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Scientific Committee
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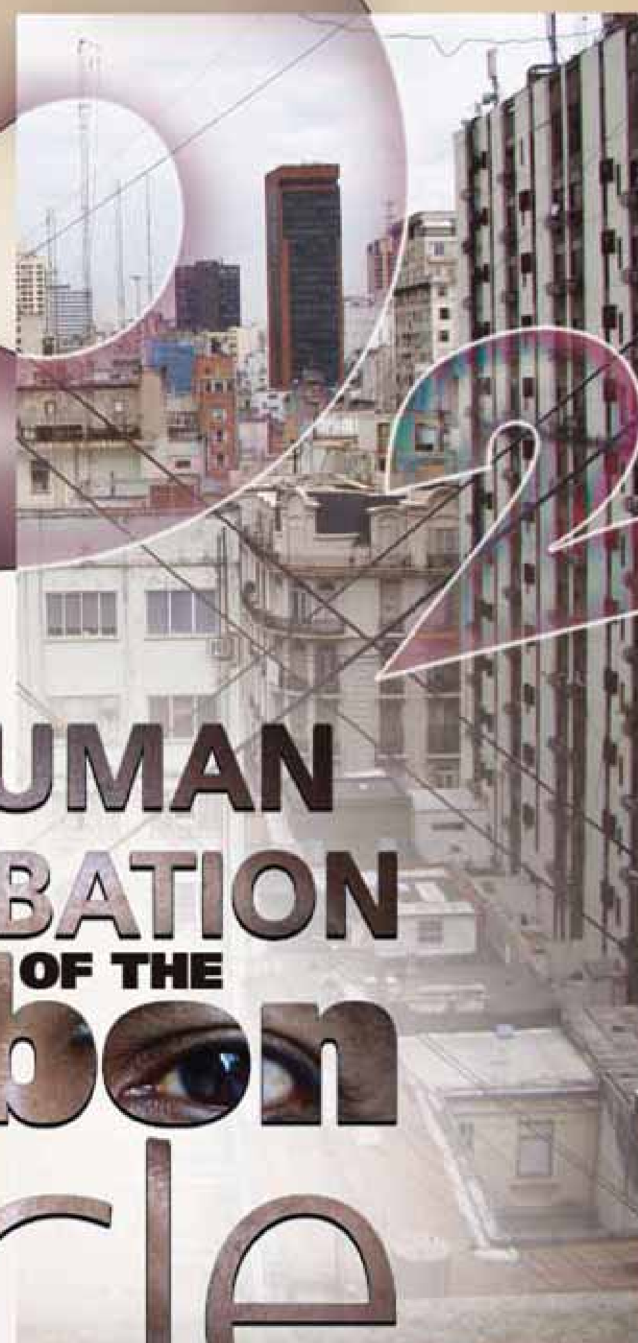


