000)



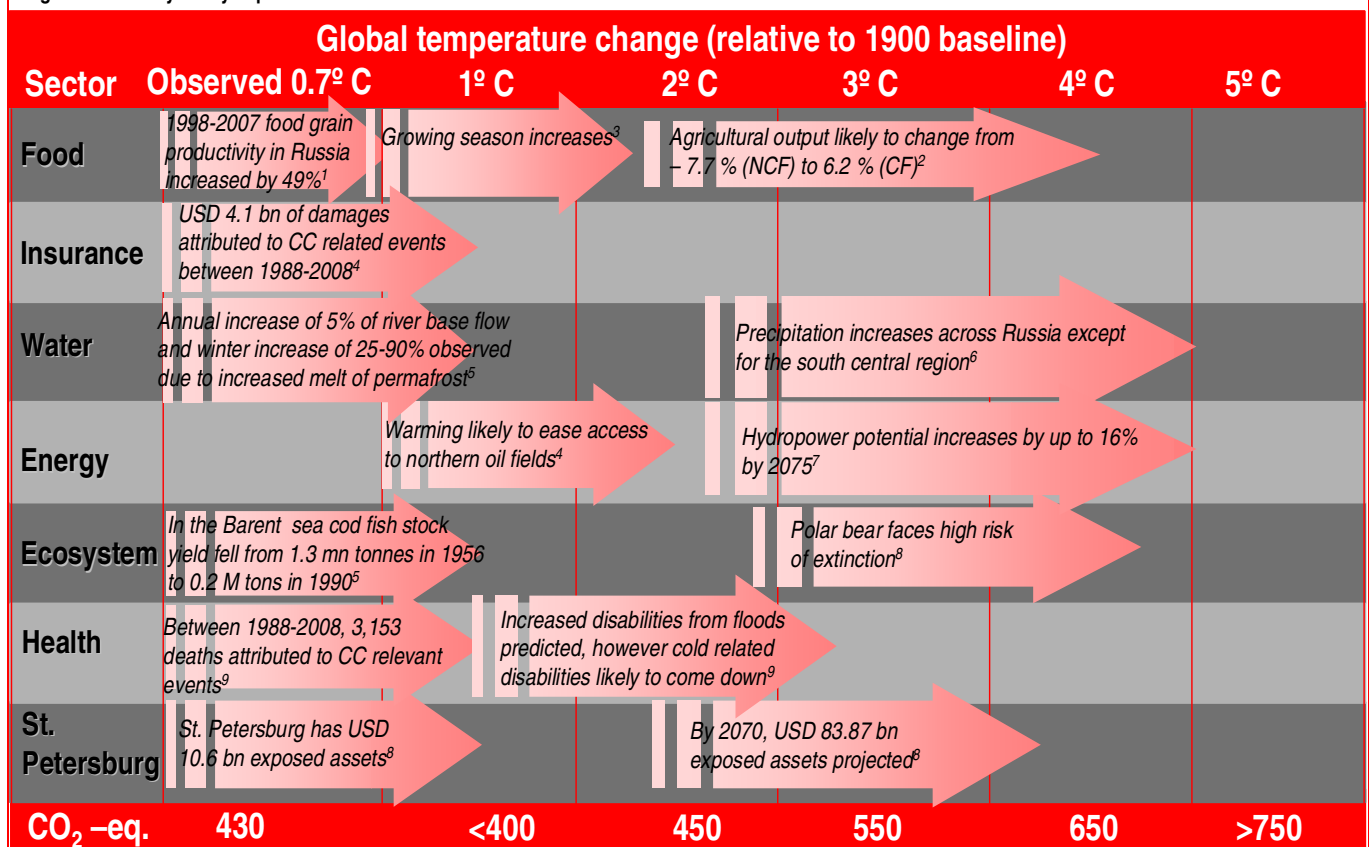
Source: HSBC (WHO, 2007)

We estimate that currently climate change related disabilities cause USD 167 mn pa of labour productivity losses in Mexico which is likely to rise to USD 720 mn pa by 2020. This would necessitate new infrastructure for flood control and new investments in public health programmes to mitigate the impacts.

Russia

- ▶ HCVA assessment: 4th quartile; marginally vulnerable
- ▶ On the positive side per capita water availability could increase by c32%
- ▶ While cereal production could decrease by c13 – 18%
- ▶ Climate change induced disabilities could increase marginally

Fig 134: Summary of key impacts – Russia

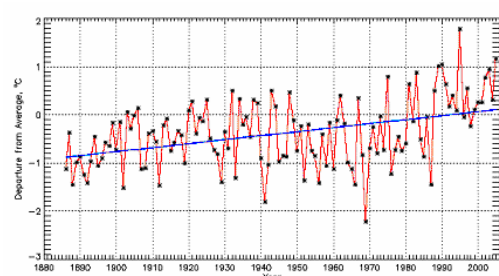


Source: 1HSBC (FAO database); 2Bill Cline, 2007 (NCF – No CO2 fertilisation effect and CF – with CO2 fertilisation effect); 3US report, 2008; 4EMDAT database, 2008 & HSBC 5WWF, 2007; 6CRU, WWF, 1999; 8OECD, 2008;; 7 Lehner et al., 2001; 8Arctic Climate Assessment, 2004; 9WWF, 2007; 10OECD, 2008;

Russia has warmed more than 1°C over the last century (Fig 135). It is the largest country in the world by area, and has a rather skewed distribution of population and assets, with large stretches of very sparse levels of both. Hence currently Russia experiences relatively modest climate related losses.

More than half of the country is north of 60°N latitude, and extensive regions of the country are covered by snow for more than 6 months of the year, with the subsoil frozen up to a depth of several hundred meters.¹²⁹ Most of the country receives low to moderate levels of rainfall, with no region having a year-round growing season.

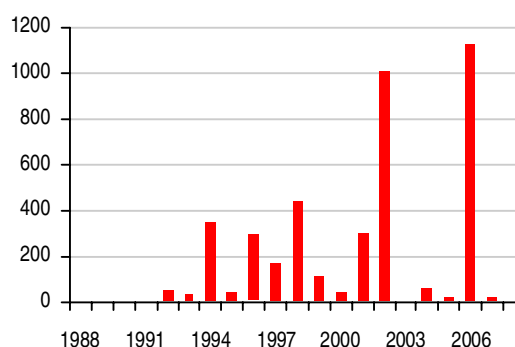
Fig 135: Temperature anomaly in Russia 1880-2005 (°C)



Source: <http://www.ncdc.noaa.gov/gcag/GCAGtsalt?dat=GHCN&SYST=TS&TS=2>

Based on the disaster database maintained by EMDAT, we estimate that currently Russia experiences climate-related disaster losses to the tune of USD205 mn pa.

Fig 136: Losses due to climate related disasters in Russia (USD mn)



Source: HSBC (Based on EMDAT database)

Russia's total level of warming is likely to reach 1.2-2° C by 2020, under different scenarios (Table 25).

Table 25: Projected temperature (by 2020) changes in Russia

	2020			
	B1-Low	B2-Mid	A1-Mid	A2-High
Temperature (°C) ¹³⁰	1.2	1.5	1.8	2.0

Source: Hulme, M. and Sheard, N. (1999) Climate Change Scenarios for Russia

Results of the PAGE V.4.1 simulations indicate that the regions comprising the former USSR and Eastern Europe stand to gain USD 2781 mn by 2020 in terms of climate benefits¹³¹. However by the end of the century, as the region experiences higher temperatures, profits turn into losses and the region suffers a loss of up to 8 % of the GDP by 2100.

Impact on the agriculture sector

Russian agriculture is stymied by low temperatures and a short growing period. Only 7% of its vast land area is arable, and food and drink constitute about 22% of its imports. Agriculture employs 10% of the workforce and makes up about 5% of GDP. This makes agriculture about 5 times larger in importance to the domestic economy compared to the Western European countries of France, Germany or the UK, where it is only about 1-2% of the GDP.

¹²⁹ <http://countrystudies.us/russia/24.htm>

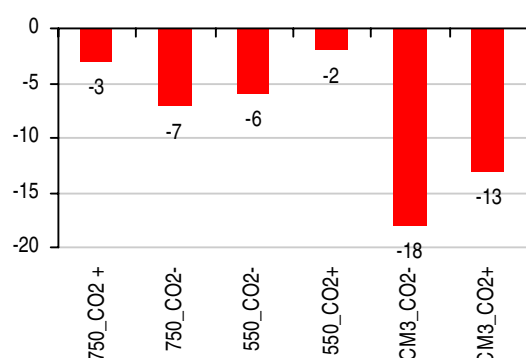
¹³⁰ Relative to pre-industrial baseline (1850)

¹³¹ Warren et al., 2006 – contribution to Stern Review

It is generally expected that a warmer climate would be beneficial for agriculture in the high latitudes (IPCC, AR4). However, this general tendency doesn't hold true for Russia as a short growing period is not the only factor limiting agriculture here. For example, a recent modelling study by Nikolai Doronin and Andrei Kirilenko¹³² suggests that increasing droughts in the currently most productive southern regions of Russia, would sharply reduce total production. Even though the central and northern forested regions would experience an increase in productivity this would not be able to compensate for the sharp drop in yields in the southern regions.

Crop impact models suggest that yield decreases in Russia could vary between 2% and 18% (Fig 137).

Fig 137: % change in cereal yield in Russia by 2020e



Source: SEDAC(750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

We estimate that under this particular scenario food grain production could decrease by about 9 mn tonnes pa. The biggest decrease is estimated to be in wheat production followed by coarse grains.

Fig 138: Change in food grain production in Russia by 2020e (Mt pa)



Source: HSBC (SEDAC)

Currently, Russia produces 72 mn tonnes of cereals pa. Per capita food grain production in Russia is currently estimated at 0.51 tonnes pa which could decrease by 6.6% even when carbon fertilisation is taken into account.

Impact on the water sector

Russia has a good endowment of water resources, with a per capita availability of 31,572 m3/year (2007). More than 97% of its population has access to safe water. Current per capita water demand stands at 520 m3/year¹³³ which could increase dramatically, to 650 m3/year, by 2020¹³⁴. By 2025, based on Alcamo et al (2007), we estimate that per capita water availability could increase by a further 32% and per capita water demand by a further 16.5%.

Currently Russia has very little vulnerability to drought - it has not experienced any major drought related losses in the last two decades. However, floods are a severe concern today. We estimate that Russia loses more than USD 121 mn pa to flood related hazards (averaged over 1998-2008).

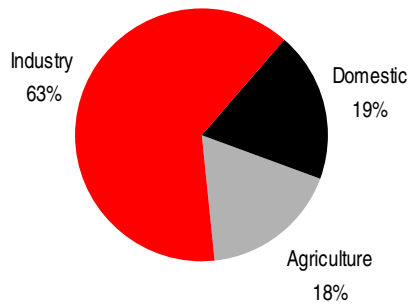
The bulk of Russia's water resources are used in industry.

¹³² <http://www.springerlink.com/content/b680351263278215/>

¹³³ HSBC calculation based on FAO-AQUASAT

¹³⁴ HSBC calculations based on Alcamo et al., 2007

Fig 139: Water use in Russia (2007)



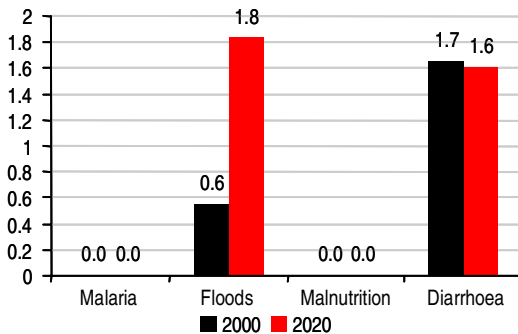
Source: World Bank statistics

According to the WHO, flood induced diseases and diarrhoea are currently the biggest source of climate induced DALY losses in Russia, accounting for year 2000 losses of 550 and 1,651 DALYs pa, respectively. We estimate that climate induced productivity losses currently amount to USD 25 mn pa, which is likely to rise to USD 39 mn pa by 2020. However, by 2020 the WHO estimates suggest that the incidence of diarrhoea could decrease marginally.

However, in the future, its southern European region may experience shortfalls in rainfall and the consequent increase in water stress.

