THE HUMAN-NATURE INTERFACE:

A Research Tool for Inquiry into the Ecological Crisis

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Opening Remarks

The Human-Nature Interface Research Tool was created to facilitate inquiry into the ecological crisis. The human species is on a very destructive path. We are living in complete disharmony with the rest of nature and as a result, the integrity of virtually all living systems is being compromised. It is clear that macro social change is urgently required to redirect human conduct to a way of life that uses fewer resources, produces less waste, and allows sufficient space for habitat for the rest of the living community that together make the conditions for life on Earth possible. Before that can happen, however, people need to understand the issues that together culminate in the ecological crisis, as well as the anthropogenic forces driving them.

This research guide provides an outline of the ecological crisis and serves as a gateway to reliable and rich sources of information that elaborate in-depth on the points mentioned. The guide is divided into various sections that correspond to different topic areas into which ecological issues can be categorized. Within each section there are several subsections that highlight the interconnectedness between topic areas. For example, in the section *Biodiversity*, there is the subsection *Biodiversity and Food*. By virtue of this organization scheme, there is a relatively high level of redundancy throughout the sections, as whole subsections may appear twice. For example, *Biodiversity and Food* may be accessed via *Biodiversity*, or as *Food and Biodiversity* via *Food*. Web links also may appear more than once. The fact that readers will approach the guide from different reference points and areas of interest makes such repetition necessary – it is important that individuals are led to crucial sources of information regardless of their starting point.

At the beginning of each section there are descriptions of key documents to consult on the topic at hand that are worth reading in full. These are also the documents from which most of the key points for the given section are drawn. The web links to information that complements and elaborates on these points are those of legitimate websites, either government sites or those of environmental organizations.

► LAND & SOIL

Documents to Consult

1) Global Environment Outlook (GEO)

Web link: http://www.unep.org/geo/

• The Global Environment Outlook is an initiative of the United Nations Environment Programme (UNEP) that analyzes environmental change, causes, impacts, and policy responses.

GEO-4 (2007): http://www.unep.org/geo/geo4/report/GEO-4_Report_Full_en.pdf

Chapter 3: Land: http://www.unep.org/geo/geo4/report/03_Land.pdf **OR** http://www.eoearth.org/article/Global_Environment_Outlook_(GEO-4)~_Chapter_3

• The chapter on land (p. 81 – 114 of the report) addresses various land issues, most notably land degradation, and identifies the pressures of human demands on the land base as the cause of degradation. The chapter explores the impacts of several types of land-use change on both the environment and human well-being, and outlines the specific drivers and pressures causing these changes. Finally, there is a discussion of measures that are being taken to address these issues.

2) Millennium Ecosystem Assessment (MA)

Web link: http://www.millenniumassessment.org/en/Reports.aspx

• The MA was initiated in 2001 and aims to assess the consequences of ecosystem change for human well-being and the scientific basis for action toward the conservation and sustainable use of these natural systems. The MA has synthesized the work of more than 1,360 experts across the globe, and their findings are presented in five technical volumes and six synthesis reports.

Current State and Trends Assessment:
http://www.millenniumassessment.org/en/Condition.aspx

• This report assesses the changing conditions of ecosystems and their services, the causes of these changes, and the consequences for human well-being. It considers terrestrial, freshwater and marine systems, and a range of ecosystem services, including food, timber, air quality regulation, nutrient cycling, detoxification, recreation and aesthetic services.

• Several chapters in the report are useful sources of information on environmental issues that pertain to the land, including those that discuss different ecosystems separately (forest systems, dryland systems, polar systems, etc.), and those that focus on different

sets of services that land ecosystems provide (food ecosystem services; timber, fuel and fiber ecosystem services, etc.)

Key Issues and Stressors

• There is about 45 million square miles of exposed land on Earth. Only about one-quarter of it, little more than 12 million square miles, is arable.
▸ http://pages.prodigy.net/jhonig/bignum/qland2.html

• Soil is a combination of minerals derived from the weathering of rocks and decaying organic matter derived from wastes and the remains of plants and animals. Soil contains microbes and other detritivores, making it "not only a variable mix of inorganic and organic compounds, but also a 'living layer' of the biosphere" (Harper, 2008, p.46).
▸ http://www.epa.gov/gmpo/edresources/soil.html

• Topsoil layers are particularly rich in nutrients, many of which are necessary for primary producers such as trees to carry out photosynthesis. We in turn depend on these organisms for food and many other services.

• Humans are almost entirely dependent on the land for food: 98% of human food is produced on the land. Globally, 12% of Earth's land surface is used for cultivating food and fiber crops, 24% is pasture used for grazing livestock that produces meat and milk, and 31% is covered by forests, which are largely exploited for fuel, lumber, paper, and other products. The remaining land, less than one-third, is desert, mountains, tundra, and other terrain unsuitable for agriculture (Harper, 2008, p.46).

• Land use patterns, as well as the amount of arable land, vary from nation to nation. As of 2005 in Canada, 4.57% of the land is arable, .65% of the land is used for the cultivation of permanent crops, and 94.78% is used for other purposes.
▸ https://www.cia.gov/library/publications/the-world-factbook/fields/2097.html

• In general, human activities are negatively impacting the condition of the land and soil on Earth, and these changes are in turn wreaking further ecological havoc on other natural systems and processes. The key issues and stressors are:

• ***Issue(s)***: Overexploitation of land resources (food, fiber, fuel, raw materials)
• ***Stressor(s)***: Size and growth of the human population; overconsumption; economic development; poverty

• ***Issue(s)***: Unsustainable land use patterns
• ***Stressor(s)***: Size and growth of the human population; overconsumption; economic development; urbanization; poverty

• ***Issue(s)***: Land degradation (soil erosion, nutrient depletion, chemical pollution, water scarcity, salinization, disruption of biological cycles)
• ***Stressor(s)***: Unsustainable land use, particularly industrial agriculture; industrial production, size and growth of the human population, overconsumption and waste

• ***Issue(s)***: Loss of forest, grassland, and wetlands

• ***Stressor(s)***: Size and growth of the human population; land use patterns (urban development and sprawl, cropland expansion)

• ***Issue(s)***: Desertification
• ***Stressor(s)***: Size and growth of the human population, industrial agriculture, overexploitation of water resources

► Land Resources

Key Online Resources:

•http://www.fao.org/docrep/v8047e/v8047e00.htm#Contents
•http://www.wri.org/
•http://www.millenniumassessment.org/documents/document.278.aspx.pdf

• Resources that we extract from the land include raw materials such as timber, fuel, metals and minerals, as well as crops we grow for food and fiber. In keeping with the global trends of overpopulation and overconsumption, land resources are being overexploited and depleted, with negative consequences for both the planet and future generations of human beings.
▸ http://www.fao.org/docrep/v8047e/v8047e04.htm#land%20and%20land%20resources

• Globally, adding together production of cereals, fruit, vegetables, and meat, output per farmer and unit of land has increased (GEO-4, 2007, p.86). The continued shift from cereal to animal products and the recent move towards **biofuels** will add to the demand for farm production (p.83).
▸ http://74.125.95.132/search?q=cache:ULaLvYvFCZAJ:ftp://ftp.fao.org/docrep/fao/011/i0100e/i0100e02.pdf+biofuels+and+agriculture+fao&cd=1&hl=en&ct=clnk&gl=ca
▸ http://earthtrends.wri.org/updates/node/340