CO_2 THE HUMAN PERTURBATION OF THE carbon cycle

The Global Carbon Cycle II

Global Carbon Project

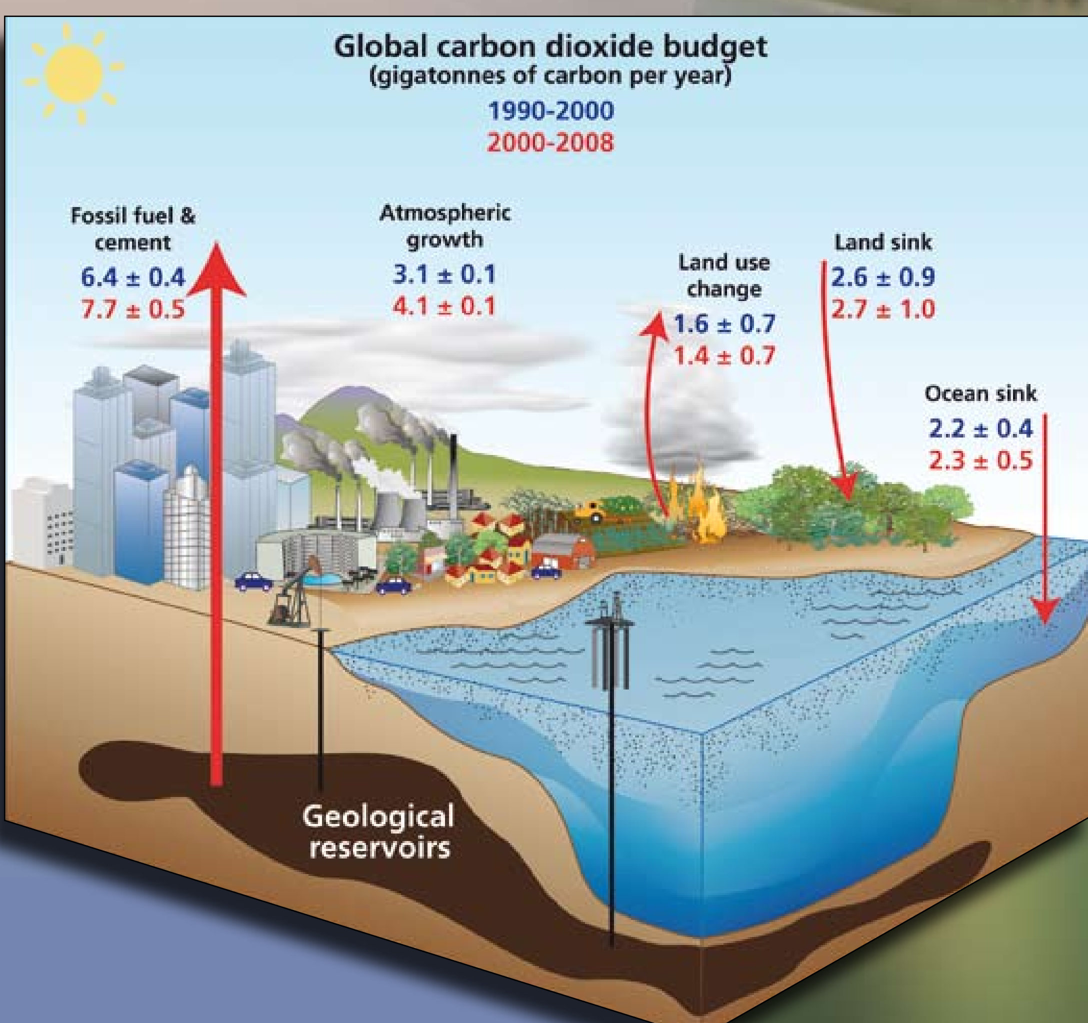
Earth System Science Partnership

DIVERSITAS IGBP IHDP WCRP

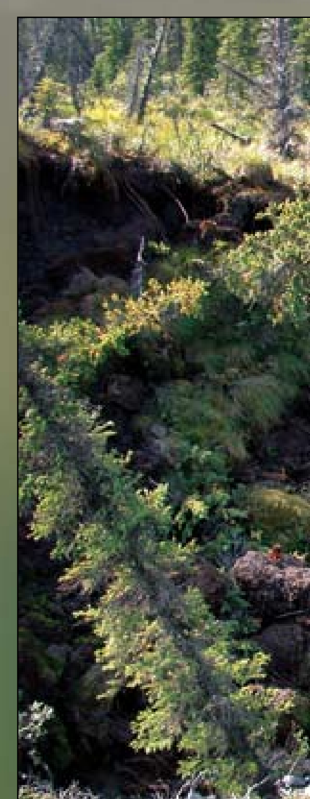
The carbon-climate-human system

The carbon cycle is closely linked to the climate system and is influenced by the growing human population and associated demands for resources, especially for fossil-fuel energy and land.

The rate of change in atmospheric CO_2 reflects the balance between carbon emissions from human activities and the dynamics of a number of terrestrial and ocean processes that remove or emit CO_2. The long-term evolution of this balance will largely determine the speed and magnitude of human-induced climate change and the mitigation requirements to stabilize atmospheric CO_2 concentrations at any given level.



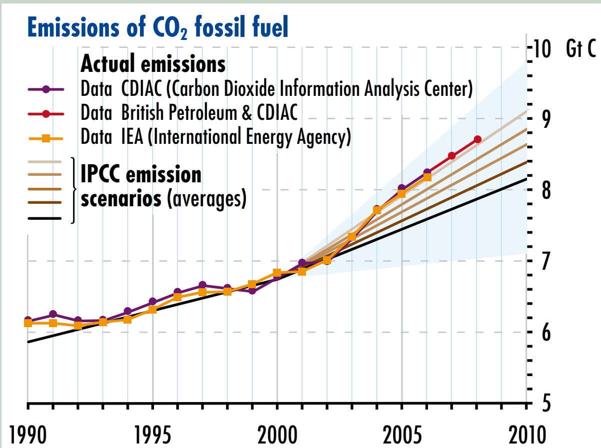
IGBP for the Global Carbon Project based on Le Quéré et al. 2009