Impact on the health sector

Fig 140: Disability adjusted life year losses attributable to climate change in Russia for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

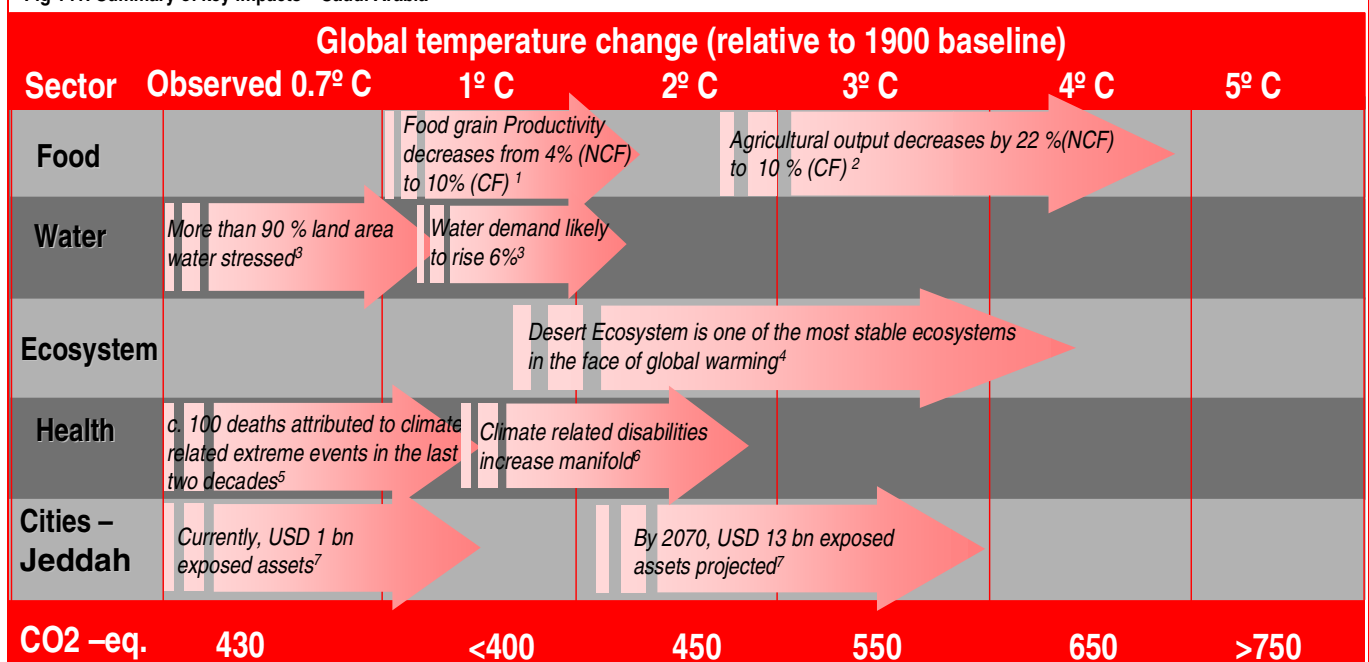
Saudi Arabia

- ▶ HCVA assessment: 2nd quartile; moderately vulnerable
- ▶ Saudi Arabia is already severely water stressed and we estimate its per capita water availability could decrease by 15% by 2020
- ▶ Agricultural production could decrease by up to 86% due to government regulation as well as the impacts of climate change
- ▶ While climate change induced disabilities could rise by more than twofold

Saudi Arabia is the most water stressed country in the G-20. The desert kingdom has built itself on oil wealth. It meets its water needs by converting some of its energy to water by the process of desalination and by importing water embedded in food.

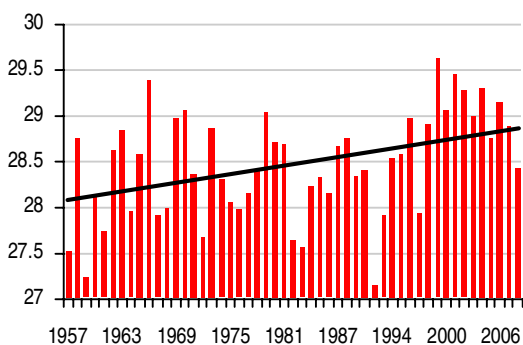
In the absence of country specific average temperature change estimates for Saudi Arabia we present data collected from an individual meteorological station in Medina. The change in the trend level of temperature for Medina is about 0.8°C from 1956 to 2006.

Fig 141: Summary of key impacts – Saudi Arabia



Source: 1 Rosenweig, 2003; 2 Bill Cline, 2007 (NCF-without carbon fertilisation and CF- with carbon fertilisation); 3 <http://www.usf.uni-kassel.de/watclim/karten/>; 4 IPCC, 2001; 5 EMDAT database, 2008 & HSBC; 6 WHO, 2008; 7 OECD, 2008;

Fig 142: Temperature trend over Medina (Saudi Arabia) in °C



Source: NOAA

We do not have climate loss information for Saudi Arabia.

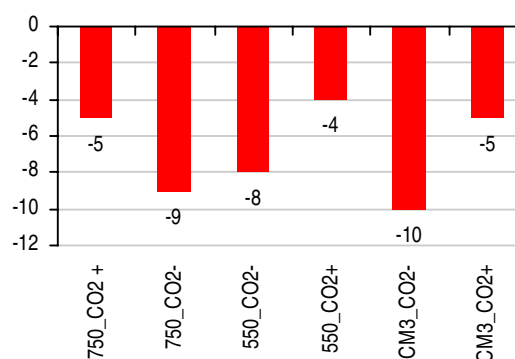
Neither are credible regional climate change scenarios and projections available for Saudi Arabia. However, based on global studies we estimate that climate change would severely impact the agriculture, water and health sectors in Saudi Arabia.

Impact on the agriculture sector

Saudi Arabia is a net importer of food grains, with 2% of the country's land area being arable. While agriculture accounts for 7% of employment, it constitutes only 3% of GDP, albeit over 19% of all imports.

Crop impact modelling suggests that climate change could reduce food grain productivity in Saudi Arabia by up to 10% under different climate change scenarios over the next decade.

Fig 143: % change in cereal yield in Saudi Arabia by 2020e



Source: SEDAC(750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_CO2- means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

In Jan 2008, Saudi authorities, realizing the severe water stress the country faces (see the water sector table for details, Table 7) decided to cut its domestic wheat procurement by 12.5% each year from 2008, to conserve water. Saudi Arabia aims to depend on imports for 100% of its grain needs by 2016¹³⁵. It has realised that whatever water is available is better used for domestic and industrial purposes (see Fig 144 for water use). By 2016, wheat production will cease, as without the high support prices paid by the local government (currently 2-3x world average wheat prices), farmers would find it uneconomical to grow wheat.

This exposes Saudi to long term food grain price risk. This can be mitigated by long term supply contracts with global firms, or by investing directly in other countries' agricultural land. Neither of these is without risks. The latter has sensitive political implications whilst the supply chain risks are repudiation of the contract, or the imposition of export taxes on the grain. This could leave Saudi Arabia exposed to spot price risk for possibly the bulk of its grain imports. High market prices are likely to be seen at precisely the same time as land contracts are likely to come under pressure, as the probability of default goes up

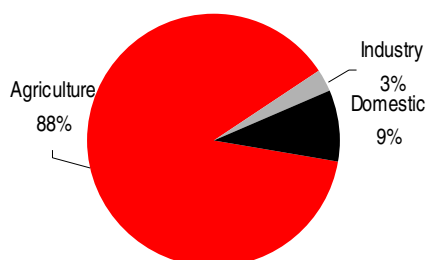
¹³⁵ <http://www.reuters.com/article/latestCrisis/idUSL08699206>

when grain prices are higher. All things considered, we feel that long term take-or-pay arrangements with leading food aggregation companies offer the best way forward. This is a major positive for the large food conglomerates, many of which are based in the US and Brazil, among other places.

Impact on the water sector

Saudi Arabia qualifies as the most water stressed country in the G-20, with fresh water availability at a meagre 97.03 m³/capita/per year. The consumption of water is many times higher than its availability, which is made feasible by the use of desalination. Saudi Arabia is the world's largest producer of desalinated water drawn from the sea. The amount produced covers about 48% of all municipal use¹³⁶. Currently, the bulk of its water is used for irrigation, but this will be progressively reduced. Our estimate based on modelling projections from Alcamo et al (2007), suggests that per capita water availability could decrease by 15% by 2025, however we project that with increased efficiency per capita water demand could decrease by 24%.

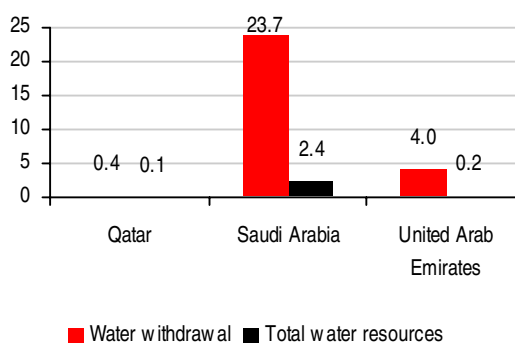
Fig 144: Water use in Saudi Arabia (2007)



Source: World Bank statistics

Currently, more than 91% of Saudi Arabia's land area is severely water stressed.¹³⁷ However, to its credit, Saudi Arabia has still been able to provide access to clean water for 97% of its population, comparable with the clean water access level of the US of 99%. Saudi Arabia is one of the 6 members of the Gulf Co-operation Council (GCC) – which has spent more than USD 40 billion on building seawater desalination stations over the last 25 years.

Fig 145: Comparison of water use and water availability (in bn m3)*



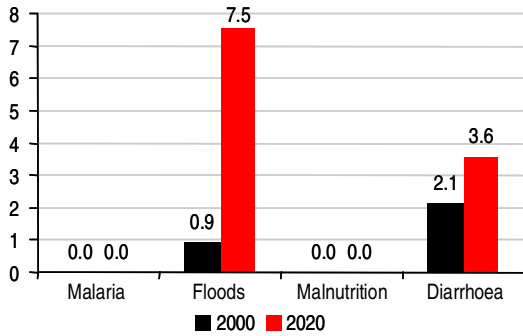
* Total water resources for 2007 for all countries. Water demand data is from 2006 for Saudi Arabia, 2005 for Qatar and 2000 for UAE
Source: World Bank Statistics;

¹³⁷ Esty, Daniel C., Marc Levy, Tanja Srebotnjak, and Alexander de Sherbinin (2005). 2005 Environmental Sustainability Index: Benchmarking National Environmental Stewardship. New Haven: Yale Center for Environmental Law and Policy

¹³⁶ http://www.fao.org/hr/water/aquastat/countries/saudi_arabia/index.stm

Impact on the health sector

Fig 146: Disability adjusted life year losses attributable to climate change in Saudi Arabia for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

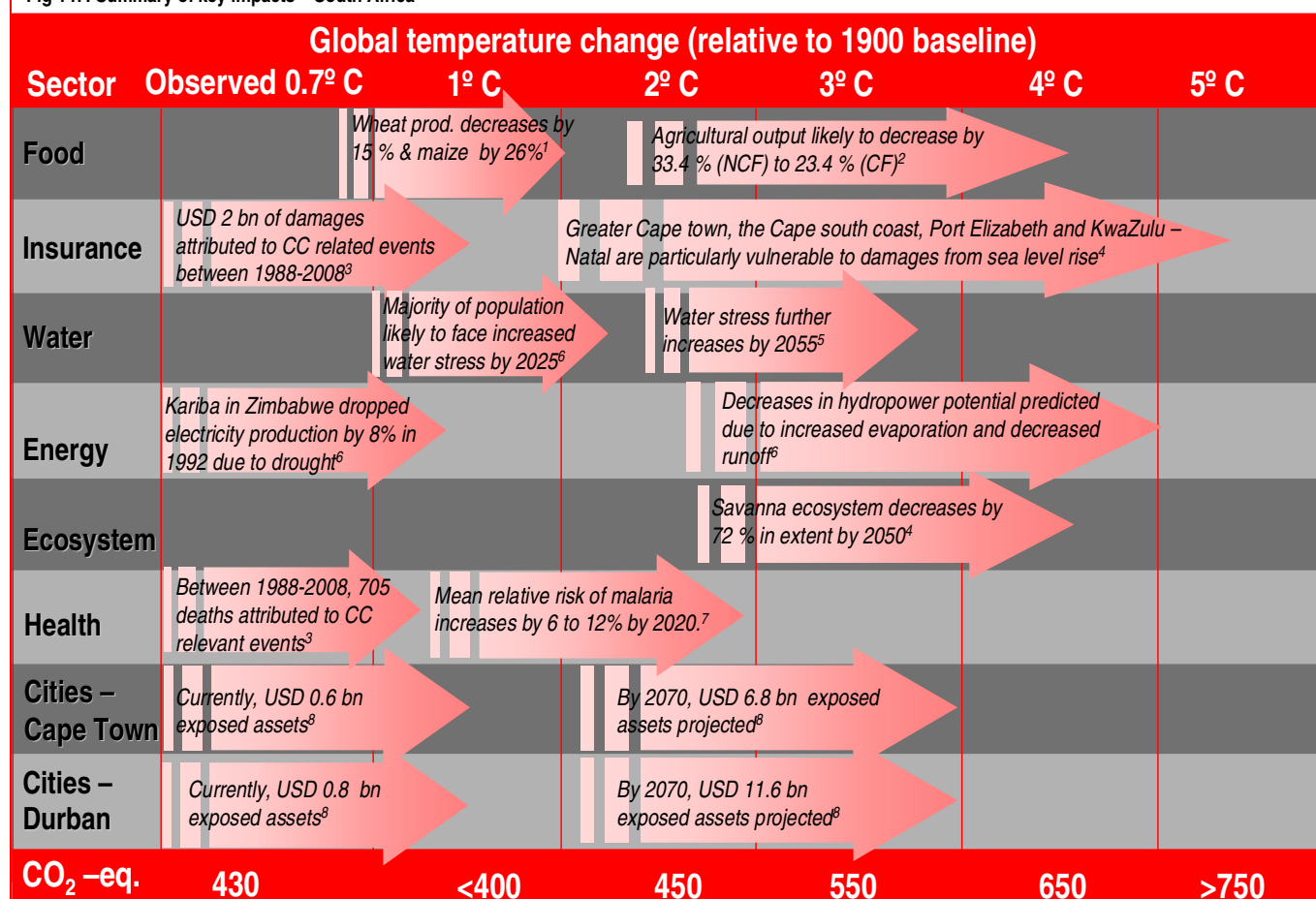
Saudi Arabia is estimated to have two major climate change related health hazards, one emanating from diarrhoea and another from flood related disabilities. In 2000, diarrhoea caused more than 2,000 DALY losses pa which is projected to increase to 3,500 by 2020. Floods currently cause approx 900 DALY losses pa which increases to more than 7,500 by 2020.