• Increasing demand for **commercial timber** and other wood and paper products has encouraged many countries to expand the area devoted to **forest plantations**, but pressures on rapidly-diminishing natural forests have not been reduced (Matthews, 2000, p.1). However, production from natural forests will continue to be replaced by production from plantation forests, especially in tropical and subtropical regions (MA, 2005, p.250). Recently, there have been major shifts in the location of timber production, generally from north to south (p.245).
▸ http://earthtrends.wri.org/pdf_library/feature/for_fea_roundwood_complete.pdf
▸ http://earthtrends.wri.org/searchable_db/index.php?theme=9&variable_ID=304&action=select_countries
▸ http://www.fao.org/docrep/004/Y2316E/y2316e0b.htm

• Forest plantations are intensively managed and are often **monocultures** and **exotic species** (MA, 2005, p.248). Environmental concerns over single-species plantation forests compared with managed natural forests include reduced biodiversity, soil degradation, reduced water conservation, increased vulnerability to pests (p.254).
▸ http://www.fao.org/docrep/004/AC130E/ac130e04.htm

• China's rapidly developing economy accounts for a substantial portion of the growth in global wood consumption. During the past decade, **China** has increased its imports of logs and wood products by more than 50%, largely because of policies limiting domestic harvest levels. If unabated, this rate of increase will put significant pressure on wood supplies in many regions, particularly Russia and Southeast Asia (MA, 2005, p.245).
▸ http://74.125.95.132/search?q=cache:5FOBMavsy_4J:www.cfr.washington.edu/Research/factSheets/18-CINTRAchinamkt.pdf+China+rapid+economy+wood&cd=1&hl=en&ct=clnk&gl=ca

• Poorly planned or excessive timber harvesting can increase road access into remote forest areas, leading to a reduction in forest interior and increasing the **"edge" effects** associated with forest fragmentation. This has resulted in wildlife population declines and reduced species richness (MA, 2005, p.254).
▸http://www.for.gov.bc.ca/hfd/pubs/docs/En/En21.pdf

• During the last four decades the highest **deforestation** rates have been in tropical forests in Africa, Southeast Asia and South America, where it is currently estimated that over 100,000 square kilometers per year are deforested (MA, 2005, p.254).
▸http://earthobservatory.nasa.gov/Features/Deforestation/

• The **rural poor** are particularly dependent on forest resources. As many as 300 million people, most of them very poor, depend substantially on forest ecosystems for their subsistence and survival (MA, 2005, p.587).
▸http://www.eoearth.org/article/Forest_environmental_income_and_the_rural_poor

• **Cotton** is the single most important textile fiber in the world, accounting for over 40% of total world fiber production (MA, 2005, p.262). Global cotton production has doubled since 1961, which is largely the result of intensification via the use of fertilizers and pesticides; the land area on which it is harvested has stayed virtually the same (p.246). Production has to a large extent shifted from Japan to China.
▸http://www.ers.usda.gov/briefing/Cotton/USTextileApparel.htm

Illustrative Facts & Statistics

▸*Food*

• Global food production has increased by 168% over the past 42 years (MA, 2005, p.211).
• Global production of cereals has increased by about 130% over the past 42 years, but is now growing more slowly (MA, 2005, p.211).
• Since 1987, cereal yields have increased by 17% in North America, 25% in Asia, 37% in West Asia, and by 40% in Latin America and the Caribbean (GEO-4, 2007, p.86).
• In the 1980s, one farmer produced one ton of food, and one hectare of arable land produced 1.8 tons, annually on average. Today, one farmer produces 1.4 tons, and one hectare of land produces 2.5 tons. The average amount of land cultivated per farmer remained the same, about 0.55 ha (GEO-4, 2007, p.86)

▸*Timber*

•Forests annually provide over 3.3 billion cubic meters of wood (including 1.8 billion cubic meters of fuelwood and charcoal), and about 5000 different commercial products, including numerous non-wood forest products that play a significant role in the economic life of hundreds of millions of people. The Forestry sector contributes about 2% of global GDP (MA, 2005, p.587-588).
• Global timber harvest has increased by 60% in the last 4 decades (MA, 2005, p.245)
• Between 1961 and 2001, the market value of global wood consumption more than doubled in real terms, growing at 2.7% per year (MA, 2005, p.249).
• In 2000, plantations were 5% of the global forest cover, but they provided some 35% of harvested roundwood, an amount anticipated to increase to 44% by 2020 (MA, 2005, p.245).

• Forest plantations covered 187 million hectares in 2000, with Asia accounting for 62%. In 1980 they covered only 17.9 million hectares (MA, 2005, p.248).
• Plantations for industrial purposes have increased by 25% since 1980 (MA, 2005, p.599).
• The global value of timber harvested in 2000 was around $400 billion (MA, 2005, p.245).
• It is estimated that up to 15% of global timber trade involves illegal activities, and the annual economic toll is around $10 billion (MA, 2005, p.245).
• Fuelwood is the primary source of energy for heating and cooking for some 2.6 billion people, and 55% of global wood consumption is for fuelwood (MA, 2005, p.245).
• China is now importing 107 million cubic meters of wood, an increase of more than 50% from 1997-2003 (MA, 2005, p.249).
• The global production of wood pulp has almost tripled in the past 40 years (MA, 2005, p.251).

►*Fuel*

• At current rates of consumption, about 80% of know oil reserves will last for between 40 and 90 years (Harper, 2008, p.115).
• More than 2 billion people worldwide rely on biomass for their main energy source (MA, 2005, p.247).
• Global consumption of charcoal appears to have doubled between 1975 and 2000, largely as a result of continuing population shifts toward urban areas (MA, 2005, p.259).
• Currently, about 85% of global production of liquid biofuels is in the form of ethanol (FAO, Biofuels, p.6).

►*Fiber*

• According to the United States Deptartment of Agriculture, total world fiber production has grown by 63% in the last 2 decades, while the proportion of natural (cellulosic) fibers has declined from almost two-thirds to under one-half (MA, 2005, p.262).
• Global cotton production has doubled since 1961 (MA, 2005, p.246).
• Global silk production has tripled since 1961 (MA, 2005, p.246).
• The total area devoted to flax production has declined from over 2 million hectares in 1961 to less than 450,000 hectares in 2000 (MA, 2005, p.264).

► Land Use and Degradation

Key Online Resources:

• http://www.fao.org/nr/lada/

• Many of our land-use patterns are unsustainable and continue to have adverse affects on the land itself and on larger ecosystems and natural processes.

• Over the last 20 years, **human population growth**, **economic development** and **emerging global markets** have driven unprecedented **land-use change** http://www.cara.psu.edu/land/lu-primer/luprimer07.asp. The most dynamic changes have been in **forest cover and composition** http://www.wri.org/publication/content/8152, **expansion and intensification of cropland**, and the **growth of urban areas** http://science.nasa.gov/headlines/y2002/11oct_sprawl.htm. Since 1987, the largest forest conversions have occurred in the Amazon Basin, South East Asia, and Central and West Africa (GEO-4, 2007, p.84-85).