State of change

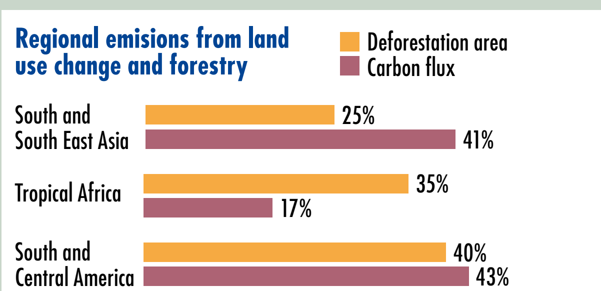
Increasing carbon emissions

Carbon emissions from fossil fuel combustion and cement production in 2008 were 8.7 Gt C, 41% higher than in 1990 (Kyoto Protocol base year), following the average of the most carbon-intense scenarios of the Intergovernmental Panel on Climate Change (IPCC).



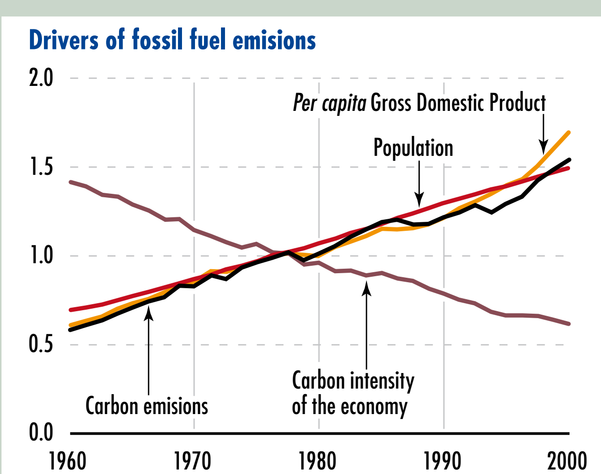
Updated from Raupach et al. 2007; Le Quéré et al. 2009

Emissions from land use change are on average 1.5 Gt C per year. They are largely determined by deforestation in tropical regions resulting from domestic policies, economic development, and global commodity prices which are often interlinked in complex ways.



Canadell et al. 2009

Combined emissions for fossil fuels and land use change increased by over 3% per year since 2000, up from 1.9% over the period 1959-1999. The growth of these emissions is driven by population, per capita Gross Domestic Product (GDP), and carbon intensity of GDP. The increase in the growth of population and per capita income weigh equally in driving emissions upward, the latter becoming more important in recent years.



Raupach et al. 2008

Rising temperature

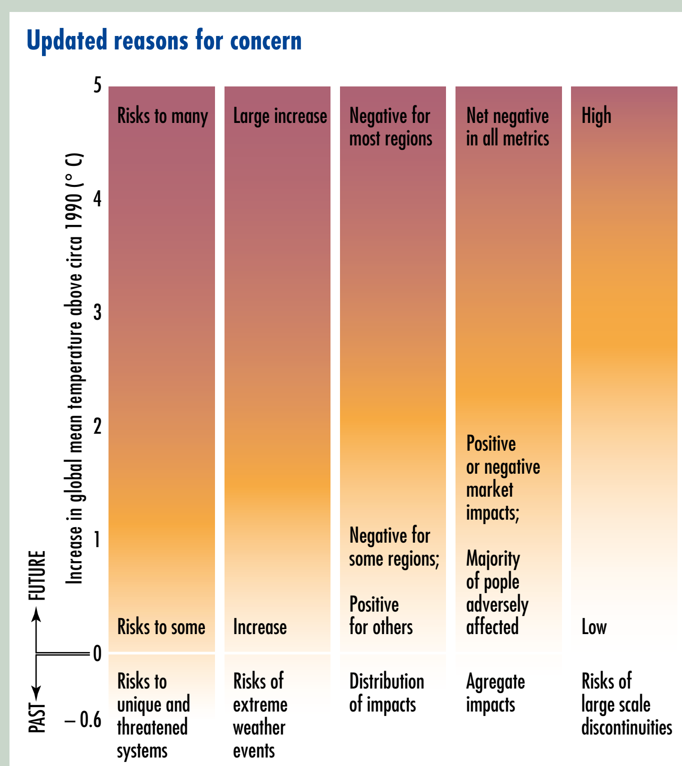
Carbon dioxide is responsible for more than 60% of the 2.6 Watts/m2 warming that has resulted from the increase in human-induced long-lived greenhouse gases. The relative importance of carbon dioxide in climate change will further rise as we continue to burn larger amounts of fossil fuels. Carbon has a uniquely long residence time. An estimated 20-35% of today's emissions will remain in the atmosphère for several centuries into the future.