We estimate that currently climate change related disabilities cause a loss of USD 58 mn pa which increases to USD 211 mn pa by 2020.

South Africa

- ▶ HCVA assessment: 1st quartile; highly vulnerable
- ▶ Per capita water availability could decrease by 20% while per capita water demand could increase by 21%
- ▶ Agricultural production could decrease by 7-10%
- ▶ Currently South Africa experiences 0.17 mn disability adjusted life year losses pa which could increase marginally by 2020

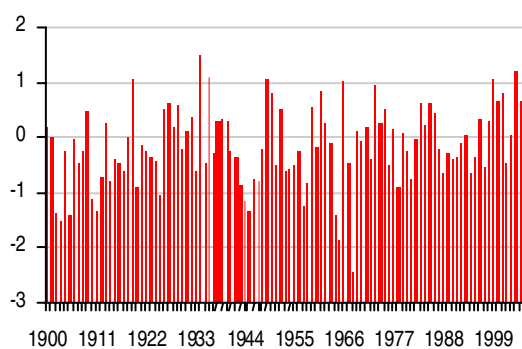
Fig 147: Summary of key impacts – South Africa



Source: 1Lobell et al., 2008; 2Bill Cline, 2007 (NCF – No CO₂ fertilisation effect and CF – with CO₂ fertilisation effect); 3EMDAT database, 2008 & HSBC; 4Turpie et al., 2002; 5Arnell, 2004; 6Mukheibir, 2007; 7WHO, 2007; 8OECD, 2008;

In South Africa (SA) the temperature has increased by approximately 0.6 °C in the last century.

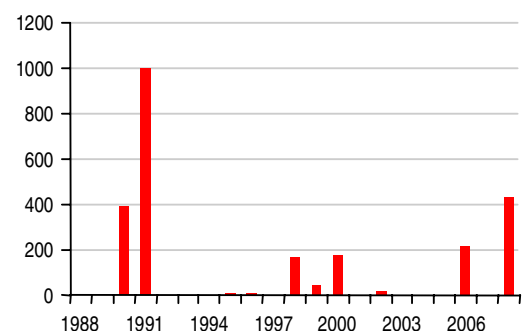
Fig 148: Temperature anomaly in South Africa 1900-2005 (°C)



Source: <http://www.ncdc.noaa.gov/gcag/>

According to our estimates, South Africa currently loses more than USD 122 mn pa to climate relevant events. However, the distribution of climate related losses has been highly skewed in South Africa over time, and no trend is visible.

Fig 149: Losses due to climate related disasters in South Africa (USD mn)



Source: EMDAT database

A South African country study with the help of the HadCM2 model predicts an increase in temperature of about 2.5° C by 2050. Rainfall is also projected to experience major changes, especially a decrease in precipitation in the western half of the country.¹³⁸ The country study concludes that most biophysical impacts predicted for South Africa are greatest in the western half.

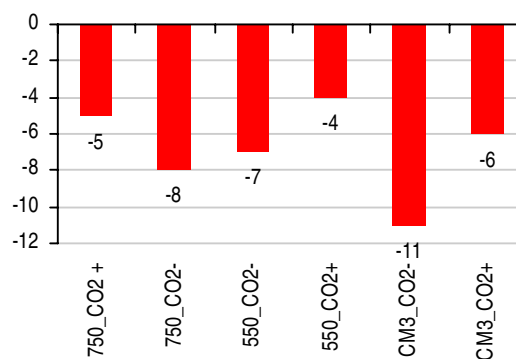
¹³⁸ <http://www.fitzpatrick.uct.ac.za/pdf/turpie02.pdf>

Though South Africa currently does not experience much loss due to climate change related extreme events, in a warmer world South Africa is projected to lose up to 3% of GDP pa due to climate change by 2050.

Impact on the agriculture sector

South Africa has about 10% of its workforce in the agriculture sector, contributing 2.8% of GDP. About 12% of its land is arable, and it has modest water reserves- barely enough for now. The impact on the agriculture sector has been estimated based on data provided by SEDAC (http://sedac.ciesin.org/giss_crop_study/CCMscenarios.html). Impact modelling suggests that under different scenarios of climate change food grain productivity in South Africa could decrease between 4 % and 11%.

Fig 150: % change in cereal yield in South Africa by 2020e



Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

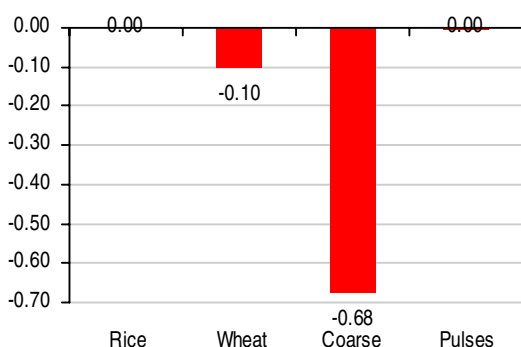
Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

Under this scenario, food grain production in South Africa could decrease by approximately 0.78 mn tonnes pa. Given that South Africa currently produces on an average 12 mn tonnes of food grains pa, this is a loss of about 6.5%. The biggest decrease in 2020 is estimated to be in coarse grain production, followed by wheat. Production of rice and pulses is

unaffected, though South Africa doesn't produce much of either.

Per capita food grain production in South Africa is currently estimated at 0.24 tonnes per year which could decrease by 10 % even when carbon fertilisation is taken into account (as the South African population is expected to increase by about 6.7% by 2020); without carbon fertilisation, the decline is even more profound, reaching up to 13%.

Fig 151: Change in food grain production in South Africa by 2020e (Mt pa)



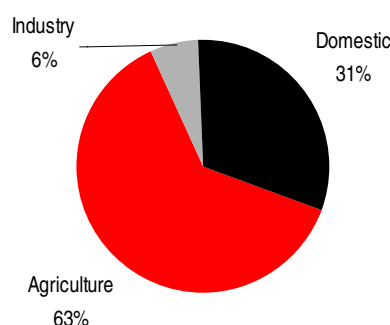
Source: <http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor>

In a poor country, a loss of this magnitude would put considerable strain on national food security. The country exports maize to numerous southern African countries, as well as deciduous fruit to Europe, which would undoubtedly feel the repercussions of lower harvests and thus lower exports from South Africa.

Impact on the water sector

At 1029 m³/capita/year of water availability, South Africa is barely above the danger line. The saving grace is its low current per capita water demand which is estimated at 275 m³/year. However, in the next decade per capita water availability is projected to decrease by 20% and per capita demand is projected to rise by 6%. This could deal a deadly blow to the already constrained water resources. Moreover, there is a palpable divide between urban and rural amenities. While 100% of the urban population has access to improved drinking water, only 82% of the rural population has the same facilities and more than half of the rural population doesn't have access to proper sanitation¹³⁹. This background makes South Africa very sensitive to the impacts of climate change. Water stress is further exacerbated by the fact that the bulk of the water is consumed for irrigation purposes.

Fig 152: Water use pattern in South Africa

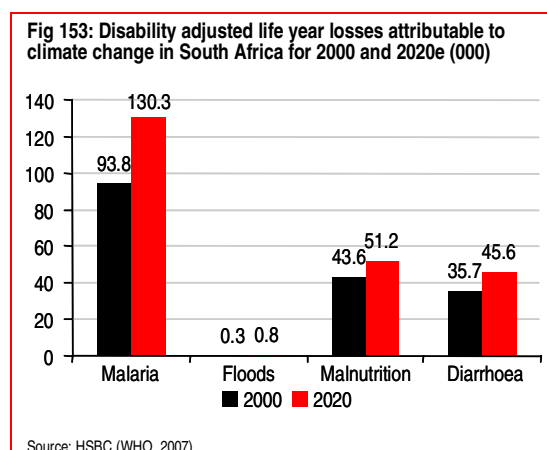


Source: World Bank statistics

¹³⁹

http://apps.who.int/whosis/database/core/core_select_process.cfm?countries=zaf&indicators=PopAccessImprovedWaterUrban&indicators=PopAccessImprovedWaterRural&indicators=PopAccessImprovedSanitationUrban&indicators=PopAccessImprovedSanitationRural

Impact on the health sector



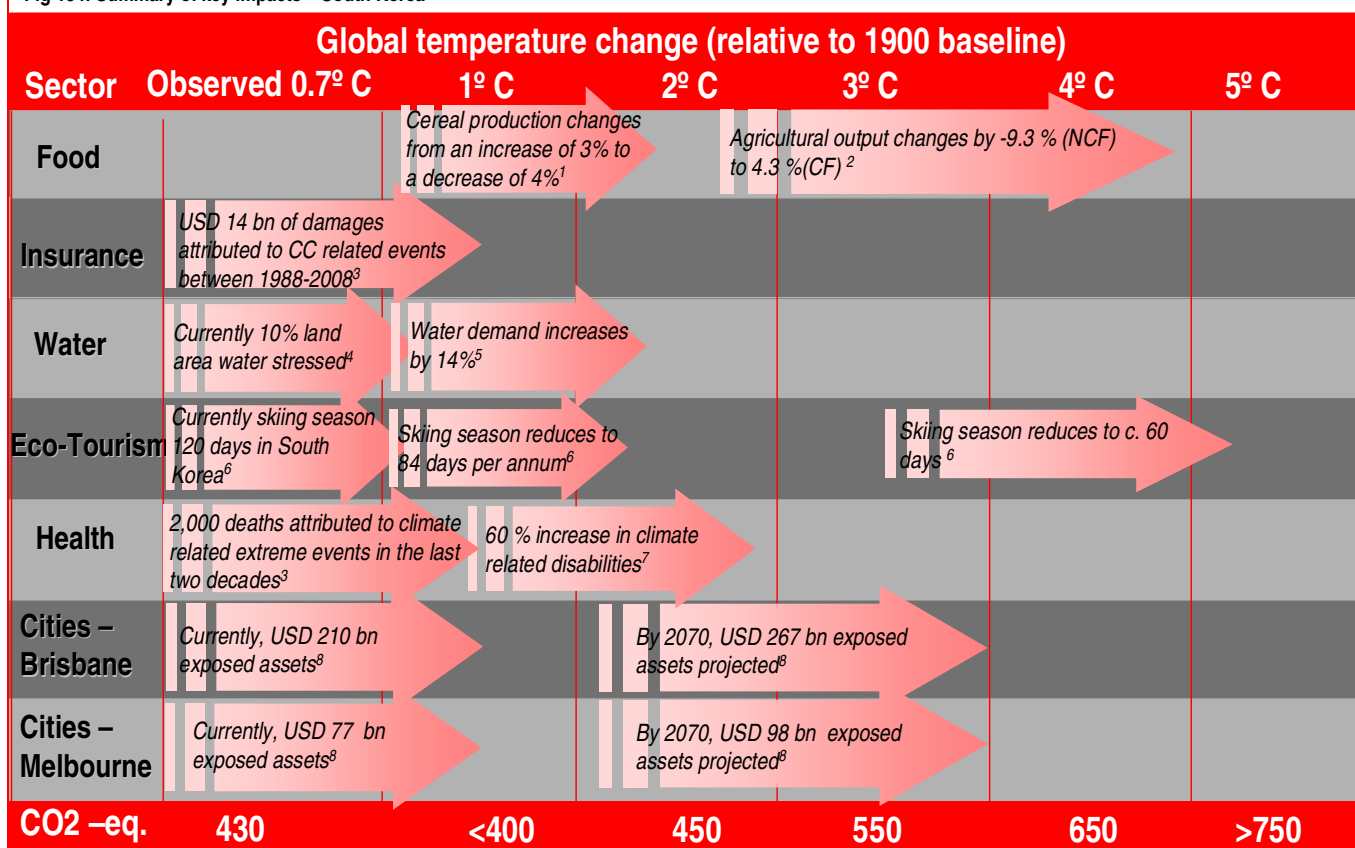
According to WHO estimates South Africa is likely to experience a 40% increase in malaria related DALY losses by 2020. Diarrhoea related DALY losses could increase by 27% and malnutrition related DALY losses by 17% during this period and flood induced disabilities, though very small at present, could double.