• Towns and cities occupy only a few percent of the land surface, but "their demand for food, water, raw materials and sites for waste disposal dominate the land around them" (GEO-4, 2007, p.86). They are often built on prime farmland, and are a source of **sewage** flows, run-off and other forms of **waste** that become environmental problems, often affecting surrounding rural areas, as well as **degrading water quality** (p.111). **Urban expansion** not only concentrates pollutants, solid and organic wastes; it **disrupts hydrological and biological cycles**, results in a **loss of habitat and biodiversity**, and creates **urban heat islands** (p.87).
▸ http://74.125.113.132/search?q=cache:SVKbbS8SjOYJ:www.populationenvironmentresearch.org/papers/Urban_Expansion_background_paper.pdf+environment+urban+expansion&cd=1&hl=en&ct=clnk&gl=ca

• The construction of **housing** and **infrastructure** in rural areas is often in conflict with other land uses, such as agriculture, recreation and other ecosystem services, particularly in rapidly industrializing cities (GEO-4, 2007, p.111).

• Land can be degraded and eroded so that it is less productive or even useless for human cultivation. Land is always eroding naturally, topsoil is being dissolved or carried away by water or wind, and the rate of this natural erosion varies with local geology, climate, and topography. However, human intervention has produced a "**net degradation of soil**" (Harper, 2008, p.46).

• **Land degradation** is defined as "a long-term loss of ecosystem function and services, caused by disturbances from which the system cannot recover unaided" (GEO-4, 2007, p.92) and is largely driven by unsustainable land use (p.84). Direct effects include: **losses of soil organic carbon, nutrients, soil water storage and regulation, and below-ground biodiversity.** Indirectly, it means a **loss of productive capacity** and **wildlife habitat. Water resources** are diminished by disruption of the water cycle, **off-site pollution** and **sedimentation**.
▸ http://www.acdi-cida.gc.ca/CIDAWEB/acdicida.nsf/En/JUD-1118165457-TPW

• **Loss of forest, grassland and wetlands** amounts to losses of habitat, biodiversity, stored carbon, soil water retention and regulation, disturbance of biological cycles and food webs. It has also led to diminished variety of resources and diminished water resources and water quality. Implications for human health and safety include: loss of forest ecosystem services, including

potential new medicinal products, increased hazard of flooding and landslides during extreme weather and tsunamis (GEO-4, 2007, p.87).

• **Tropical deforestation** is driven mainly by **agricultural expansion**, **high levels of wood extraction**, and the **extension of roads** and other **infrastructure** into forested areas (MA, 2005, p.587). Indirect drivers include human demographic factors such as **population growth**, **density**, and **migration**.
▸ http://earthobservatory.nasa.gov/Features/Deforestation/deforestation_update3.php
▸ http://www.bio-medicine.org/biology-news-1/The-drivers-of-tropical-deforestation-are-changing--say-scientists-4347-1/

• While **temperate and boreal forest cover** has stabilized and even increased, the quality of these forests is still threatened by **air pollution, fire, pest and disease, continued fragmentation,** and **inadequate management** (MA, 2005, p.587).

• In many regions, forest is a major stabilizing component of natural landscapes, providing protection of soil and water, households, and fields and reducing or preventing floods and landslides (MA, 2005, p.603).
▸ http://www.eoearth.org/article/Forest_environmental_services
▸ http://www.wri.org/publication/content/8155

• **Desertification** occurs when individual land degradation processes, acting locally, combine to affect large areas in drylands (GEO-4, 2007, p.106). It is land degradation in arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities. It leads to loss of habitat and biodiversity, reduced groundwater recharge, water quality and soil fertility, increased soil erosion, dust storms, and sand encroachment (p.88). The direct cause has been the expansion of cropping, grazing or wood exploitation (p.107).
▸ http://www.fao.org/desertification/default.asp?lang=en

• **Chemical pollution** affects soil and water, poisoning water reserves and leading to water scarcity (GEO-4, 2007, p.87). Chemicals are used in every aspect of life, including industrial processes, energy, transport, agriculture, pharmaceuticals, cleaning and refrigeration (p.93). Releases, by-products and degradation of chemicals, pharmaceuticals and other commodities contaminate the environment (p.93-94). Chemical wastes from **industry** and **agriculture** are a big source of contamination, particularly in developing countries and countries with economies in transition (p.94). Increasingly, some of the chemical waste stream comes from everyday products; increasing consumption remains coupled to increased generation of wastes, including chemical wastes. Most domestic waste still goes into landfills (p.95). Atmospheric pollutants have been implicated in increasing soil acidity and forest decline (p.95).

• Implications of chemical contamination for human health and safety include: poisoning, accumulation of persistent pollutants in human tissue with potential genetic and reproductive consequences, increased risk of exposure and of contamination in food chains; in severe cases, areas become uninhabitable (GEO-4, 2007, p.87).

• **Soil erosion** becomes a problem when the natural process is accelerated by inappropriate land management, such as **clearance of forest** and **grasslands** followed by cropping which results in inadequate ground cover, **inappropriate tillage** and **overgrazing** (GEO-4, 2007, p.95). Soil erosion is also caused by activities such as **mining**, **infrastructural** and **urban development**

(p.95). The result is a loss of soil, nutrients, habitat, and property; as well as siltation of reservoirs, and thus a loss of food and water security (p.87).
▸http://soilerosion.net/

• Implications of soil erosion for human health and safety include: hunger, malnutrition, exposure to diseases due to weakened immune system, risk of floods and landslides (GEO-4, 2007, p.87).

• Soil erosion can be reduced by encouraging terracing, contour plowing, multiple cropping, using low-tillage methods, and using more organic fertilizer (Harper, 2008, p.48).

• **Nutrient Depletion** is a decline in levels of plant nutrients such as nitrogen, phosphorus and potassium, and in soil organic matter, resulting in declining soil fertility. The removal of the harvest and crop residues depletes the soil, unless the nutrients are replenished by manure or inorganic fertilizers. Nutrient depletion is commonly accompanied by **soil acidification**, which increases the solubility of toxic elements, such as aluminum (GEO-4, 2007, p.96).

• Deficiency of plant nutrients in the soil is the most significant biophysical factor limiting crop production across very large areas in the tropics, where soils are inherently poor. Several studies in the 1990s indicated serious nutrient depletion in many tropical countries, particularly in **sub-Saharan Africa** http://www.independent.co.uk/news/world/africa/soil-crisis-is-holding-back-african-recovery-472161.html. About 950,000 km^2 of land in the region is threatened with irreversible degradation if nutrient depletion continues (GEO-4, 2007, p.96-97).

• **Salinity** is defined by the desired use of land and water; it is "salt in the wrong place" when found in farmland, drinking and irrigation water, and in freshwater habitats. Soils, streams and groundwater in drylands contain significant amounts of naturally-occurring salt, which inhibits the absorption of water by plants and animals, breaks up roads and buildings, and corrodes metal (GEO-4, 2007, p.99).
▸http://www.gov.mb.ca/agriculture/soilwater/soilmgmt/fsm01s05.html

• **Salinization** is caused by inappropriate forms of land use and management, particularly with regard to agriculture. Irrigation typically applies much more water than can be used by crops; the added water itself contains salt and it mobilizes more salt that is already in the soil. In addition, leakage from irrigation canals, ponding because of poor land leveling and inadequate drainage raise the water table. Once the water table rises close to the soil surface, water is drawn to the surface by evaporation, further concentrating the salt, which may eventually create a salt crust on the soil surface (GEO-4, 2007, p.99).