Emissions cap

There is no consensus about the level of global temperature increase defining "dangerous anthropogenic interference of the climate system". However, growing evidence shows that keeping global warming below 2 degrees Celsius above pre-industrial levels could avoid the worst impacts of climate change.

To keep below this 2-degree limit with 50% probability, only an additional 500 billion tonnes of carbon can be emitted into the atmosphere. This would bring the total anthropogenic cumulative emission allowance close to 1 trillion tonnes (including the 500 billion tonnes already emitted over the past 200 or so years).

This budget approach can help policy makers to explore how the remaining carbon emissions for a given global temperature target can be partitioned among countries and citizens around the world. Unless urgent emission reductions are implemented, 500 billion tonnes of carbon will be emitted within the next 30 years.



Smith et al. 2009

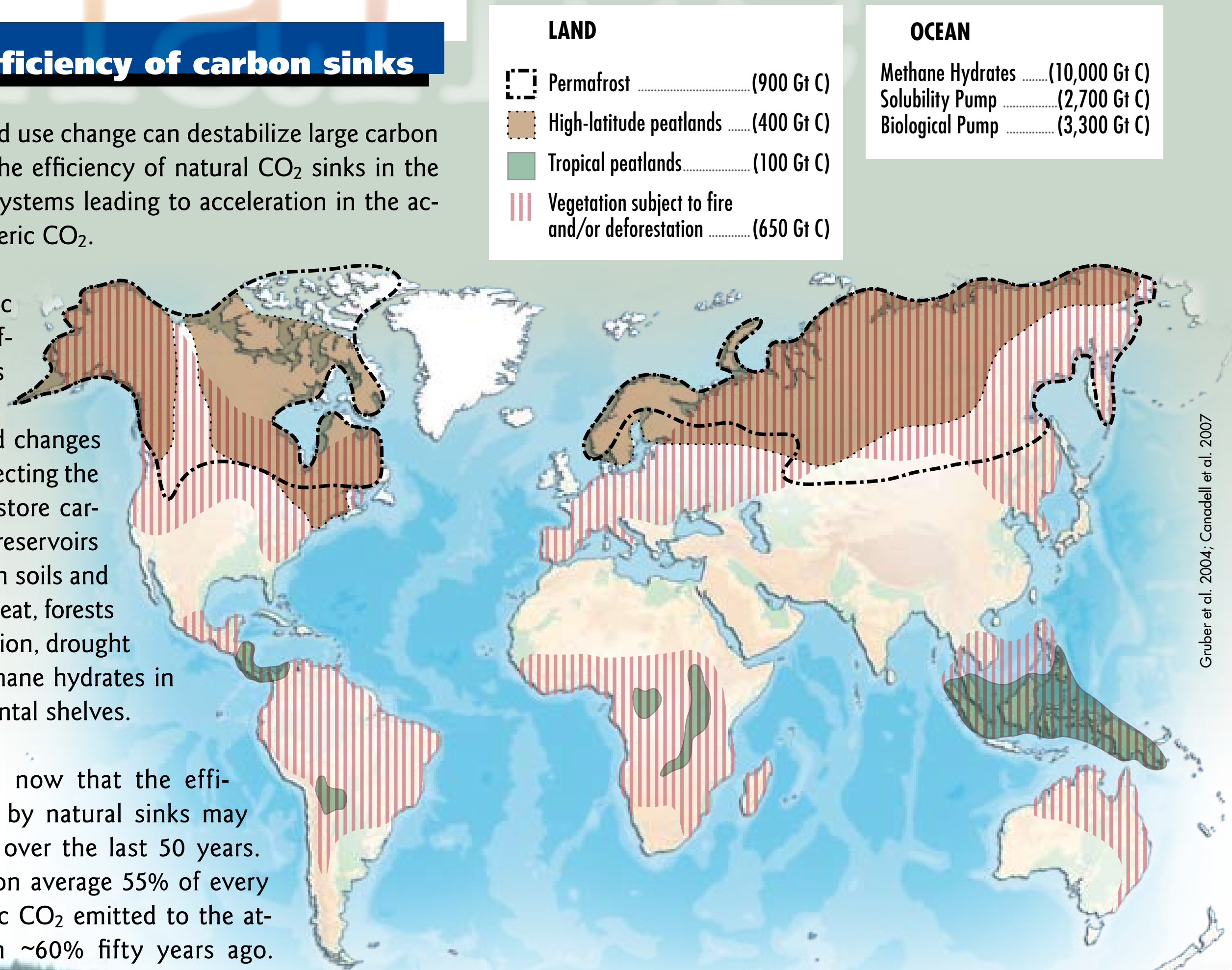
Decreasing efficiency of carbon sinks

Climate change and land use change can destabilize large carbon reservoirs and reduce the efficiency of natural CO_2 sinks in the ocean and in land ecosystems leading to acceleration in the accumulation of atmospheric CO_2.

Changing atmospheric CO_2 concentrations affect ocean carbon sinks leading to ocean acidification and widespread changes in marine biota thus affecting the capacity of oceans to store carbon. Other vulnerable reservoirs include carbon in frozen soils and northern peat, tropical peat, forests vulnerable to deforestation, drought and wildfires, and methane hydrates in permafrost and continental shelves.

There are indications now that the efficiency of CO_2 uptake by natural sinks may have already declined over the last 50 years. Natural sinks remove on average 55% of every tonne of anthropogenic CO_2 emitted to the atmosphere, down from ~60% fifty years ago.

Vulnerable carbon pools



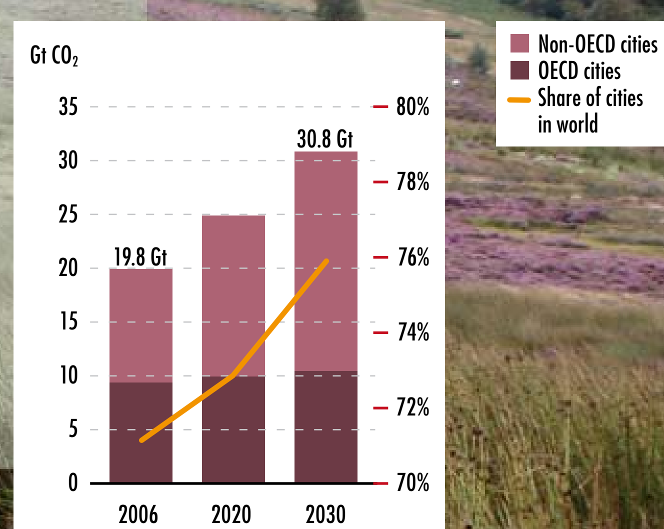