Our estimates suggests that currently South Africa loses more than USD 986 mn pa to climate related DALY losses. We estimate that the cost of climate related DALY losses in South Africa could reach USD 1.3 bn pa by 2020.

South Korea

- ▶ HCVA assessment: 3rd quartile; less vulnerable
- ▶ On the positive side per capita water availability could increase by 2.7% and the agriculture sector could see some positive impacts
- ▶ Climate change induced disabilities could increase marginally

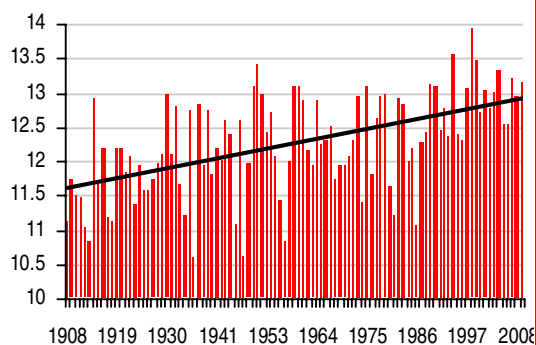
Fig 154: Summary of key impacts – South Korea



Source: 1Rosenweig, 2003; 2 Bill Clime, 2007 (NCF-without carbon fertilisation and CF- with carbon fertilisation) 3EMDAT database, 2008 & HSBC; 4<http://sedac.ciesin.columbia.edu/es/es/downloads.html#data>, 5<http://www.usf.uni-kassel.de/watchclim/>; 6<http://geolove.net/home/ski.pdf>; 7 WHO, 2007; 8OECD, 2008;

South Korea's capital, Seoul, has warmed by more than 1°C in the last century (Fig 155).

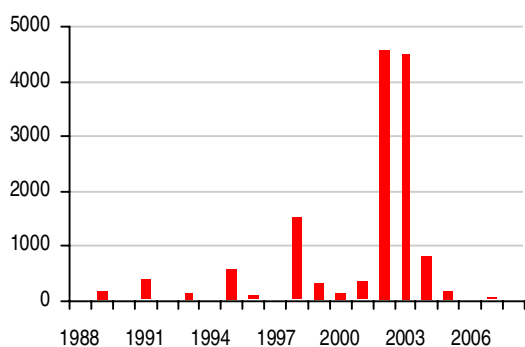
Fig 155: Average temperature at Seoul station (°C) during the last century



Source: NOAA

According to our estimates, currently South Korea loses approximately USD 700 mn pa due to climate related disasters. Floods in Aug 2002 and Sept 2003 caused severe economic losses – to the tune of more than USD 4 bn each. The 2003 flood loss is thought to be highest natural disaster loss in South Korea in the last century.¹⁴⁰

Fig 156: Losses due to climate related disasters in South Korea (USD mn)

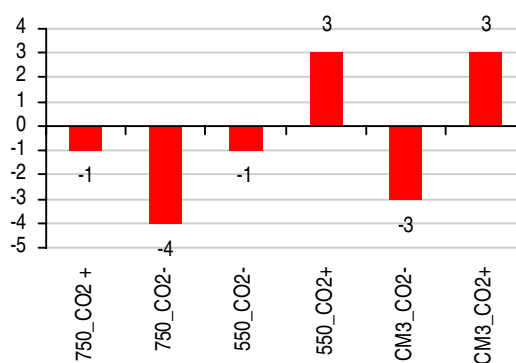


Source: EMDAT database

Impact on the agriculture sector

South Korea's agriculture sector constitutes about 3.3% of GDP, and employs 8% of the workforce. It has 16% arable land, but it imports about 70%¹⁴¹ of its food grain requirements. Climate change impact modelling suggests that food grain productivity could fluctuate within a range of -4% to +3% by 2020.

Fig 157: % change in cereal yield in South Korea by 2020e



Source: SEDAC/750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

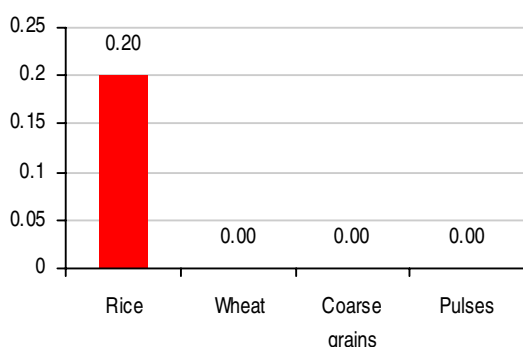
Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

Our analysis suggests that by 2020 cereal production in South Korea would increase by 0.2 mn tonnes pa. The biggest increase would be witnessed in rice production, while wheat, coarse grain and pulse production is stable.

¹⁴⁰ <http://www.emdat.be/result-country-profile>

¹⁴¹ www.fas.usda.gov/psdonline

Fig 158: Change in food grain production in South Korea by 2020e (Mt pa)



Source: HSBC (SEDAC)

Currently, South Korea produces 7 mn tonnes of cereals pa. Per capita food grain production in South Korea is currently estimated at 0.15 tonnes pa, which would increase by 6 % when carbon fertilisation is taken into account.

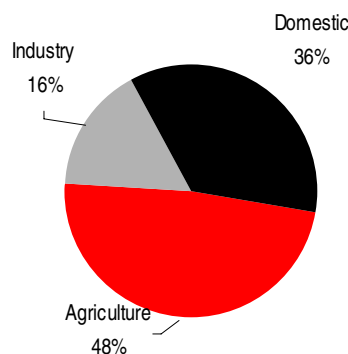
Impact on the water sector

South Korea lies very close to the danger line of water stress, with water availability of only 1,444 m³/capita/ year. Per capita water availability is projected to increase by a modest 2.75% by 2025. Its current per capita water demand is estimated at 378 m³/ year,¹⁴² which is projected to rise by 27% over the next decade¹⁴³.

It also faces threats from floods - annual losses from flood amount to USD 128 mn pa.

Korea uses the bulk of its water supply in irrigation which places further stress on the limited supply.

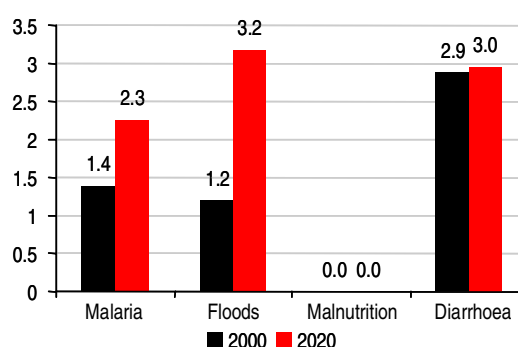
Fig 159: Water use in South Korea (2007)



Source: World Bank statistics

Impact on the health sector

Fig 160: Disability adjusted life year losses attributable to climate change in South Korea for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

South Korea suffers more than 5,000 climate related DALY losses pa (based on 2000 WHO estimates) which is projected to rise to more than 8,000 by 2020. Currently, most of its losses are from diarrhoea; however these losses remain stable even in a climate change scenario, although DALY losses from malaria and floods are projected to increase sharply by 2020 (Fig 160).

We estimate that currently South Korea loses USD 104 mn pa due to climate related disabilities and the loss estimate rises to USD 161 mn pa by 2020.

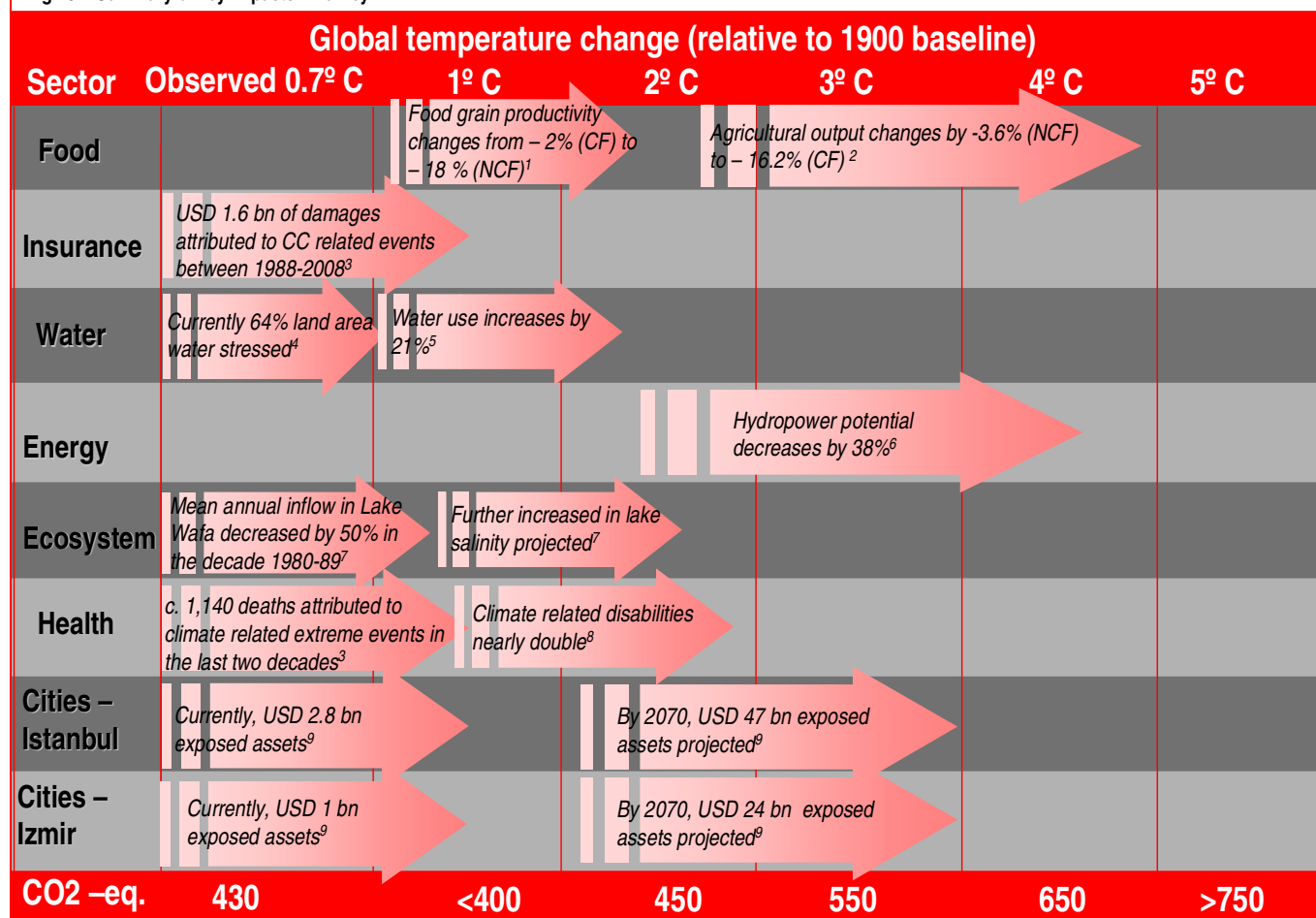
¹⁴² FAO-AQWASAT, 2008

¹⁴³ Alcamo et al., 2007

Turkey

- ▶ HCVA assessment: 4th quartile; marginally vulnerable
- ▶ However it could still lose 30% in terms of per capita water availability
- ▶ Cereal production could be reduced by 12-18% by 2020

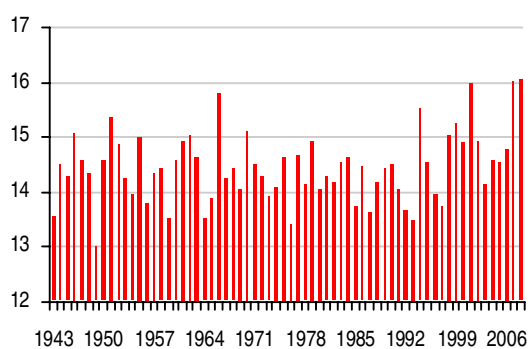
Fig 161: Summary of key impacts – Turkey



Source: 1 Rosenweig, 2003; 2 Bill Clime, 2007 (NCF-without carbon fertilisation and CF- with carbon fertilisation) 3EMDAT database, 2008 & HSBC; 4http://sedac.ciesin.columbia.edu/es/esi/2005ESI_DataCoverage.xls?bcsi_scan_B786307563EE7842=0&bcsi_scan_filename=2005ESI_DataCoverage.xls; 5Alcamo et al., 2007; 6 Lehner, 2001; 7http://www.balwois.com/balwois/administration/full_paper/ftp-1198.pdf; 8 WHO, 2007; 9OECD, 2008;

Turkey's capital, Istanbul, has seen a temperature rise of over 2°C, comparing 2006 with 1943 data.

