AGRICULTURE

ESTIMATES GLOBAL CARBON IMPACT

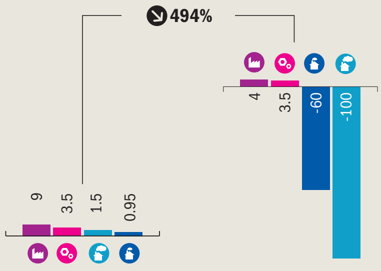
2010 EFFECT TODAY

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

2030 EFFECT TOMORROW

USD **GAIN** PER YEAR **150 BILLION**

ECONOMIC IMPACT



CONFIDENCE
INDICATIVE

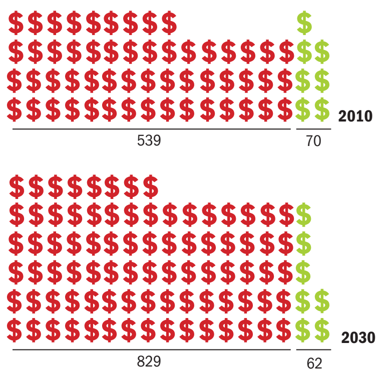
SEVERITY

AFFECTED

MDG EFFECT

- Air pollution harms people and has damaging and toxic effects for plants, impairing agricultural productivity
- Not all emissions are toxic: CO_2 is a natural ingredient in photosynthesis, and enhances plant growth in optimal conditions
- The positive effects of "carbon fertilization" are often cancelled out by negative effects of localized/regional air pollution
- Net losses are substantial; but as CO_2 levels climb, so do positive effects on plant growth, and by 2030 will far outweigh harmful concerns linked to localized pollution, making the effect for agriculture the largest positive contribution of the carbon economy

RELATIVE IMPACT



HOTSPOTS

2010	$	2030
6,750	USA	8,000
1,500	RUSSIA	4,750
350	SYRIA	2,500
200	IRAN	1,250
650	CANADA	1,250

GEOPOLITICAL VULNERABILITY

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

$ = Losses per million USD of GDP

Change in relation to overall global population and/or GDP

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

It has long been recognized that crop growth can be positively stimulated when the air contains more CO_2 (Idso, 1989). It has also been assumed that this positive effect—thought to entail a 30% boost to agriculture in the medium term—offsets completely or partially all other negative effects of climate change, at least initially (Mendelsohn in Griffin (ed.), 2003). However, GHG emissions and their by-products or co-pollutants also have a wide range of negative effects on crops and their yields; these concerns have increased significantly, with the evidence of gigantic transcontinental atmospheric brown clouds, which shut out sunlight and choke plant life (Auffhammer et al., 2006; Ramanathan and Fen, 2009). Bangladesh has actually seen its sunlight hours shrink by one-quarter over the past approximately 30 years, as a result of the growing dimming effect of pollution, and its negative implications for agricultural productivity (Ashan et al., 2011; Ramanathan et al., 2008). Toxic pollutants, such as acid rain and ozone that are trapped at ground-levels further inhibit plant growth (World Bank, 2005: Leisner and Ainsworth, 2011). By 2030, ground ozone alone in the South Asian region is expected to surpass the level at which crop losses would attain 25% (Ramanathan et al., 2008). Extensive field-testing of crop responses to ambient CO_2 has also slashed earlier estimates of potential benefits by half or more (Ainsworth et al., 2008; Leaky et al., 2009). Regional studies that attempt to "disentangle" all the different contributing factors have shown that the negative effects of the carbon economy and climate change outweigh any positive benefits, and worsen with further warming (Welch et al., 2010). From the perspective of the carbon economy alone, initial negative impacts should progressively be cancelled out as CO_2 increases its concentration in the Earth's atmosphere. Today's losses are not significant or geographically pertinent enough to directly affect food security. The large-scale gains expected in 2030 are still only half the scale of the losses simultaneously estimated to be incurred as a result of climate change.