• Salinization results in unproductive soils and thus diminished farm and forest production, unusable water resources, a loss of freshwater habitat.

Illustrative Facts & Statistics

▸*Land-use change*

• More land was converted to cropland in the 30 years after 1950, than in the 150 years between 1700 and 1850 (GEO-4, 2007, p.5).

• Since 1700 cropland has increased by 1,200 million hectares (466%), including major expansion in North America and the former Soviet Union, with the greatest expansion occurring in the past 150 years (MA, 2005, p.749).
• Over the past 40 years cropland area has expanded globally by some 15% - from 1.3 billion to 1.5 billion hectares, the area of pasture has grown some 11% from 3.14 billion to 3.48 billion hectares, and practically all corners of the world's oceans are accessible to the world's fishing fleet (MA, 2005, p.229).
• Globally, agricultural land has expanded by around 130,000 square kilometers per year over the past 25 years, predominantly at the expense of natural forests and grasslands (MA, 2005, p.760).
• In the 1920s and 1930s there were more than 6 million farms of around 40 hectares each. By the late 1900s, there were fewer than 2 million farms and they averaged 200 hectares each (MA, 2005, p.228).
• By 1950 all but two biomes – boreal forests and tundra – had lost substantial natural land cover to croplands and pasture (MA, 2005, p.109).
• More than 300 000 km^2 of land have been converted to agricultural use in the tropics alone (GEO-4, 2007, p.172).
• About 43% of tropical and subtropical dry and monsoon forests and 45% of temperate broadleaf and mixed forests globally have been converted to croplands (MA, 2005, p.221).
• About 43% of tropical and subtropical dry and monsoon forests and 45% of temperate broadleaf and mixed forests globally have been converted to croplands (MA, 2005, p.221).
• In Brazil, the area of land used for growing soybeans (most of which are exported to China) grew from 117,000 km^2 in 1994 to 210,000 km^2 in 2003. This was driven by a 52% increase in world consumption of soybeans and soybean products, and these figures continue to rise dramatically (GEO-4, 2007, p.173).
• Cropland in Latin America, Africa, Australia, and South and Southeast Asia expanded very gradually between 1700 and 1850, but subsequently expanded rapidly. Since 1950, cropland area in North America has stabilized, while it has decreased in Europe and China. In the 2 decades before 2000, the major areas of cropland expansion were located in Southeast Asia, parts of Asia, eastern Africa, and in the Amazon Basin. The major decreases of cropland occurred in the southeastern United States, eastern China, and parts of Brazil (MA, 2005, p.749).
• More than for any other crop (and excluding pastures), it is the global area expansion of oil crops over the past 40 years that has driven cropland expansion. Food use of oil and vegetable oil crops, expressed in oil equivalent, grew from 6.3 kg per capita per year in 1964/66 to 11.4 kg in 1997/99 (MA, 2005, p.214).
•Between 1992 and 2001, the extent of organic cropland in the United States grew by over 200%, from about 163,000 hectares to 526,000 (MA, 2005, p.767).

►*Land degradation*

• From 1945 to 1990, 1.2 billion hectares of land is estimated to have suffered moderate to extreme soil degradation, and degraded areas accounted for 17% of Earth's vegetated lands (MA, 2005, p.603).
• The arrival of humans practicing agriculture increased the volume of soil and silt being carried into the ocean by at least two and a half times the original rate (Harper, 2008, p.46).
• It is estimated that about one-third of the world's soil that ever existed has been lost (Harper, 2008, p.47).

• Soil is eroding on approximately 38% of the world's cropland; soil erosion and degradation has reduced food production on about 16% of the world's cropland (Harper, 2008, p.47).
• It is estimated that American soils are eroding 16 times faster than it can form, and the Great Plains states have lost half their topsoils since agriculture began there (Harper, 2008, p.47).
• Erosion rates reported from Africa range from 5-100 tons/ha/yr, depending on the country and assessment method (GEO-4, 2007, p.95).
• It is estimated that globally, 20,000 – 50,000 km^2 is lost annually through land degradation, chiefly soil erosion, with losses 2-6 times higher in Africa, Latin America and Asia than in North America and Europe (GEO-4, 2007, p.95).
• 6 million square km of drylands bear a legacy of land degradation (GEO-4, 2007, p.3).
• Drylands cover about 40% of Earth's land surface and support 2 billion people, 90% of them in developing countries (GEO-4, 2007, p.106).
• In 2000, the average availability of freshwater for each person in drylands was 1300 $meters^3$/yr, far below the estimated minimum of 2000 needed for human well-being (GEO-4, 2007, p.106).
• Land degradation costs an estimated US$40 billion annually worldwide, without taking into account hidden costs of increased fertilizer use, loss of biodiversity and loss of unique landscapes (LADA, p.3).
• Worldwide, some 20% of irrigated land (450 000 km^2) is salt-affected, with 2,500 – 5,000 km^2 lost from production every year as a result of salinity (GEO-4, 2007, p.99-100).
• Since 1800, soil pH values have fallen by 0.5-1.5 pH units over large parts of Europe and eastern North America (GEO-4, 2007, p.101).

►*Forest Cover*

• FRA-2000 estimates the total area of global forests at 3,869 million hectares (0.6 hectares per capita) or about 30% of Earth's land surface. (MA, 2005, p.592)
• Three-quarters of the world's forests are located in two biomes: tropical (46%) and boreal (29%). Tropical rain forest is the most extensive forest type in the world, representing 26% of global forest area. Most are in South America, Africa and Asia. (MA, 2005, p.595).
• 70% of the world's forests can be considered to be natural, 20% semi-natural, and 10% anthropogenic - half of which are plantations. (MA, 2005, p.596).
• About 8000 years ago, forest covered an estimated 6.2 billion hectares of the planet – about 47% of Earth's land surface. Since the pre-agricultural era, the planet has lost about 40% of its original forest and what remains has suffered varying degrees of degradation and fragmentation. Most of this loss has occurred since the industrial revolution, during the past two centuries (MA, 2005, p.588).
• Forests have completely disappeared in 25 countries, and another 29 countries have lost more than 90% of their forest cover. Deforestation of natural forests in the tropics continues at an annual rate of over 10 million hectares per year (MA, 2005, p.587).
• More than 1.7 billion people live in the 40 nations with critically low levels of forest cover, in many cases hindering prospects for sustainable development (MA, 2005, p.613).
• The total net change in global forest area between 1990 and 2000 is estimated at -9.4 million hectares a year. (MA, 2005, p.597)
• The total loss of natural tropical forests between 1990 and 2000 is estimated at 15.2 million hectares per year, with a net change of -12.3 million hectares a year (MA, 2005, p.597).