Fig 162: Annual average temperature (°C) Istanbul

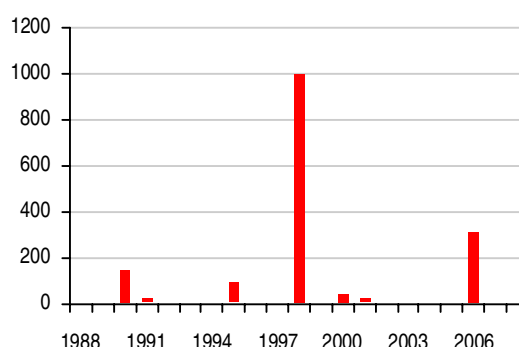


We assess Turkey to be the least vulnerable among the G-20 to climate change in 2020. This should be read in the context of the high levels of sector specific impacts Turkey could face by that time.

Over the long term (Fig 161), a global temperature rise of over 2°C threatens to bring lower agricultural yields (-3.6 to -16.2%) and lower hydropower (by as much as 38%). In the current climate, Turkey experiences very few climate related disaster losses on average (Fig 163). However, in May 1998, Turkey suffered a severe flash flood which affected 1.2 mn people, caused damage of USD 1,000 mn, and resulted in 10 deaths¹⁴⁴.

Turkey does experience a lot of geophysical events such as earthquakes, which are not reflected in the data shown in Fig 163.

Fig 163: Losses due to climate related disasters in Turkey (USD mn)



Short term regional climate projections for Turkey have been provided by UNDP: under both the IPCC A2 and B2 scenarios, temperature could rise 1.8 °C while rainfall could decrease slightly across the country.

Table 26: Projected temperature (by 2030) and precipitation (by 2030) changes in Turkey

	2030	
	A2	B2
Temp (°C) ¹⁴⁵	1.8	1.8
Rainfall (%)	-5	-5.8

Source: UNDP, Turkey: <http://europeandcis.undp.org/environment/show/6C27F762-F203-1EE9-B6E081020AABCE7>

According to our climate vulnerability model Turkey is the least vulnerable country in the G20. A 2007 study by Robert Mendelsohn and his colleagues predicts a slight increase in GDP by 2100 under a climate change scenario. However, in our sector specific studies, which is independent of the HCVA analysis, we find that Turkey does pay a price for climate change in terms of losses in cereal production and decline in water availability

Impact on the agriculture sector

Currently, Turkey produces over 33.5 mn tonnes of cereals pa and is a net exporter of food grains. 6% of the land is arable. Agriculture accounts for

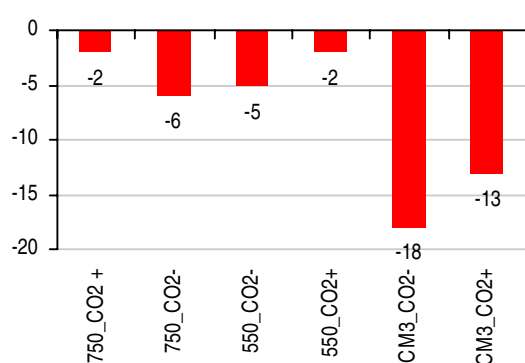
¹⁴⁴ EMDAT data base

¹⁴⁵ Relative to Pre-Industrial baseline (1850)

4% of employment, and it makes up 2.8% of GDP and over 2.7% of exports.

Crop modelling studies suggest that under different scenarios of climate change, decreases in food grain productivity in Turkey could vary from 2% to 18% by 2020.

Fig 164: % change in cereal yield in Turkey by 2020e

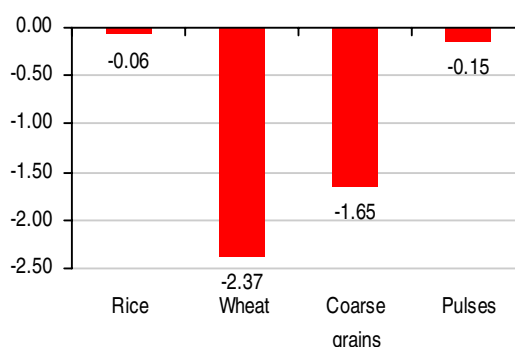


Source: SEDAC(750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

We estimate that food grain production in Turkey could decrease by approximately 4.2 mn tonnes pa.¹⁴⁶ The biggest decreases have been estimated to occur in wheat production, followed by coarse grain production.

Fig 165: Change in food grain production in Turkey by 202e (Mt pa)



Source: <http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor>

Per capita food grain production in Turkey is currently estimated at 0.47tonnes pa, which could decrease by 27 %, even when carbon fertilisation is taken into account.

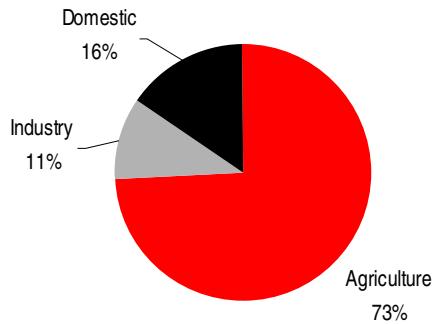
Impact on the water sector

Turkey is comfortably placed in terms of per capita water availability at more than 3,000 m3/year, while current water demand per capita is estimated to be 614 m3/year. However our estimate suggests that by 2025 Turkey could face a loss of 30% in per capita water availability while per capita water demand could decrease by 11.5%. About 97% of the Turkish population has access to safe water.

Turkey is especially prone to floods. Our analysis suggests that Turkey loses more than USD 80 mn pa to floods. In a warmer climate, floods in Turkey are likely to be more frequent and severe.

¹⁴⁶ <http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor>

Fig 166: Water use in Turkey (2007)



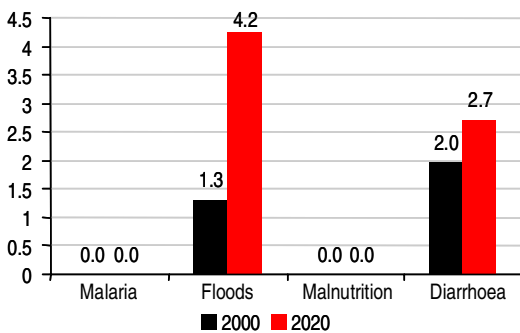
Source: World Bank statistics

5

Currently, the bulk of Turkey's water resources are used for agricultural purposes.

Impact on the health sector

Fig 167: Disability adjusted life year losses attributable to climate change in Turkey for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

WHO estimates suggest that flood induced diseases and diarrhoea are currently the biggest source of DALY losses, based on year 2000 data.

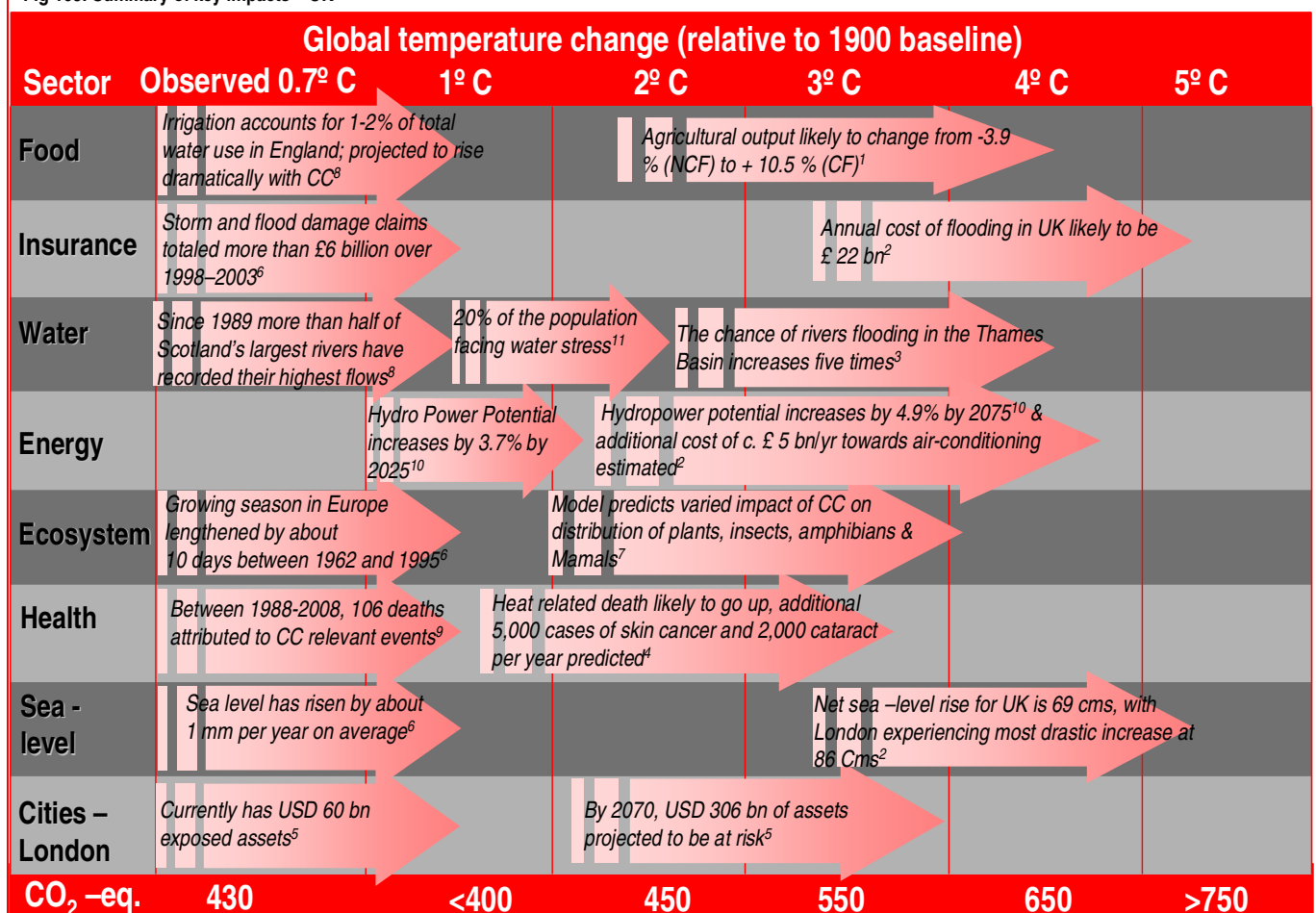
Approximately 1,300 DALYs were lost due to flood induced disability, and diarrhoea caused larger losses at around 2,000 DALYs. In a climate change scenario, these disabilities are projected to rise further, with flood induced disabilities likely to reach 4,200 DALYs pa and diarrhoea related DALY losses likely to reach 2,700 pa by the year 2020.

We estimate that currently climate change related disabilities in the form of flood disabilities and diarrhoea cost Turkey USD 35 mn pa in terms of productivity losses. By 2020, this is estimated to rise to USD 75 mn pa.

UK

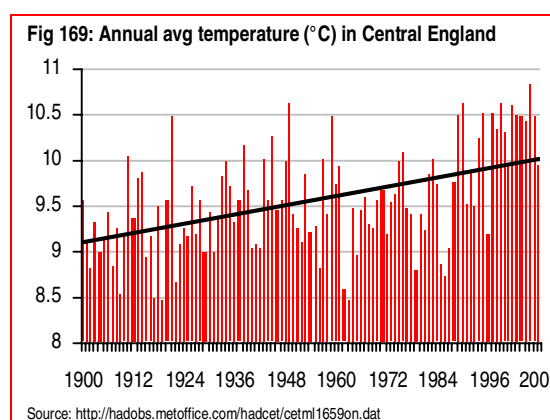
- ▶ HCVA assessment: 4th quartile; marginally vulnerable
- ▶ Per capita water availability could decrease by 4%
- ▶ While climate change induced disability losses could show a manifold increase
- ▶ On balance, the agricultural sector could see some positive impacts

Fig 168: Summary of key impacts – UK

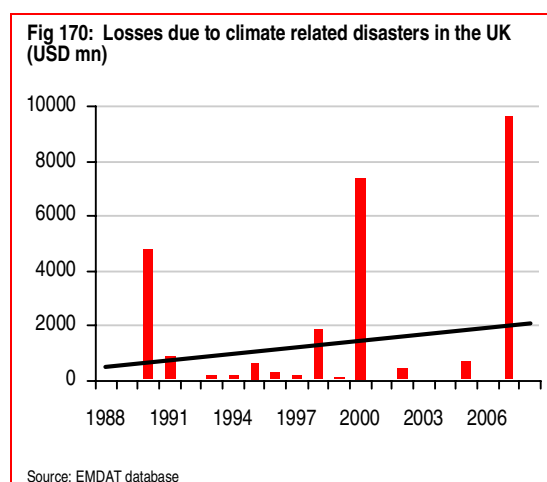


Source: 1Bill Cline, 2007 [NCF – No CO₂ fertilisation effect and CF – with CO₂ fertilisation effect.]; 2FOE, 2006; 3WWF - HSBC Climate Partnership, 2008; 4Department of Health; 5OECD, 2008; 64th National Communication, 2004 (UK); 7MONARCH project, 8Oxford University, 2007; 9EMDAT database, 2008 & HSBC; 10Lehner et al, 2001, 11Arnell, 2004

Central England has warmed by about 0.8°C in the last century. Despite not being among the most vulnerable of the G-20 nations, the UK is still exposed to the effects of climate change to a very expensive and dangerous extent. Specific exposures are illustrated in Fig 168. For example, annual flood losses could be around GBP 22 bn in the event of a temperature increase in excess of 3°C.¹⁴⁷



In the current climate UK experiences infrequent but relatively large economic losses due to climate related disasters¹⁴⁸. Intensity as well as the severity of these losses have increased in the last 20 years and are expected to rise further in a changed climate.