HAZARD MECHANISM

Common air pollutants from industrial and transportation sources affect agriculture in four key ways. First, ozone is a by-product of many carbon-intensive activities, and, while acting beneficially in the upper atmosphere, it is toxic for humans and plant life at ground level and limits agricultural productivity and growth potential in a variety of ways (OECD, 2012). Affected zones are shown to experience reductions in the productivity of a range of staple crops from 5 to 20% (Feng and Kobayashi, 2009; Leisner and Ainsworth, 2011; Wilkinson et al., 2012). Second, instance, acid rain, formed in particular from sulphur and nitrogen emissions, increases the acidity of soils with limited natural capacity to neutralize acidity loads; it is also toxic for plants, impairing productivity (World Bank, 2005; Wang et al., 2009; Ping et al., 2011). Third, in some areas a lowering of the plant photosynthesis potential for many crops is an impact of so-termed "global dimming," or a persistent reduction in solar energy due to widespread atmospheric pollution clouds which absorb and alter the transmission qualities of solar radiation (Stanhill and Cohen, 2000; Kumari et al., 2007; Wang et al., 2009; Ramanathan et al., 2008). However, some experts have argued that certain staple crops, such as shade-casting canopy-type plants, may benefit from more diffuse light refracted through immense atmospheric brown clouds (Zheng et al 2011; Roesch et al., 2012). All these effects are geographically restricted and mainly confined to regions peripheral or adjacent to the world's major industrial centres. The fourth effect, referred to as "carbon fertilization," is the only one considered to be positive and differs from the other concerns in that it can be felt globally, since CO_2 is evenly dispersed in the earth's atmosphere. As a result, its benefits are more widespread and significant than the counteracting effects of ozone, acid rain, and dimming, but may only be gained up to a certain point (not surpassed by 2030); plants only receive the full benefits under optimal conditions, since accelerated growth requires more moisture and nutrients to sustain (Van Veen et al., 1991; Long et al., 2005 and 2006; IPCC, 2007).

IMPACTS

The global impact of carbon-related emissions on agriculture is today estimated at around 15 billion dollars a year in losses. By 2030 however, an incremental increase in losses tied to anticipated emissions growth is estimated to be largely offset through CO_2-derived stimulus of the world's

BIGGER PICTURE

N/A

SURGE

OCCURRENCE

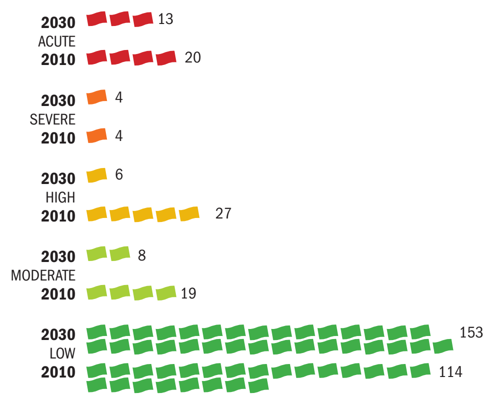
N/A

PEAK IMPACT

N/A

GENDER BIAS

VULNERABILITY SHIFT



INDICATOR INFORMATION

MODEL: Avnery, 2011; Hansen et al., 2007; Ramanathan et al., 2008; World Bank, 2005

EMISSION SCENARIO: OECD, 2012

BASE DATA: FAOSTAT, 2012; Portmann et al., 2010; Ramankutty and Foley, 1999

= 5 countries (rounded)