• Only 40% of the planet's remaining forests are "frontier forests": large, intact natural forest ecosystems big enough to maintain all of their biodiversity. 39% of these are threatened by logging, agricultural clearing, etc (MA, 2005, p.596).
• Africa accounts for over 50% of net recent global deforestation, although the continent has only 17% of the world's forests (MA, 2005, p.598).
• Deforestation and forest degradation affect 8.5% of the world's remaining forests, nearly half of which are in South America (MA, 2005, p.75).
• Net global forest loss has slowed since the 1980s; the net loss from 1980-1990 was -13 million hectares, and -11.3 million hectares from 1990-1995. This is largely attributable to increases in plantation forestry (MA, 2005, p.597).
• Forest plantations covered 187 million hectares in 2000, with Asia accounting for 62%. In 1980 they covered only 17.9 million hectares (MA, 2005, p.248).
• Plantations for industrial purposes have increased by 25% since 1980 (MA, 2005, p.599).

► Land & Soil and Population

• "Anticipated human population increases and continued economic growth are likely to further increase exploitation of land resources over the next 50 years" (GEO-4, 2007, p.84). Our sheer numbers are putting immense pressure on virtually *all* natural resources. The **human population** increases **exponentially**, thus the amount of time it takes for our numbers to double is getting shorter and shorter: "If it takes the lily a year to fill the pond, it takes a full 364 days to fill half the pond" (PAI).
▸ http://216.146.209.72/Publications/Reports/People_in_the_Balance/Interactive/peopleinthebalance/pages/?s=1
▸ http://www.census.gov/ipc/www/idb/worldpopinfo.html
▸ http://www.populationaction.org/Publications/Reports/Why_Population_Matters/Population_-_Facts_and_Figures.shtml

• In addition, because people are **living longer** today – thanks to modern science, technology and medicine – the human population is simply exploding; it is possible that there are more people alive today than have ever existed.
▸ http://ecology.com/features/population/

•An expanding human population requires more of *everything* – more space, more food, more land on which to grow it, more water, more infrastructure, and countless other goods and services. Furthermore, more human beings generate more waste and pollution, and generally exacerbate environmental problems.

• The world's population is projected to increase to over 9 billion by 2050 http://www.un.org/apps/news/story.asp?NewsID=13451&Cr=population&Cr1. Thus, to meet the Millennium Development Goals on hunger, a doubling of global food production will be required (GEO-4, 2007, p.110).

• In addition, a continuation of the shift from cereal to meat consumption, combined with overconsumption and waste, will increase food demand to between 2.5 and 3.5 times the present figure (GEO-4, 2007, p.110).

• To feed a growing global population on increasingly degraded and expensive agricultural resources, we will need to increase the productive yield of agriculture while protecting the fertility of cropland soils (Harper, 2008, p.47), as well as strive to curb population growth http://vhemt.org/.

• **Half the world** now lives in **urban areas** http://www.abc.net.au/rn/science/earth/stories/s726535.htm, with positive and negative implications for the environment and human well-being. Densely populated cities use less land than do sprawling suburbs; they are easier to serve with public transportation, and can be more efficient in energy use, such as for transport and heating, and for waste reduction and recycling (GEO-4, 2007, p.111) http://www.ecocitybuilders.org/.

• Human population growth in developing countries has drastically shrunk the forest-to-people ratio from 1.2 hectares per capita in 1960 to 0.6 hectares per capita at present. By 2025, the ratio is predicted to decline further, to 0.4 (MA, 2005, p.613).
▸ http://www.unep-wcmc.org/forest/data/cdrom2/conclus.htm

Illustrative Facts & Statistics

• From 1959 to 1999, the world population doubled, increasing from 3 billion to 6 billion (United States Census Bureau). Over roughly the same period (1963 to 2005), global food production increased by 168% and global production of cereals increased by about 130% (MA, 2005, p.211).
• In the last 40 years, world grain harvest has doubled (GEO-4, 2007, p.5).
• Global timber harvest has increased by 60% in the last 4 decades (MA, 2005, p.245)
• Between 1961 and 2001, the market value of global wood consumption more than doubled in real terms, growing at 2.7% per year (MA, 2005, p.249).
• Global cotton production has doubled since 1961 (MA, 2005, p.246).
• Global silk production has tripled since 1961 (MA, 2005, p.246).
• Between 1950 and 1995, rapid population growth halved the amount of cultivated land per person, from more than half a hectare to barely a quarter (FAO, World Food Summit)

► Land & Soil and Water

• Land and water are irrevocably intertwined; changes in either inevitably effect changes in the other.

• **Forests** play a significant role in the regulation of the **hydrological cycle**. Globally, they increase precipitation, decrease evaporation, regulate the total and redistribution of surface and belowground runoff, increase total annual river runoff, protect landscapes against soil erosion and landslides, especially in mountain areas; prevent and diminish the consequences of floods, maintain water quality, protect river banks against abrasion, and prevent the siltration of reservoirs (MA, 2005, p.603).
▸ http://www.eoearth.org/article/Forest_environmental_services

• Over three-quarters of the world's accessible freshwater comes from forested catchments. Water quality declines with decreases in forest condition and cover. **Grassland** and **wetlands** also function to safeguard water resources and water quality, and to buffer against floods (MA, 2005, p.587).
▸ ftp://ftp.fao.org/docrep/fao/011/i0410e/i0410e04.pdf

• Rivers, lakes and coastal waters receive large amounts of **nutrients** from the land, and overloading of nutrients often results in **algal blooms**, or **eutrophication**. If this increases in intensity and frequency, whole ecosystems may be subject to hypoxia (**dead zones** due to lack of oxygen) as can be seen in the Gulf of Mexico and the Baltic Sea (GEO-4, 2007, p.111).
▸ http://www.eoearth.org/article/Eutrophication

Illustrative Facts & Statistics

TBA

► Land & Soil and Food

Key Online Resources:

•http://ngm.nationalgeographic.com/2008/09/soil/mann-text
•http://www.fao.org/docrep/006/y4683e/y4683e06.htm

• Humans are almost entirely dependent on the land for food: 98% of human food is produced on the land. Globally, **12%** of Earth's land surface is used for cultivating **food and fiber** crops, **24%** is **pasture** used **for grazing livestock** that produces meat and milk, and **31%** is covered by **forests**, which are largely exploited for fuel, lumber, paper, and other products. The remaining land, **less than one-third**, is desert, mountains, tundra, and other terrain **unsuitable for agriculture** (Harper, 2008, p.46).
▸http://www.ifpri.org/2020/BRIEFS/NUMBER18.HTM

• **Agriculture** first emerged about **10,000 years ago** in several different regions, including Mesopotamia, eastern China, meso-America, the Andes, and New Guinea (MA, 2005, p.749). **The Neolithic Revolution** was sparked by a number of changing climatic and social factors, which resulted in gradual demographic and geographic expansion. During this process of expansion, human societies depleted their local and regional natural environments, and were forced to change their mode of existence – from surviving off of wild food sources to cultivating plants and domesticating animals (Broswimmer, 2002, p.30).
▸http://www.bbc.co.uk/dna/h2g2/A2054675

• Swidden or **slash-and-burn agriculture** is one of the oldest forms of farming and consists of cropping on cleared plots of land, alternated with lengthy fallow periods. These systems are the dominant form of agriculture in tropical humid and sub-humid upland regions and are typically associated with tropical rain forests (MA, 2005, p.750).
▸http://www.eoearth.org/article/Slash_and_burn

• Human intervention has produced a "**net degradation of soil**" largely through **copious food production**, which overdraws and degrades natural resources to maximize production (Harper, 2008, p.46-47).