According to the most recent projections of the UK climate projections programme¹⁴⁹, summer temperatures across the UK are projected to rise between 1.8 and 2.3 °C, by 2020 under different emission scenarios compared to pre-industrial baseline.

Rainfall is projected to decrease all over the Island nation by between 2% and 7%, depending on the region and the emission scenario.

Table 27: Projected temperature and precipitation changes in the UK by 2020

	2020	
	Low emission scenario (at 50% probability)	High emission scenario (at 50% probability)
Temperature ¹⁵⁰ (°C)	1.9 to 2.3*	1.8 to 2.1
Rainfall ¹⁵¹	-3 % to -7%**	- 2% to -6%

* Change in mean summer temperature

** Change in Mean summer precipitation

Source: <http://ukclimateprojections.defra.gov.uk/content/view/513/527/>

As illustrated in Fig 170 the UK already experiences some economic losses due to climate related events, especially from floods. In a climate change scenario, the losses are expected to rise.

Impact on the agricultural sector

The UK's arable land is about 24% of its total land area. While agriculture accounts for only 1% of employment, it constitutes 0.9% of GDP and over 4.55% of exports. Currently, the UK produces 42 mn tonnes of cereals pa. The UK is a net exporter of food grains.

Climate change impact modelling for the UK suggests that under different scenarios of climate change, changes in food grain productivity in the UK could vary from a decrease of 3% to an increase of 4% by 2020.

¹⁴⁷ FOE, 2006

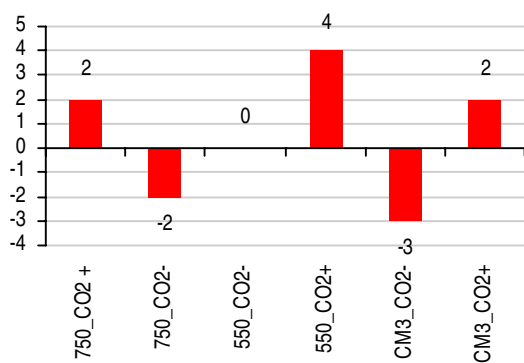
¹⁴⁸ Climate related disasters, considered in this analysis are as follows:- Drought, Extreme temperature, flood, Insect infestation, mass movement wet, mass movement dry, Storm and Wild fire.

¹⁴⁹ <http://ukclimateprojections.defra.gov.uk/>

¹⁵⁰ Relative to pre-industrial baseline (1850)

¹⁵¹ Relative to 1990 baseline

Fig 171: % change in cereal yield in the UK by 2020e

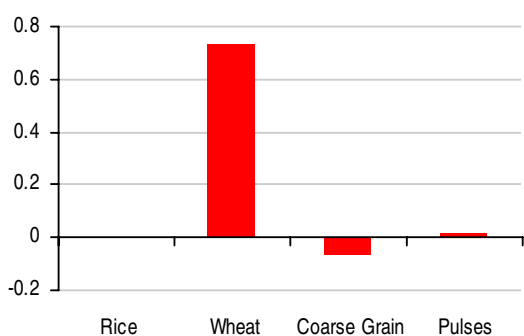


Source: SEDAC(750_CO2+ symbolizes 750 ppm stabilization scenario with co2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

Under this scenario, by 2020, food grain production in the UK could increase by about 1.6 mn tonnes pa. The biggest increase would be in wheat production, with small decreases in the production of coarse grains.

Fig 172: Change in food grain production in the UK by 2020e (Mt pa)



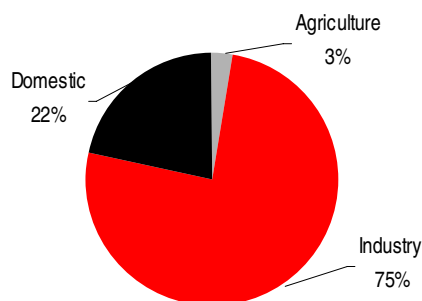
Source: HSBC

Per capita food grain production in the UK is currently estimated at 0.36 tonnes pa, which could decrease by a little under 1 % - population growth reduces the 2% increase in yield when carbon fertilisation is taken into account. Overall, agricultural impacts are unlikely to be serious in the UK.

Impact on the water sector

The UK has ample water resources, with availability of 2,420 m3/capita/year and it also provides universal supply of safe water to its citizens. Most of the water is used for industry (75%), with very little being used for agriculture (3%). In a warmer world, increased cooling needs of industry might increase demand for water.

Fig 173: Water use in the UK (2007)



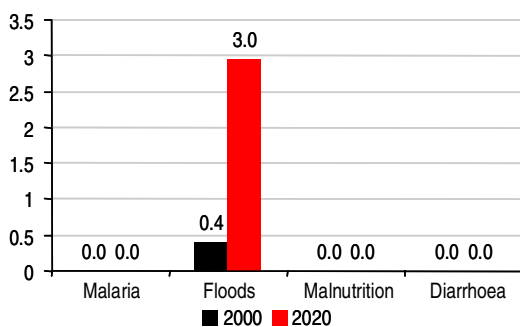
Source: World Bank Statistics

By 2025, our estimate suggests that the UK could lose 3.8% in terms of per capita water availability with per capita water demand increasing by 7%.

The UK has not suffered major drought related losses in the last two decades although it has suffered substantially from floods, to the tune of USD 15.67 bn over the last two decades (1988 to 2008), which translates into losses of USD 783 mn pa.

Impact on the health sector

Fig 174: Disability adjusted life year losses attributable to climate change in the UK for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

The WHO estimates suggest that flood induced disabilities are the biggest source of DALY losses in the UK.

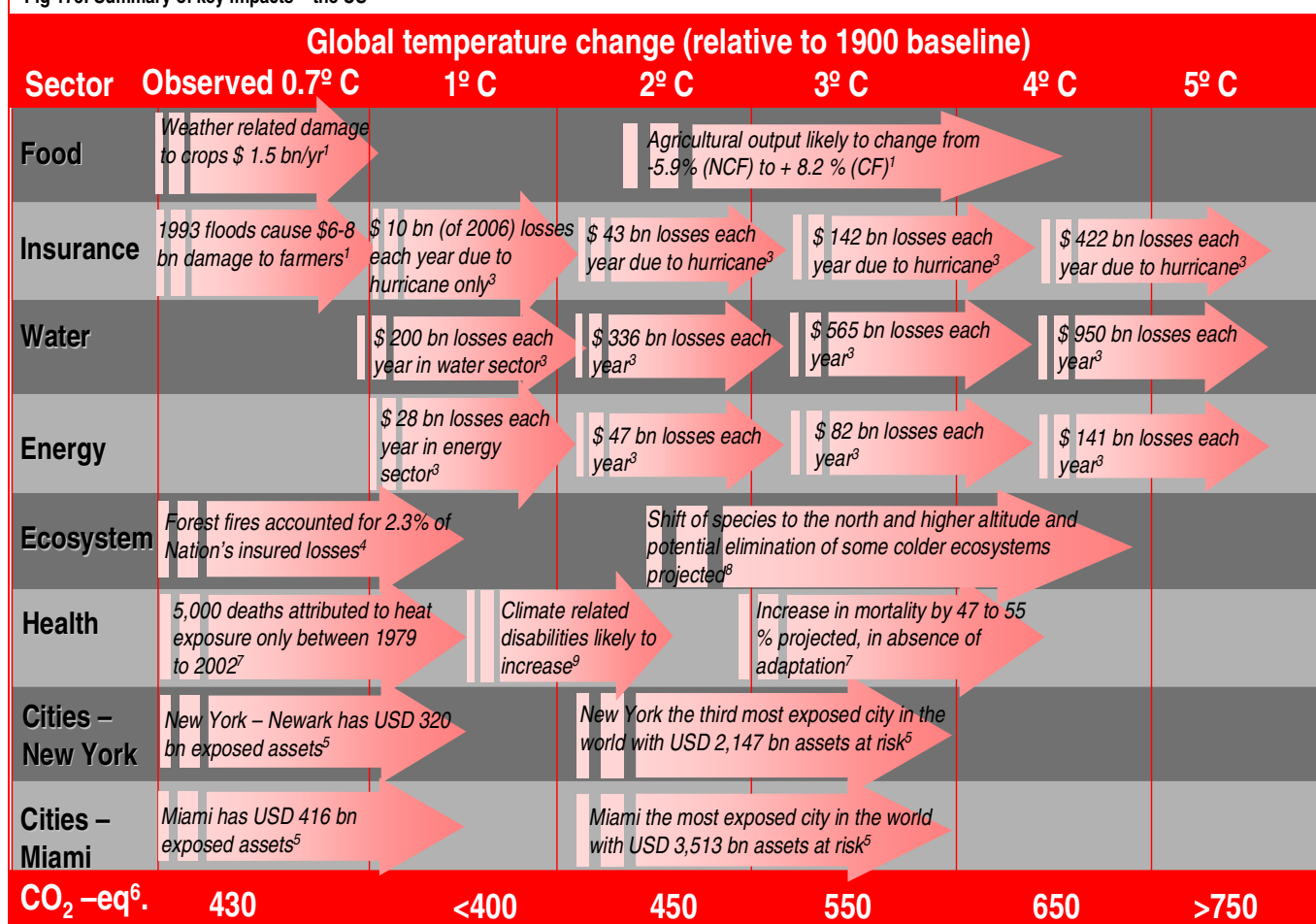
Currently, based on 2000 estimates, annual flood-related DALY losses are well below the 500 mark; these are projected to rise to 3,000 by 2020.

DALY losses cost the UK about USD 17 mn in 2000, and we estimate this cost to rise to USD 127 mn pa by 2020.

US

- ▶ HCVA assessment: 2nd quartile; moderately vulnerable
- ▶ Per capita water availability could decrease by 10%
- ▶ Cereal production could decrease by 10.5 – 15%.
- ▶ While climate change induced health losses could show a manifold increase

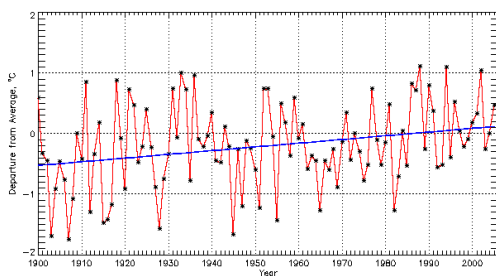
Fig 175: Summary of key impacts – the US



Source: 1Center for Integrative Environmental Research (Maryland University), 2007; 2Cline et al., 2007 [NCF – No CO₂ fertilisation effect and CF – with CO₂ fertilisation effect]; 3NRDC, 2008; 4USFS., 2006; 5OECD, 2008; 6CO₂ eqv of GHG concentration in ppm; 7US climate change Science programme, 2008; 8Pew Foundation, 2004; 9 WHO, 2007; [\$=USD

The US has seen its average temperature increase by over 0.5°C since 1900. Rainfall has become more concentrated in the last 50 years - the amount of precipitation falling in the rainfall events having the highest volume (top 1 percentile) has increased by 20%.¹⁵²

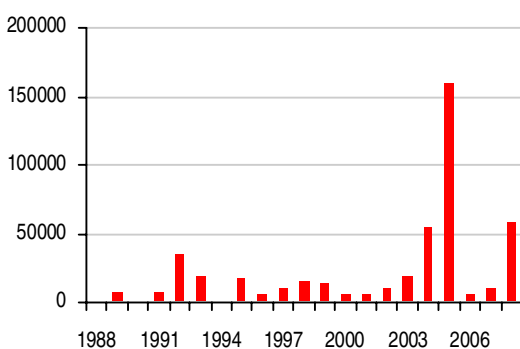
Fig 176: Temperature anomaly in the US 1900-2005 (°C)



Source: <http://www.ncdc.noaa.gov/gcag/index.jsp>

According to climate change projections from the Climatic Research Unit¹⁵³, the US is likely to experience between 1.5 and over 4 °C of temperature increases by the end of the century as well as increases of up to 16.8% in the national average rainfall.

Fig 177: Losses due to climate related disasters in the US (USD mn)



Source: EM DAT database

As illustrated in Fig 177, the US is already experiencing significant economic losses from climate related events.