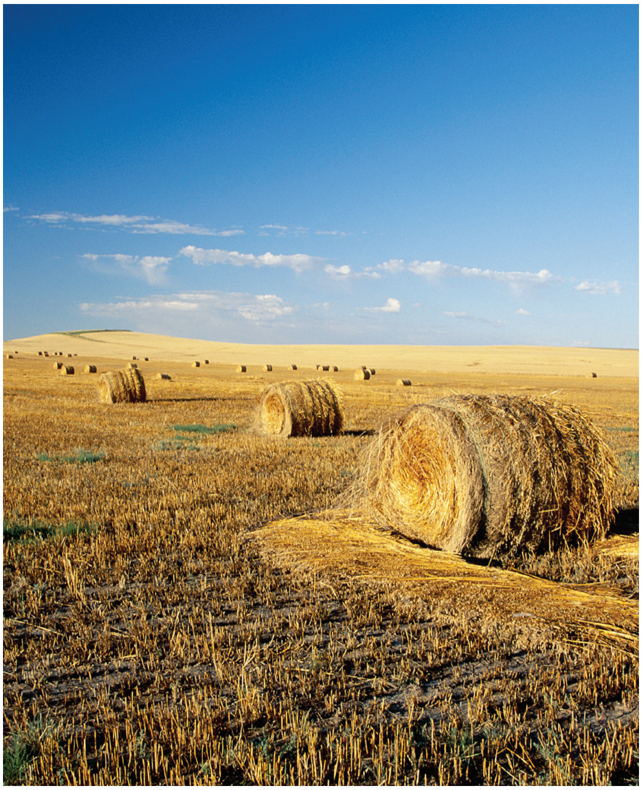
Acute · Severe · High · Moderate · Low

staple crops. Potential net gains could reach a substantial 170 billion dollars a year.

The most negative effects are quite restricted and concern a heterogeneous group, dominated by industrialized or newly industrialized economies, including numerous former Soviet Union countries. The US, China, Russia, and India experience the largest total losses, with the US incurring 7 billion dollars a year in costs in 2010 and the others between 1 and 2 billion dollars in losses.

Initially the positive end of the spectrum is dominated by low-income, low-emitting African and Pacific island nations, who, far from the toxic emissions of the fastest-growing emerging economies, enjoy less contaminated air but are predisposed to the benefits of carbon fertilization, as it is uniformly diffuse in the atmosphere.

By 2030, the picture of countries benefitting is considerably altered through the possibility of widespread gains resulting from carbon fertilization. With its 80 billion dollars in benefits, China far exceeds the more modest gains experienced by a handful of large developing countries still expected to have agricultural sectors of significant size.



THE INDICATOR

The indicator combines the separate information of acid rain effects (sulfur dioxide and nitrogen dioxide) with ground-level ozone toxicity, and crop responses to solar radiation variation resulting from atmospheric pollutant clouds (World Bank, 2005; Avnery et al., 2011; OECD, 2012; Ramanathan et al., 2008; Hansen et al., 2007). Global crop and irrigation maps and agricultural production are based on independent models and UN Food and Agriculture Organization (FAO) data (Portmann et al., 2010; Ramankutty and Foley, 1999; FAOSTAT, 2012). Carbon fertilization effects have been attributed according to the mid-point of estimates aggregated by the IPCC (IPCC, 2007). Countries are deemed to benefit completely, partially, or not at all from the stimulation, depending on the severity of combined climate change and carbon effects as assessed in the Monitor at country level. Recent research is less optimistic regarding the potential benefits of CO^2 fertilization than presented here (Ainsworth et al., 2008; Leaky et al., 2009).