• From the beginning of agriculture until about 1950, nearly all the growth of food output came from expanding cultivated land area. Since 1950, at least four-fifths of the increase in food output came from increasing *productivity* (Harper, 2008, p.46-47).

• **Intensification** has involved improved technologies, such as plant breeding, fertilizers, pest and weed control, irrigation, and mechanization; global food security now depends to a large extent on **fertilizers** and **fossil fuels** (GEO-4, 2007, p.110). However, "fertilizer is not a substitute for fertile soil. It can only be applied up to certain levels before crop yields begin to decline" (Harper, 2008, p.46-47).
▸http://www.wri.org/publication/content/8331

• Most smallholders cannot afford fertilizers now, and the prices are being driven up by **rising energy costs** and the depletion of easily exploited stocks of phosphate. Food production is also constrained by the competing claims of other land uses, not least for maintenance of ecosystem services, and large areas may be reserved for conservation (GEO-4, 2007, p.110).

▸ http://www.postcarbon.org/even-giants-hurt-rising-energy-prices

• While modern intensive agriculture dramatically increased productivity, it all but destroyed the **traditional methods** of preserving soil productivity that farmers everywhere had learned to practice, such as terracing, contour plowing, crop rotation, fallowing, organic fertilizer, etc. (Harper, 2008, p.46).

• **Intensive agriculture** has encouraged continuous cropping of **monocultures** without rotation or fallow periods, cropping on hilly and **marginal land**, and **overgrazing** in confined pasturelands (Harper, 2008, p.46-47). Cropland expansion and intensification lead to a loss of habitat and biodiversity, soil salinization, soil erosion, and eutrophication, among other problems.
▸ http://www.cnr.berkeley.edu/~agroeco3/modern_agriculture.html

• Livestock production is the **single largest user of land** either directly through grazing or indirectly through consumption of fodder and feed grains (MA, 2005, p.216). Confined **livestock production systems** in industrial countries are the source of most of the world's poultry and pig meat production and hence of global meat supplies (p.752). Problems with these systems often arise in the disposal of large amounts of **manure** and slaughtering by-products. Soils can quickly become saturated with both **nitrogen and phosphorus** because it is too costly to transport manure long distances, given its relatively low nutrient concentration (p.752).
▸ http://www.fao.org/newsroom/en/news/2006/1000448/index.html

• The expansion of extensive **beef production systems**, primarily in South and Central America, has been associated with high rates of **deforestation** (MA, 2005, p.218).
▸ http://www.guardian.co.uk/uk/2005/oct/18/bse.foodanddrink

• The continued shift from cereal to animal products and the recent move towards **biofuels** will add to the demand for farm production (GEO-4, 2007, p.83). A major shift in agricultural production from food to biofuels presents an obvious conflict (p.110).
http://www.wri.org/stories/2008/08/food-or-fuel-the-bioenergy-dilemma

• The world's population is projected to increase to over 9 billion by 2050 http://www.un.org/apps/news/story.asp?NewsID=13451&Cr=population&Cr1. Thus, to meet the Millennium Development Goals on hunger, a doubling of global food production will be required (GEO-4, 2007, p.110).

• To feed a growing global population on increasingly degraded and expensive agricultural resources, we will need to increase the productive yield of agriculture while protecting the fertility of cropland soils (Harper, 2008, p.47), as well as strive to curb population growth http://vhemt.org/.

• Nearly every credible forecast shows that if we're to have any chance of meeting future food demand in a sustainable fashion, **lowering our meat consumption** will be absolutely essential (Roberts, 2008, p.209).
▸ http://www.wellfedworld.org/PDF/CIWF%20Eat%20Less%20Meat.pdf

• Some types of production systems, such as **multi-tiered, tree and crop-based farming systems**, can be very effective in building up soil nutrients, reducing soil erosion, enhancing

water-related, climate, and flood regulation services, and even promoting biodiversity (MA, 2005, p.755-756).
▸http://www.fao.org/docrep/x5672e/x5672e04.htm

• Many types of wild food remain important for the **poor and landless**, especially during times of famine and insecurity or conflict, when normal food supply mechanisms are disrupted and local or displaced populations have limited access to other forms of nutrition. Even in normal times, these **wild land-based foods** are important in complementing staple foods to provide a balanced diet, and plants growing as weeds may often be important in this respect (MA, 2005, p.219)
▸http://www.un.org/esa/forests/pdf/ECOSOC2007_Issues_Paper.pdf

• The loss of prime agricultural land is a consequence of urban expansion, often displacing food production onto less productive land elsewhere. **Urbanization** also leads to major changes in **nutrient flows** associated with the flow of food from rural to urban areas. Whereas organic matter residues were once recycled locally, this nutrient export from rural to urban areas can deplete soil nutrient content in the production areas and can concentrate nutrients in human wastes and other residues in and around cities (MA, 2005, p.225).

Illustrative Facts & Statistics

▸*Extent and expansion of cropland*

• Globally, cultivated systems cover 36.6 million square kilometers, or approximately 27% of total land area (and a much higher share of habitable land [MA, 2005, p.221]). It is estimated that 74% of the world's population lives within the boundaries of cultivated systems (MA, 2005, p.754).
• Since 1700 cropland has increased by 1,200 million hectares (466%), including major expansion in North America and the former Soviet Union, with the greatest expansion occurring in the past 150 years (MA, 2005, p.749).
• Over the past 40 years cropland area has expanded globally by some 15% - from 1.3 billion to 1.5 billion hectares, the area of pasture has grown some 11% from 3.14 billion to 3.48 billion hectares, and practically all corners of the world's oceans are accessible to the world's fishing fleet (MA, 2005, p.229).
• Globally, agricultural land has expanded by around 130,000 square kilometers per year over the past 25 years, predominantly at the expense of natural forests and grasslands (MA, 2005, p.760).
• In the 1920s and 1930s there were more than 6 million farms of around 40 hectares each. By the late 1900s, there were fewer than 2 million farms and they averaged 200 hectares each (MA, 2005, p.228).
• Globally, 78% of the increase in crop output between 1961 and 1999 was attributable to yield increases and 22% to expansion of harvested area (MA, 2005, p.775).
• Agricultural land is expanding in 70% of countries, declining in 25% and static in 5%; forest area is decreasing in two-thirds of countries where agricultural land is expanding and forests are expanding in 60% of countries whose agricultural land is decreasing (MA, 2005, p.597).
• Cropland in Latin America, Africa, Australia, and South and Southeast Asia expanded very gradually between 1700 and 1850, but subsequently expanded rapidly. Since 1950, cropland area in North America has stabilized, while it has decreased in Europe and China. In the 2 decades before 2000, the major areas of cropland expansion were located in Southeast Asia, parts of Asia,

eastern Africa, and in the Amazon Basin. The major decreases of cropland occurred in the southeastern United States, eastern China, and parts of Brazil (MA, 2005, p.749).
• More than for any other crop (and excluding pastures), it is the global area expansion of oil crops over the past 40 years that has driven cropland expansion. Food use of oil and vegetable oil crops, expressed in oil equivalent, grew from 6.3 kg per capita per year in 1964/66 to 11.4 kg in 1997/99 (MA, 2005, p.214).
• Cereal production accounts for almost 60% of the world's harvested crop area and an often disproportionately larger share of the usage of fertilizer, water, energy, and other agrochemical inputs (MA, 2005, p.216).