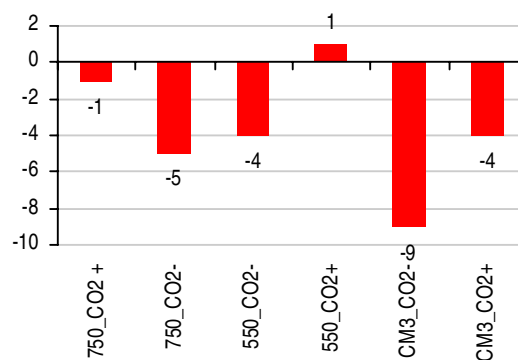
In a climate change scenario these losses are expected to rise. A recent NDRC (Natural Resources Defense Council) study estimates that by 2025, hurricane damage will reach USD 10 bn pa, real estate losses will reach up to USD 34 bn pa, and the energy sector might suffer a loss of USD 28 bn pa. Also, the water sector might suffer huge losses of USD 200 bn pa by 2025¹⁵⁴.

Impact on the agricultural sector

Currently, the US produces 352 mn tonnes of cereals. It was the world's largest food exporter by far in 2007. 19% of its land is arable, but agriculture constitutes only 0.9% of GDP and accounts for only 2% of employment.

Crop impact modelling suggests that under different scenarios of climate change, by 2020 changes in food grain productivity in the US could vary from a decrease of up to 9% to an increase of just 1%.

Fig 178: % change in cereal yield in the US by 2020e



Source: SEDAC (750_CO2+ symbolizes 750 ppm stabilization scenario with CO2 fertilisation effect, similarly 550_ means 550 ppm stabilization scenario; CM3 is a global climate model output while + and - respectively denote the presence and absence of CO2 fertilisation effect)

Out of these scenarios, we have chosen the CM3_CO2+ scenario, which includes the benefit of carbon fertilisation, for further analysis.

We estimate that food grain production in the US under our chosen scenario could decrease by

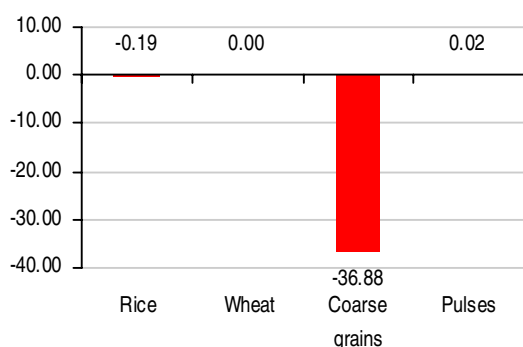
¹⁵² Global Climate Change Impacts in the US (Global Change, US)
¹⁵³ University of East Anglia

¹⁵⁴ <http://www.nrdc.org/globalwarming/cost/cost.pdf>

about 37 mn tonnes pa. The decrease in productivity is different for different plants, and coarse grains (corn, barley, oats, etc.) suffer the most. Under this scenario, coarse grain productivity decreases by 13%, and this brings the overall US food grain production loss to 10.5% since they make up more than 60% of the cropped area in the US.

Per capita food grain production in the US is currently estimated at 1.14 tonnes pa, which could decrease by 20% by 2020, even when carbon fertilisation is taken into account.

Fig 179: Change in food grain production in the US by 2020e (Mt pa)



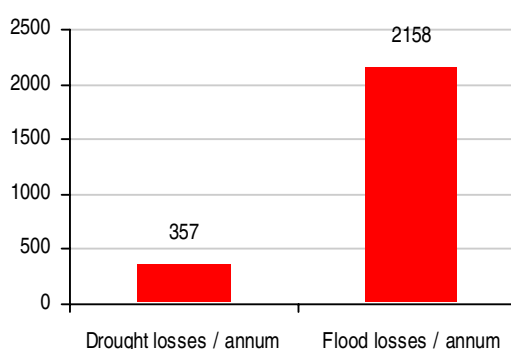
Source: <http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor>

Impact on the water sector

Like other well-developed countries, the US has excellent water provision with the majority of the population having access to fresh water supplies. Currently, per capita water availability is estimated to be 9,976 m³/capita/year (2007), which is much higher than the 1,000 m³/capita/year threshold for categorizing a country or population as water stressed. However, water resources are not evenly distributed across the country. While the eastern parts of the country are water abundant, western and interior parts suffer from perennial water shortages. Our analysis suggests that the US loses more than USD 2.5 bn pa to floods and droughts.

We estimate that per capita water availability could decrease by 10% by 2025 while water demand, which is currently estimated at 972 m³/capita/year, could increase by a whopping 51% making the US one of the most water thirsty countries among the G-20.

Fig 180: Flood and drought related average losses pa (1988-2008) in the US (USD mn)



Source: HSBC (Based on EMDAT data)

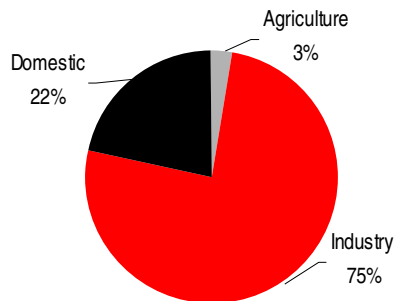
As a result of the inequitable geographic distribution of water currently 31% of the land area is categorised as water stressed, which is projected to expand considerably in the south-western and mid-west regions of the US.

More than 75% of current water resources in the US are used for industrial purposes. There have been no major losses in the power generation sector in the US due to heat waves - however, in 2007, nuclear plants in the south-eastern US faced a major threat of closure due to drought induced water shortages.¹⁵⁵

¹⁵⁵

http://www.ceres.org/Document.Doc?id=406&bcsi_scan_B786307563EE7842=z2nDBwbKAPi54kK2i0Uj+CMAAAAs5usQ&bcsi_scan_filename=Document.Doc

Fig 181: Water use in the US (2007)

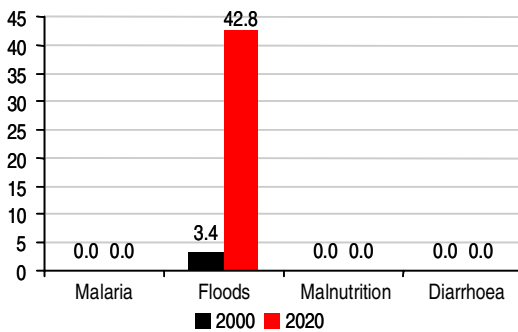


Source: World bank Statistics

In a warmer climate, drought and heat induced water shortages could bring significant power-related costs for industry, either from price spikes, or from lost production due to lack of water for cooling nuclear or thermal power plants.

Impact on the health sector

Fig 182: Disability adjusted life year losses attributable to climate change in the US for 2000 and 2020e (000)



Source: HSBC (WHO, 2007)

Flood induced disabilities seem to be significant in the US and on an average cause a loss of more than 3,000 DALYs pa, based on WHO estimates from 2000. Our analysis suggests that due to more frequent severe floods, flood induced disabilities are likely to rise to 43,000 DALYs pa by 2020.

Malaria, malnutrition and diarrhoea are not expected to be health concerns in the US, even with climate change, at least up until 2020.

Our analysis suggests that currently flood induced disabilities cost the US more than USD 150 mn pa in terms of lost productivity, which we expect could rise to USD 2 bn pa by 2020.

Appendices

Appendix 1

SRES Scenarios

Different storylines of growth

The Special Report Emission Scenarios (SRES)¹⁵⁶ are defined by the IPCC thus:

A1 storyline

The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).

Balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end-use technologies.

A2 storyline

The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions

converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines.

B1 storyline

The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

B2 storyline

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

¹⁵⁶ <http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf>

Appendix 2

Methodology

HSBC Climate Vulnerability Assessment

Concept of Vulnerability

According to Working Group II of the IPCC Fourth Assessment Report, vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. It further states that vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

IPCC defines **exposure** as the character, magnitude, and rate of climate change and variation to which a system is exposed; **sensitivity** is defined as the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise) and **adaptive capacity** is defined as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Methodology

The HSBC Climate Vulnerability Assessment (HCVA) has been designed following the OECD methodology, as outlined in Freudenberg., 2003 - an OECD technical paper .

The methodology involves the following steps:

- 1 Developing a theoretical framework for the composite.
- 2 Identifying and developing relevant variables.
- 3 Standardizing variables to allow comparisons.
- 4 Weighting variables (and groups of variables).
- 5 Conducting sensitivity tests on the robustness of aggregated variables.

We have computed the composite indicator by using the following equation.

where :

$$I = \sum_{i=1}^n w_i X_i$$

I : Composite Index

X_i: Normalised variable,

w_i: Weight of the X_i , where 0 ≤ w_i ≤ 1 and

i: 1,2,3,...n.

Sector profiles

While we use the IPCC climate scenarios (explained in Appendix 1) for the storyline of the changes over the next 10 years, we also rely on some of the global climate models for some of the maps and tables shown in this study, such as the HadCM3 and ECHAM4 models.

HadCM3 (abbreviation for the Hadley Centre Coupled Model, version 3) is a coupled atmosphere-ocean general circulation model (AOGCM) developed at the Hadley Centre in the United Kingdom. It is a global climate model, which is used to project future climate.

ECHAM4 is the fourth-generation atmospheric general circulation model developed at the Max Planck Institute for Meteorology (MPI) in Hamburg.

In the Agriculture sector analysis, forecasts for a few scenarios have been provided: scenario 750_CO2 refers to a 2020 scenario leading to 750 ppm of CO2 stabilization by 2100, 550_CO2 refers to a pathway leading to a CO2 stabilization scenario at 550 ppm by 2100. For the 2020 timeframe, we consider CM3 as being the most

likely and discuss the results of this model in detail for each country. The (+) and (–) signs next to each scenario, refers to the inclusion or the exclusion of the CO2 fertilisation effect.

For the water sector analysis, we have used a number of sources, including Alcamo et al., 2007, World Bank Statistics, FAO- AQUASAT, 2008.

Identifying and developing relevant variables

As described in the text above, for the purpose of the present analysis we have considered vulnerability as the function of climate change exposure, sensitivity and adaptive capacity.

Vulnerability = function of (exposure, sensitivity, adaptive capacity).

Table 29: Projected impact of climate change on 2020 GDP estimates (%)

Country	NORDHAUS, 2008	STERN, 2006	Min 2020	MENDELSON, 2007	
	2020	Mean 2020		Max 2020	Mean 2020
Argentina	NA	NA	NA	NA	-0.03
Australia	NA	NA	NA	NA	0.02
Brazil	NA	NA	NA	NA	0.02
Canada	NA	NA	NA	NA	-0.01
China	NA	0	0	0.02	0.01
EU	NA	0.02	0	0.06	-0.02
France	NA	NA	NA	NA	-0.01
Germany	NA	NA	NA	NA	-0.01
India	NA	0.8	0.1	2.2	0.02
Indonesia	NA	NA	NA	NA	0.03
Italy	NA	NA	NA	NA	0
Japan	NA	NA	NA	NA	0
Mexico	NA	NA	NA	NA	-0.01
Russia	NA	-0.07	-0.2	0	-0.04
Saudi Arabia	NA	NA	NA	NA	0.02
South Africa	NA	NA	NA	NA	0.01
South Korea	NA	NA	NA	NA	0
Turkey	NA	NA	NA	NA	-0.05
UK	NA	NA	NA	NA	-0.01
US	NA	0.01	0	0.02	0.01

Source: HSBC (Nordhaus, 2008; Stern, 2006; Mendelsohn et al., 2007)

Table 30: Variables used for computation of sensitivity scores¹⁵⁷

Country	1988 to 2008 No. of Deaths (Nos.)	1988 to 2008 No. of Homeless (in 000s)	1988 to 2008 No. of Affected (in mn)	1988 to 2008 Estimated damage cost (US\$(mn))	1998 Population (in mn)
Argentina	317	127.5	5.7	5495.2	36.1
Australia	234	17.0	15.7	16174.5	18.7
Brazil	2597	903.2	17.6	5358.2	169.1
Canada	106	12.9	0.1	11639.1	30.1
China P Rep	42135	52663.1	2357.1	217801.2	1248.9
France	21379	0.5	3.6	27372.2	58.8
Germany	9634	0.0	0.6	35170.1	82.2
India	58352	7570.6	913.2	35348.1	1009.9
Indonesia	5825	70.4	9.7	11833.5	206.0
Italy	20473	10.5	0.1	27547.5	57.5
Japan	1340	14.0	1.8	59005.9	126.5
Mexico	4009	677.7	7.2	20878.2	96.9
Russia	3153	43.1	3.9	4115.6	148.3
Saudi Arabia	99	0.0	0.0	0.0	19.7
South Africa	705	45.3	16.9	2450.8	44.0
South Korea	1906	195.8	0.8	13921.4	46.1
Turkey	877	99.6	1.6	1657.5	66.0
UK	605	30.0	0.8	27575.7	58.5
US	7357	401.0	11.4	463155.1	279.0

Source: EMDAT database (<http://www.emdat.be/>)

There is no universal consensus among scientists as to which data points best represent sensitivity, exposure and adaptive capacity to climate change (CC). It is agreed that vulnerability analysis is highly situation specific and appropriate representative data may be chosen based on the expert judgment and availability of data. For the purpose of the present analysis, we have selected the following proxy data points to effectively represent each of the determinants of vulnerability as shown in table 28.