Gruber et al. 2004; Canadell et al. 2007

Rapid urbanization

Urban areas contributed 71% of global energy-related CO_2 emissions in 2006. World urbanization – 49.6% in 2007 – is expected to reach 70% by 2050. Almost all of this increase will come from further urbanization of developing countries, providing a challenge and an opportunity to manage carbon emissions.

Cities import large amounts of energy and products which result in carbon emissions at the point of production far away from the cities themselves (eg. in coal power plants that generate electricity or industries producing cement or goods for cities). If one attributes these emissions to cities, these indirect carbon flows dominate the total carbon budgets of urban areas. This offers opportunities for cities to manage more carbon than the direct emissions from their physical territories such as emissions from city vehicles.

CO_2 contributions of urban areas



WEO, 2008

Carbon-climate feedbacks

FACTS and FIGURES

Key carbon measurements and projections pointing to rapid acceleration of the carbon-climate feedback

Carbon emissions

- Carbon emissions from fossil fuel combustion and cement production in 2008 were 8.7 Gt C, 41% higher than in 1990 (Kyoto Protocol base year).
- For the first time developing countries are now emitting more fossil fuel CO_2 emissions (55%) than developed countries. *Per capita* emissions, however, continue to be led by developed countries by an ample margin.
- Tropical deforestation is responsible for about 1.5 Gt C per year, accounting for about 15% of total anthropogenic carbon emissions.

Atmospheric CO_2 concentrations

- CO_2 concentration in 2008 reached 385 ppm, 38% above pre-industrial levels.
- 385 ppm is the highest CO_2 concentration in at least the last 2 million years.
- For the period 2000-2008 the growth rate of atmospheric CO_2 was 1.9 ppm per year, a significant growth increase from earlier trends (1.3 for 1970-1979, 1.6 for 1980-1989, and 1.5 for 1990-1999).