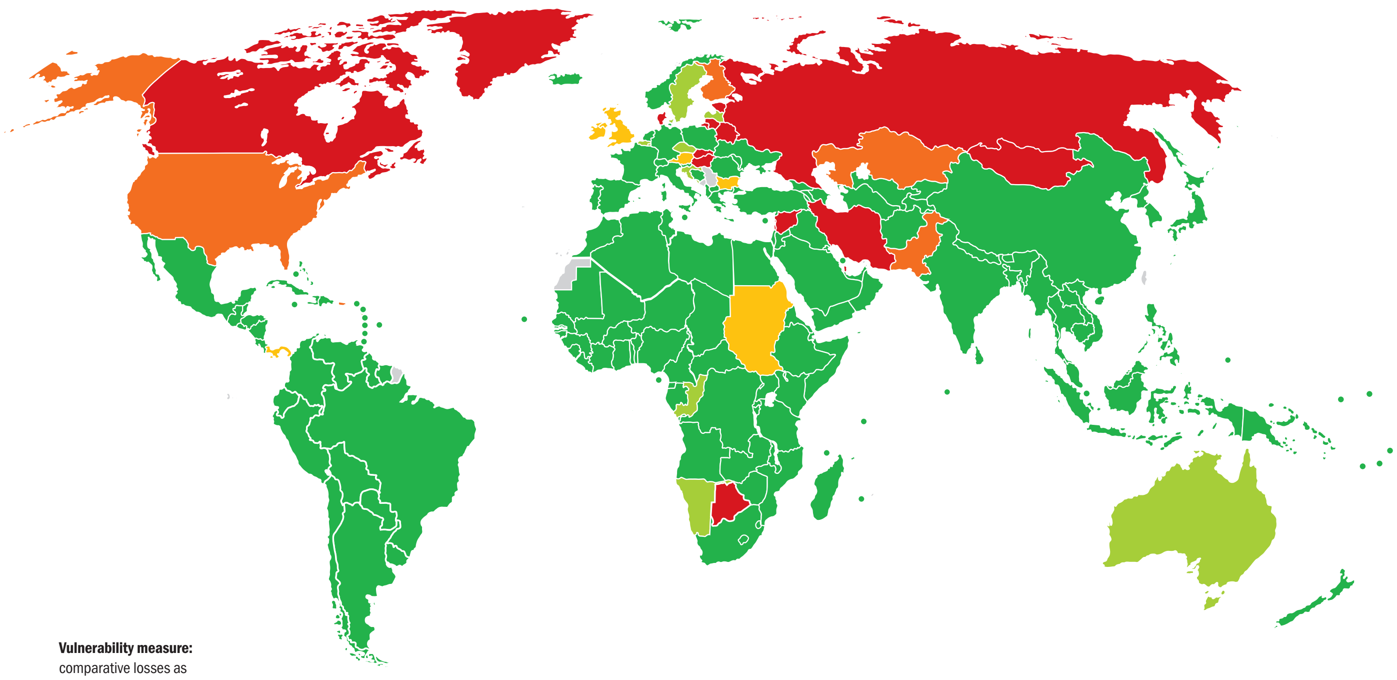
ESTIMATES COUNTRY-LEVEL IMPACT

COUNTRY	2010 ($)	2030 ($)
ACUTE		
Belarus	200	750
Botswana	15	90
Canada	650	1,000
Denmark	150	250
Estonia	40	250
Hungary	300	1,000
Iran	200	1,500
Lithuania	15	100
Mongolia	5	60
Qatar	40	300
Russia	1,500	5,000
Slovakia	95	400
Syria	350	2,500
SEVERE		
Finland	45	80
Kazakhstan	150	300
Pakistan	250	700
United States	6,500	8,000
HIGH		
Austria	75	100
Bulgaria	150	90
Ireland	25	30
Panama	10	20
Sudan/South Sudan	5	40
United Kingdom	450	850
MODERATE		
Australia	80	85
Belgium	100	40
Congo	1	1
Croatia	40	1
Czech Republic	100	65
Latvia	10	5
Namibia	1	
Sweden	35	30
LOW		
Afghanistan	-10	-350
Albania	15	-100
Algeria	-1	-750
Angola	-25	-750
Antigua and Barbuda	-1	-20
Argentina	-25	-4,500
Armenia	-1	-90
Azerbaijan	20	-90
Bahamas	-1	-85
Bahrain	-1	-75
Bangladesh	-85	-3,500
Barbados		
Belize		-15
Benin	-10	-250
Bhutan	-1	-55
Bolivia	1	-150
Bosnia and Herzegovina	10	-95
Brazil	250	-3,000
Brunei	-5	-250
Burkina Faso	-10	-250
Burundi	-5	-100
Cambodia	-10	-700
Cameroon	-40	-1,000
Cape Verde	-1	-15
Central African Republic	-1	-35
Chad	-5	-200
Chile	10	-400
China	1,500	-80,000
Colombia	-1	-700
Comoros		-1
Costa Rica	-10	-400
Cote d'Ivoire	-35	-800
Cuba	-10	-650
Cyprus		
Djibouti	-1	-55
Dominica		-10
Dominican Republic	-5	-250
DR Congo	-20	-450
Ecuador	-10	-550
Egypt	150	-2,000
El Salvador	-5	-200
Equatorial Guinea		-5
Eritrea	-1	-20
Ethiopia	-40	-1,500
Fiji	-1	
France	250	-950
Gabon	-5	-250
Gambia	-1	-40
Georgia	1	-75
Germany	250	-100
Ghana	-65	-1,500
Greece	-55	-400
Grenada	-1	-10
Guatemala	-10	-350
Guinea	-10	-250
Guinea-Bissau	-1	-50
Guyana	1	-10
Haiti	-1	-80
Honduras	-5	-300
Iceland		-1