►*Extent of various farming systems*

• Between 1992 and 2001, the extent of organic cropland in the United States grew by over 200%, from about 163,000 hectares to 526,000 (MA, 2005, p.767).
• Roughly 18% (250 million hectares) of total cultivated area is irrigated. Rain-fed agricultural systems account for the largest share (about 82%) of the total agricultural land area and exist in all regions of the world (MA, 2005, p.750).
• Slash-and-burn agriculture is practiced on about 22% of all agricultural land in the tropics and is the primary source of food and income for some 40 million people (MA, 2005, p.751).
• Mixed crop-livestock farming systems are the backbone of small-holder agriculture throughout the developing world, supporting an estimated 678 million rural poor (MA, 2005, p.751).

►*Environmental Impacts of Agriculture*

• The arrival of humans practicing agriculture increased the volume of soil and silt being carried into the ocean by at least two and a half times the original rate (Harper, 2008, p.46).
• Soil is eroding on approximately 38% of the world's cropland; soil erosion and degradation has reduced food production on about 16% of the world's cropland (Harper, 2008, p.47).
• It is estimated that American soils are eroding 16 times faster than it can from, and the Great Plains states have lost half their topsoils since agriculture began there (Harper, 2008, p.47).
• Worldwide, some 20% of irrigated land (450 000 km^2) is salt-affected, with 2,500 – 5,000 km^2 lost from production every year as a result of salinity (GEO-4, 2007, p.99-100).
• The soil of nearly a third of all arable land is so acid that it can't support high-yielding crops (Roberts, 2008, p.214).
• Half a billion people now live and farm on lands so hilly and erosion prone that further intensification won't be possible without a considerable cost, and, globally, erosion is so severe that, by 2050, the world may be trying to feed twice as many people with half as much topsoil (Roberts, 2008, p.214).
• Of the 230 pounds of synthetic nitrogen applied to the typical acre of United States corn, as much as 50 pounds will leave the soils and enter the surrounding environment (Roberts, 2008, p.216).
• In China, overgrazing transforms 1400 square miles of grasslands into desert each year (Roberts, 2008, p.221).

►*Intensity of food production*

• In the 1980s, globally, one farmer produced one ton of food, and one hectare of arable land produced 1.8 tons, annually on average. Today, one farmer produces 1.4 tons, and one hectare of

land produces 2.5 tons. The average amount of land cultivated per farmer remained the same, about 0.55 ha (GEO-4, 2007, p.86)

• Cereal production accounts for almost 60% of the world's harvested crop area and an often disproportionately larger share of the usage of fertilizer, water, energy, and other agrochemical inputs (MA, 2005, p.216).

• The roughly 18% (250 million hectares) of total cultivated area that is irrigated accounts for about 40% of crop production (MA, 2005, p.750).

• Today, the food security of two-thirds of the world's population depends on fertilizers, particularly nitrogen fertilizer (GEO-4, 2007, p.100).

• Three cereals – rice, wheat, and maize – receive 56% of all nitrogen fertilizer applied in agriculture (MA, 2005, p.753)

• Between 1992 and 2001, the extent of organic cropland in the United States grew by over 200%, from about 163,000 hectares to 526,000 (MA, 2005, p.767).

• Globally, 78% of the increase in crop output between 1961 and 1999 was attributable to yield increases and 22% to expansion of harvested area (MA, 2005, p.775).

• Most forecasts suggest that of the one billion tons of extra grain needed by 2030, four-fifths must come not by planting extra acres, but from intensification – getting more food from existing acres, largely because farmland is continually being lost to commercial and residential development, especially in the United States (Roberts, 2008, p.213).

► Land & Soil and Energy

• All energy on Earth ultimately comes from the **sun**. We are now living off the **stored energy** capital of millions of years ago.

• The modern **carbon-based energy system** is connected with environmental problems of all kinds, including air pollution, oil spills, and **global climate change**; "the human use of energy – its mining, refining, transportation, consumption, and polluting by-products – accounts for much of the human impact on the environment" (Harper, 2008, p.111).
▸ http://www.davidsuzuki.org/Climate_Change/Energy/Fossilfuels/

• Since the beginning of the 21st century, three nonrenewable **fossil fuels** – oil, natural gas, and coal – supplied about 75% of the world's commercial energy needs (Harper, 2008, p.114).

• Burning fossil fuels is a major source of **anthropogenic CO_2**, which is the chief **greenhouse gas** implicated in climate change. It also produces nitrous and sulfur oxides that damage human populations, crops, trees, fish, and other species (Harper, 2008, p.118).

• **Oil spills** and leakage from pipelines poison the land and water system. The ecosystem disruption from oil spills can last as long as 20 years, especially in cold climates (Harper, 2008, p.118).
▸ http://www.davidsuzuki.org/Climate_Change/Energy/Fossilfuels/oil.asp

• **Coal** is hazardous and ecologically destructive to mine and the dirtiest, most toxic fuel to burn.
▸ http://www.davidsuzuki.org/Climate_Change/Energy/Fossilfuels/coal.asp

• Fuelwood, charcoal, and other wood-derived fuels (collectively known as woodfuels) are the world's most important form of non-fossil energy. Production and consumption are concentrated in low-income countries, with five countries – Brazil, China, India, Indonesia, and Nigeria – accounting for about 50 percent of the total.
▸ http://www.wri.org/publication/content/8156

• Land is increasingly being used to grow crops for fuel as opposed to food. The World Energy Outlook 2006 forecasts an increase in the area devoted to **biofuels** from the current 1% of cropland to 2-3.5% by 2030 (when using current technologies). A major shift in agricultural production from food to biofuel presents an obvious conflict (GEO-4, 2007, p.110).
▸ http://www.wri.org/stories/2008/08/food-or-fuel-the-bioenergy-dilemma

• Forest products and the non-food cellulose component of food crops have a huge potential as an energy source, but technologies are still too costly to compete with fossil fuels at current prices (GEO-4, 2007, p.110-111).

Illustrative Facts & Statistics

• More than 2 billion people worldwide rely on biomass for their main energy source (MA, 2005, p.247).
• In 2000, biomass other than fuelwood and charcoal may have provided 5% of global world energy (MA, 2005, p.260).

• Taking into account the NPP of the world's ecosystems and conventional energy technology, global biomass could provide energy at a theoretical rate of 9 – 26 terawatts, compared with the current rate of global energy use of 15 terawatts (MA, 2005, p.261).
• More than 2 billion people worldwide rely on biomass for their main energy source (MA, 2005, p.247).
• Global consumption of charcoal appears to have doubled between 1975 and 2000, largely as a result of continuing population shifts toward urban areas (MA, 2005, p.259).
• Between 50 and 90% of the oil reaching the oceans comes from the land, when waste oil dumped on the land by cities, individuals, and industries ends up in streams that flow into the ocean (Harper, 2008, p.118).