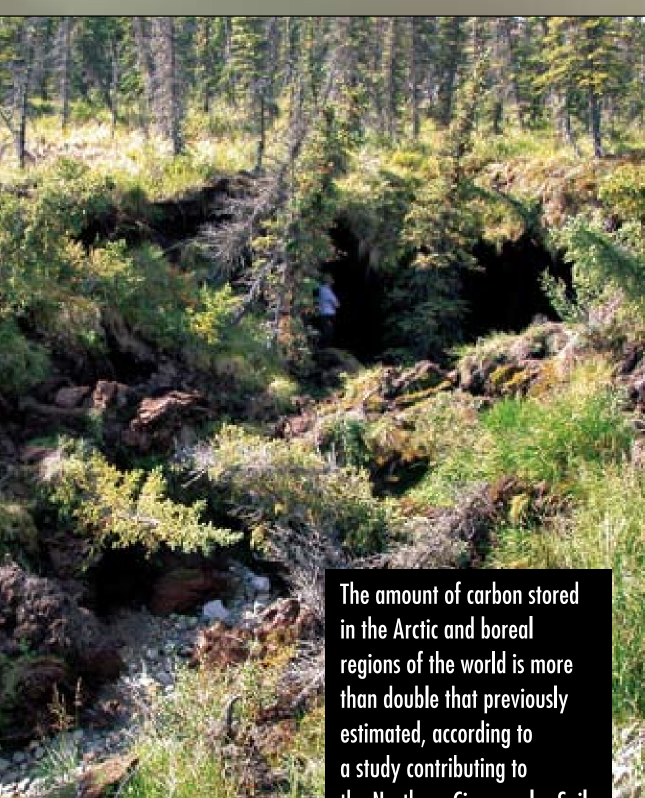


Photo ©: Larissa Yocum

The amount of carbon stored in the Arctic and boreal regions of the world is more than double that previously estimated, according to a study contributing to the Northern Circumpolar Soil Carbon Database. Shown here, a close-up of a boreal ecosystem on the north slope of the Alaska Range, at Denali National Park.

Raising temperature

- Air temperature increase from 1850-1899 to 2001-2005 is 0.76°C.
- Temperature of the global ocean has increased to depths of at least 3000 m storing more than 80% of the heat added to the climate system since 1961.

Natural CO_2 sinks

- Natural CO_2 sinks in the ocean and land currently remove an average of 55% of all CO_2 emissions from human activities every year.
- Rapidly growing emissions are outpacing growth in natural sinks.

Carbon futures

- The world's energy demand is expected to rise by 50% by 2030, and unless major changes are implemented rapidly, 80% of that increase will depend on fossil fuels (oil, gas, and coal).
- If current trends prevail, global fossil fuel emissions are expected to rise to between 12 and 18 Gt C per year by 2050 (2 to 3 times the level in 2000).

System approach

Towards sustainable management of the carbon-climate-human system

Management of the carbon-climate-human system requires a systems approach. Such an approach provides a framework that is able to assess the technical potential of emissions mitigation, resource trade-offs and the socio-economic constraints and opportunities consistent with pathways of development, equity, and sustainability. Examples that show the need for a systems approach are:

- impacts of large afforestation programmes on the hydrological cycle and biodiversity, particularly on downstream agricultural activity, wood production, and wetland conservation;
- impacts of current and future generation of biofuels on food production and carbon stocks, particularly on livelihoods in developing countries;
- impacts of urban development pathways on fossil fuel emissions and ecosystem services;
- impacts of ocean iron fertilization on the composition and functioning of marine biota; and
- issues of security, disposal, and societal acceptance for nuclear energy and carbon geosequestration options.

Useful links

United Nations Educational, Scientific and Cultural Organization (UNESCO): http://portal.unesco.org/science/en/ev.php-URL_ID=5296&URL_DO=DO_TOPIC&URL_SECTION=201.html
http://portal.unesco.org/en/ev.php-URL_ID=43031&URL_DO=DO_TOPIC&URL_SECTION=201.html
Scientific Committee on Problems of the Environment (SCOPE): http://www.icsu-scope.org
United Nations Environment Programme (UNEP): http://www.unep.org

Sources

Annual carbon budget update of the Global Carbon Project. http://www.globalcarbonproject.org/carbonbudget

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