Data descriptions

Exposure:

Data on the projected impact of CC on GDP has been compiled from peer-reviewed published literature. Data sources and scenarios taken into consideration for this parameter are mentioned in table 29. The Nordhaus study does not report impact estimates for 2020, hence Nordhaus estimates are not utilized in preparing our headline 2020 vulnerability score. However, we

do incorporate Nordhaus (2008) estimates in the sensitivity analysis as presented in Appendix 3, for the scenario of long term (2100) modelling.

Data on sensitivity

Sensitivity data was obtained from the International disaster database (EMDAT). EMDAT is a global database on natural and technological disasters that contains essential core data on the occurrence and effects of more than 17,000 disasters in the world from 1900 to present. EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the School of Public Health of the Université catholique de Louvain located in Brussels, Belgium¹⁵⁸.

Sensitivity data used in the analysis is shown in Table 30. All estimates pertain to 20 years' climate related disasters loss data, from 1988 to 2008. Sensitivity was computed by using the adding the four factors of number of deaths, homeless population, affected population, and climate change related damages in USD

¹⁵⁷ Droughts, extreme temperatures (e.g. heat waves, cold waves), floods, insect infestation, mass movements wet and dry (landslides, avalanche etc.), storms and wild fires – For their detailed definitions see the section on Climate Risks

¹⁵⁸ <http://www.emdat.be/>

(weighted in the ratio of 50%: 25%: 5%: 20% respectively) and dividing by the total population of that country for the year 1998, which is the mid year of the 20-year span used.

Table 31: Data set representing adaptive capacity

Country	2006 Life Expectancy (years)	2007 Adult Literacy rate (aged 15 and above) (%)	2007 GDP/Per capita (PPP) \$
Argentina	76.32	97.2	13244
Australia	80.62	99	34882
Brazil	72	88.6	9570
Canada	80	99	35729
China	72	90.9	5345
EU	79	99	30513
France	81	99	33414
Germany	79	99	33154
India	64	61	2753
Indonesia	70.16	90.4	3728
Italy	81	98.4	29934
Japan	82	99	33525
Mexico	74	91.6	12780
Russia	66	99.4	14743
Saudi Arabia	75.88	82.9	22907
South Africa	51	82.4	9736
South Korea	79.1	99	24712
Turkey	72.88	87.4	12481
UK	79	99	33535
US	78	99	45790

Source: World Bank, 2008 & UNDP, 2008

Standardizing variables

To allow comparisons, the variables were standardized using the following approach:

Standard value =

$$100 * [(Actual\ value - Minimum\ value) / (Maximum\ value - Minimum\ value)]$$

Weighting variables

Variables are assigned the weights as shown as in However for the countries where only no Stern or Nordhaus estimates were available, Mendelsohn values were assigned a weight of 1. Sensitivity to this weighing scheme is explored in the appendix 3.

Table 32: Dataset representing the weighting scheme

Variables	Weight (%)	Parameters	Source	Weight (%)
Exposure	0.5	% Impact on GDP	Nordhaus, 2007	0
			Stern, 2006	0.5
			Mendelsohn, 2007	0.5
Sensitivity	0.25	No. of persons Killed due to weather related events	EMDAT disaster database	0.5
		No. of persons rendered homeless due to weather related events		0.25
		No. of persons affected due to weather related events		0.05
		Damage Cost (USD)		0.2
Adaptive capacity	0.25	Life Expectancy	World Bank, 2008	0.25
		Literacy (%)	UNDP, 2008	0.25
		Per Capita GDP	World Bank, 2008	0.5

Source: HSBC

Appendix 3

Sensitivity Analysis

How reliable are our vulnerability estimates?

Models and estimates are based on assumptions. However, it is useful to know to what extent our assumptions influence the model results.

On **Exposure** measures, we note that there is a large difference between the estimates of economic impact of climate change from three sources used namely Nordhaus, 2008; Stern, 2006 and Mendelsohn, 2007.

Nordhaus and Stern data is available only for 3 to 4 countries, as opposed to Mendelsohn, which is available for all the countries. This might affect the results for these 3-4 countries.

To test this sensitivity, we ran the vulnerability model twice - firstly with the inclusion of Stern and Nordhaus values alongside Mendelsohn values (for 2020) and secondly with only the Mendelsohn values.

The result of this sensitivity analysis was:

- 1 China swaps rank with Indonesia, moving into 2nd place from 5th.
- 2 Some other countries also change positions by one or two ranks.
- 3 South Korea, Italy, Mexico, Canada, Germany, UK, Argentina, Russia and Turkey do not change their relative ranking.

We note here that there was no change at either end of the spectrum, as India remains at the top of the list of vulnerable countries among the G-20 under both approaches and Turkey, Russia, and Argentina remain among the least vulnerable countries.

On **Adaptive capacity**, we note that some of the input variables might have high correlation between them. Life expectancy and literacy may be closely linked and it may be assumed that they measure the same underlying phenomenon, therefore it may be appropriate to increase the relative weight of per capita GDP in the adaptive capacity measure.

To assess the sensitivity of such a phenomenon, we run the model using two approaches. One in which we retain all 3 parameters, life expectancy, literacy and per capita GDP as the constituents of our adaptive capacity measure and, second, in which we retain only two constituents ie life expectancy and per capita GDP, thus essentially putting a larger weight on the per capita GDP variable than in the former approach.

The result of this sensitivity analysis was:

- 1 Brazil jumps from 4th to 3rd rank
- 2 Indonesia moves from 5th to 2nd
- 3 South Africa moves from 6th to 4th rank.

However, the broad findings remained the same - India was still the most vulnerable country and Russia, Argentina and Turkey were the least vulnerable nations in the G-20.

We believe that the sensitivity analysis reveals no major drawbacks in the choice of variables for the HCVA model.

A further test was conducted, the results of which is shown in the Fig 183. In this, we calibrated all the Nordhaus, Mendelsohn, and Stern values on a scale of 0 to 1. We find that all the studies generally agree in their trend even though they may vary in their absolute values. Hence for certain countries, the use of Mendelsohn values alone are justified, as it is the trend which is more relevant for the purpose of the HCVA score rather than the absolute values.

Short term vs. long term vulnerability (2020 vs. 2100)

Our short term as well as long term vulnerability estimates are compared in Table 33. We see that the broad secular trend remains the same. However the major change is in the relative positioning of Turkey and Canada. The difference arises mainly in the exposure score which relies heavily on Mendelsohn estimates for these two countries.

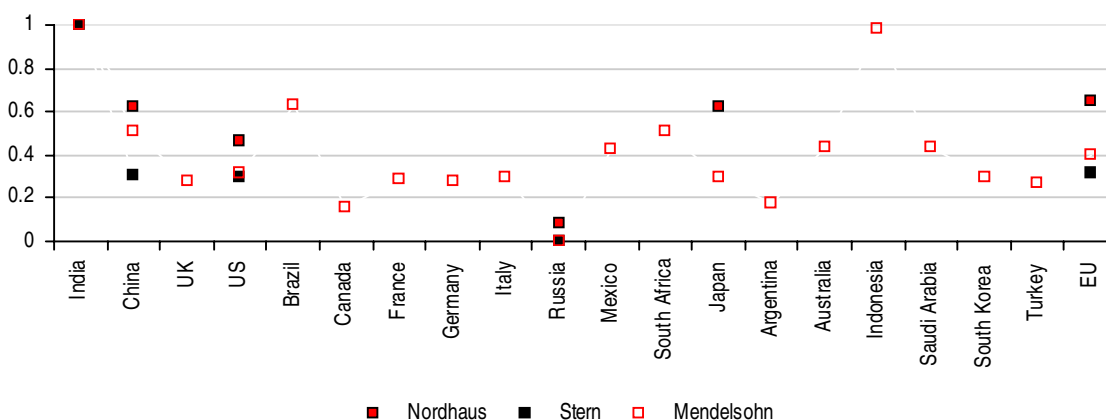
Table 33: Short term vs. long term vulnerability

Country	Rank by 2100	Rank by 2020
India	1	1
Indonesia	2	2
Brazil	3	3
China	4	5
South Africa	5	4
EU	6	11
US	7	7
France	8	8
Japan	9	10
Mexico	10	14
Saudi Arabia	11	6
Australia	12	9
Turkey	13	20
South Korea	14	12
Italy	15	13
Argentina	16	18
Germany	17	16
UK	18	17
Canada	19	15
Russia	20	19

Source: HSBC

By 2020, Turkey could gain 0.05% of its GDP as a result of climate change while Canada is estimated to gain 0.01%. By 2100, Turkey could still gain 0.04% of its GDP vs 0.23% by Canada. Hence, based on our model, the long-term trend reveals India, Indonesia, Brazil, China and South Africa to be most vulnerable and Canada and Russia to be least.

Fig 183: Trend in Composite values (on a scale of 0 to 1) from Nordhaus, Stern and Mendelsohn studies



Source: HSBC

Appendix 4

HCVA FAQs

What sources have been used?

In this analysis, an effort has been made to keep the sectoral risk assessment consistent and comparable across the G-20. To the extent possible, peer reviewed published literature, preferably frequently quoted by the IPCC, has been used. We use global studies where possible, and we have used regional and national level studies, where available, to supplement our understanding of the climate-related impacts in a particular country.

See Appendix 3 for detailed discussion on variables and models used for the HCVA and the three sector profiles (agriculture, water and health).

How was the impact on food grain production calculated?

We have calculated this impact in four steps:-

Step 1: - We obtained estimates of climate change impacts on yield (% change) from Socio-Economic Data and Application Centre) SEDAC¹⁵⁹ for wheat, rice, coarse grains and protein feeds (pulses) for the 2020 time period for the CM3 scenario under the assumption of carbon fertilisation. SEDAC is a research institute and this work of SEDAC has been extensively quoted by IPCC and other authorities (e.g. Bill Cline¹⁶⁰).

Step 2: - Regional data was extrapolated to country level by using the BLS region and country relation¹⁶¹ provided by SEDAC.

Step 3: We have estimated the impact of CC on food grain production by considering land area under cultivation (last decadal average) as constant and by varying the yield as calculated in Step 1.

Step 4: We have monetised the loss or gain by using end- 2008 prices^{162,163, 164}.

How was the impact on health calculated?

We have calculated this impact in four steps:-

Step 1: The impact of climate change on health has traditionally been estimated in terms of the number of observed and projected deaths. However, for the purpose of this study, the impact of climate change on health has been estimated in terms of DALYs (or Disability Adjusted Life Years). These estimates are reported by the World Health Organisation (WHO) for the year 2020¹⁶⁵

Step 2: Regional estimates were extended to country level estimates by using WHO regional definitions.

¹⁵⁹ http://sedac.ciesin.org/giss_crop_study/CCMmethod.html?bcsi_scan_B786307563EE7842=0&bcsi_scan_filename=CCMmethod.html
¹⁶⁰ Bill Cline, 2008

¹⁶¹ <http://sedac.ciesin.org/cgi-bin/charlotte#BLSsection>

¹⁶² <http://www.fao.org/es/esc/prices/PricesServlet.jsp?lang=en>

¹⁶³ <http://faostat.fao.org/site/570/default.aspx#ancor>

¹⁶⁴ http://siteresources.worldbank.org/INTDAILYPROSPECTS/Resources/Pnk_0809.xls

¹⁶⁵ WHO (2007) Quantifying the health impact at national and local levels, Environmental Burden of Diseases Series, No. 14.

Step 3: DALYs were monetized by multiplying total DALYs by the current per capita income (2008) in the concerned countries. (This keeps our 2020 estimates of losses in 2008 dollar terms.)

How was the impact on water resources measured?

Water availability estimates: A review of the water availability data from FAO- AQUASAT suggests that total water availability has been static through the last four decades. 2025 projections for the A2 scenario were obtained based on Alcamo et al., 2007 who report 2025 projections with regard to a 1960 to 1990 baseline. Alcamo et al report water availability estimates on a river basin level, which we extrapolated to the country level. Modelled baseline estimates were compared with the observed data spanning the same time period from FAO-AQUASAT (for the year 1977) and the differences were added to the projections using the method of anomalies to make the two datasets comparable thus:

Anomalies = Observed - model baseline.

Our Projections = model projections + anomalies.

Water demand estimates: 2000 figures are the latest water withdrawal statistics available and are taken from FAO-AQUASAT, while per capita figures are available for 2002 as well. 2025 projections for the A2 scenario are obtained based on Alcamo et al., 2007 who report 2025 projections with regard to a 1995 baseline. Modelled baseline estimates were compared with the observed data spanning the same time period from World Bank statistics and the differences were added to the projections. For Saudi Arabia, water demand estimates (total and per capita) refer to 2006 and 2007, as earlier estimates are not available.

However, it is pertinent to provide a caveat here that impacts on water resources are generally difficult to quantify due to high levels of uncertainty prevailing in precipitation forecasts from global circulation models. Additionally, our extrapolation from river basin scale to country scale may not provide an accurate reflection of the countries' water resources.

Disclosure appendix

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