$ Additional economic costs (million USD PPP) - yearly average

CARBON VULNERABILITY

Acute Severe High Moderate Low



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

COUNTRY	2010	2030
India	1,500	-20,000
Indonesia	-200	-7,000
Iraq		-150
Israel	40	-150
Italy	150	-900
Jamaica	-10	-200
Japan	-200	-3,000
Jordan		-55
Kenya	-45	-1,000
Kiribati		-10
Kuwait	-10	-300
Kyrgyzstan	-5	-250
Laos	-10	-550
Lebanon	10	-40
Lesotho		-15
Liberia	-1	-40
Libya	-5	-500
Luxembourg		-1
Macedonia	30	-55
Madagascar	-15	-400
Malawi	-20	-450
Malaysia	-35	-2,000
Maldives	-1	-10
Mali	-15	-400
Malta	-1	-5
Marshall Islands		-5
Mauritania	-5	-100
Mauritius	-5	-50
Mexico	75	-2,000
Micronesia		-15
Moldova	-5	-150
Morocco	-15	-900

COUNTRY	2010	2030
Mozambique	-15	-450
Myanmar	-10	-550
Nepal	-30	-900
Netherlands	65	-60
New Zealand	-5	-85
Nicaragua	-1	-100
Niger	-5	-150
Nigeria	-400	-10,000
North Korea	5	-55
Norway	1	-20
Oman	-5	-200
Palau		-5
Papua New Guinea	-5	-200
Paraguay	5	-200
Peru		-500
Philippines	-30	-2,000
Poland	400	-150
Portugal	55	-50
Romania	50	-1,000
Rwanda	-10	-250
Saint Lucia	-1	-15
Saint Vincent		-10
Samoa	-1	-15
Sao Tome and Principe		-5
Saudi Arabia	-10	-450
Senegal	-10	-400
Seychelles	-1	-5
Sierra Leone	-5	-80
Singapore	-20	-550
Slovenia	5	-15
Solomon Islands	-1	-30
Somalia	-5	-200

COUNTRY	2010	2030
South Africa	40	-300
South Korea	-95	-5,000
Spain	250	-1,000
Sri Lanka	-15	-550
Suriname		-15
Swaziland		-20
Switzerland	10	-50
Tajikistan	-1	-250
Tanzania	-40	-1,500
Thailand	-15	-4,500
Timor-Leste		-35
Togo	-5	-150
Tonga	-1	-10
Trinidad and Tobago	-5	-200
Tunisia	25	-250
Turkey	550	-1,000
Turkmenistan	-45	-1,000
Tuvalu		-1
Uganda	-25	-850
Ukraine	250	-1,500
United Arab Emirates	-15	-600
Uruguay	10	-20
Uzbekistan	-45	-1,500
Vanuatu	-1	-25
Venezuela	-10	-600
Vietnam	-100	-5,000
Yemen	-10	-350
Zambia	-5	-200
Zimbabwe	1	-25