► Land & Soil and Biodiversity

• The greatest threat to biodiversity is the **destruction and fragmentation of habitat**, most notably deforestation (Harper, 2008, p.57). **Forest** ecosystems are extremely important refuges for terrestrial biodiversity. Biodiversity is essential for the continued health and functioning of these ecosystems, and underpins the various services that forests provide (MA, 2005, p.587).
▸ http://www.wri.org/publication/content/8150
▸ http://www.wri.org/publication/content/8152

• **Tropical deforestation** is the greatest eliminator of species, followed by the **destruction of coral reefs and wetlands**. Tropical forests alone cover only about 5% of the earth's surface, but contain more than 50% of all terrestrial species (Harper, 2008, p.57).
▸ http://earthobservatory.nasa.gov/Features/Deforestation/

• **Modern agriculture** is another major cause of declining biodiversity. **Cropland expansion** and **intensification** contribute to the destruction and fragmentation of habitat, but modern agriculture reduces biodiversity in a much more direct and intentional way, through the increasingly prevalent cultivation of **monoculture** crops.

• People have historically used over 7,000 plant species for food, now reduced to largely twenty species around the world, mainly wheat, corn, millet, rye, and rice. These plants are now **selectively bred** into a few strains with greatly reduced genetic variability (Harper, 2008, p.57).
▸ http://www.newcastle.edu.au/Resources/Research%20Centres/TFI/Publications/26%20Simon%20Lubinski.pdf

• A variety of human actions have reduced biodiversity, including overfishing, commercial hunting and poaching, predator and pest control, and invasive species (Harper, 2008, p.57).

Illustrative Facts & Statistics

• IUCN estimates that 12.5% of the world's species of plants, 44% of birds, 57% of amphibians, 87% of reptiles, and 75% of mammals are threatened by forest decline (MA, 2005, p.601).
• Between 1990 and 2005, deforestation in the tropics continued at an annual rate of 130 000 km^2 (GEO-4, 2007, p.82).
• It is estimated that the current rate of species disappearance from tropical forests is about 4,000 to 6,000 species per year, which is about 10,000 times greater than the natural "background" rate of extinction before humans arrived (Harper, 2008, p.57).
• In Sri Lanka, farmers cultivated some 2,000 varieties of rice as late as 1959. Today only five principal varieties are grown. India once had 30,000 varieties of rice; today most production comes from only 10 (Harper, 2008, p.57).

► Land & Soil and Waste & Pollution

• Harmful and persistent pollutants, such as **heavy metals** and **organic chemicals**, are being continually released to the land, air and water from various sources. Chemicals are used in every aspect of life, including industrial processes, energy, transport, agriculture, pharmaceuticals, cleaning and refrigeration. Releases, by-products and degradation of chemicals, pharmaceuticals and other commodities contaminate the environment (GEO-4, 2007, p.93-94).
▸ http://www.epa.gov/epawaste/topics.htm#c_form

• Chemical wastes from **industry** and **agriculture** are a big source of contamination, particularly in developing countries and countries with economies in transition. Increasingly, some of the chemical waste stream comes from **everyday products**; increasing consumption remains tied to increased generation of wastes, including chemical wastes (GEO-4, 2007, p.94-95).

• **Urban areas** are a source of **sewage** flows, run-off and other forms of waste that become environmental problems, often affecting surrounding rural areas, as well as **degrading water quality** (GEO-4, 2007, p.111).
▸ http://74.125.113.132/search?q=cache:SVKbbS8SjOYJ:www.populationenvironmentresearch.org/papers/Urban_Expansion_background_paper.pdf+environment+urban+expansion&cd=1&hl=en&ct=clnk&gl=ca

• Most domestic waste still goes into **landfills** (GEO-4, 2007, p.95). These sites concentrate vast amounts of waste and as a result, a dangerous liquid residue derived from the break-down of that waste called **leachate** seeps into soil and drainage pipes, eventually contaminating the water system. Leachate contains over 100 toxic chemicals (Harper, 2008, p.67-68).

• Implications of chemical contamination for human health and safety include: poisoning, accumulation of persistent pollutants in human tissue with potential genetic and reproductive consequences, increased risk of exposure and of contamination in food chains; and in severe cases, areas can become uninhabitable (GEO-4, 2007, p.87).

• **Atmospheric pollutants** have contributed to soil acidification and forest decline (GEO-4, 2007, p.95). Air pollution induces changes in tree physiology, phenology, and biochemical cycling (MA, 2005, p.611).

• Sulfur, nitrogen, heavy metals, and ozone are the most pervasive air pollutants in terms of damage to forest health. However, air pollution impacts forest ecosystems in complex ways; the deteriorating condition of forests has been due to the combined effects of **eutrophication**, **acidification**, and **climate change** (MA, 2005, p.611).
▸ http://www.fao.org/DOCREP/ARTICLE/WFC/XII/0534-B1.HTM

• Rivers, lakes and coastal waters receive large amounts of **nutrients** from the land, and overloading of nutrients often results in **algal blooms**, or eutrophication. If this increases in intensity and frequency, whole ecosystems may be subject to hypoxia (**dead zones** due to lack of oxygen) as can be seen in the Gulf of Mexico and the Baltic Sea (GEO-4, 2007, p.111).
▸ http://www.eoearth.org/article/Eutrophication

Illustrative Facts & Statistics

• It is estimated that 75% of solid wastes are produced by mining and oil and gas production, 13% by agriculture, 9.5% by industry, 1.5% by municipal garbage, and 1% by sewage sludge (Harper, 2008, p.64).
• Americans throw away about 2.5 million nonreturnable plastic bottles each hour, enough aluminum to rebuild the country's entire commercial airline fleet every three months, enough disposable diapers per year which, if lines up end to end, would reach the moon and back seven times, and 1.5 billion pounds of edible food per year (Harper, 2008, p.64).
• Since 1950 pesticide use increased more than 50-fold, and most of today's pesticides are more than 10 times as toxic as those of the 1950s (Harper, 2008, p.65).
• The average American lawn is doused with 10 times as much pesticide as a hectare of American cropland (Harper, 2008, p.65).
• The United States recycles about 30% of their solid waste, an increase from 6.4% in 1960 (Harper, 2008, p.68).
• Globally, the proportion of paper and cardboard recycled grew from 38% to 41% between 1975 and 1995 (Harper, 2008, p.68).
• Studies show that with greater economic incentives and more efficient waste management systems, the MDCs (more developed countries) could boost their recycling of municipal waste to 60-80% (Harper, 2008, p.68).

► Land & Soil and Climate Change

• Climate change effects changes in land ecosystems and human settlements, and those changes in turn can exacerbate climate change.

• Climate change involves the **warming of the seas** and the **melting of glaciers and polar ice caps**, both of which effect a rise in sea level. Even "a modest rise in sea level would threaten the coastal settlements in which *half* of humanity lives" (Harper, 2008, p.94). Fertile farmland in river deltas would be lost, salinity would move upstream, and high tides and storm surges would penetrate further inland.
▸ http://www.grida.no/publications/other/ipcc_sr/?src=/Climate/ipcc/regional/253.htm

• Many **crop yields** are delicately dependent on a particular combination of temperatures, soil conditions, and rainfall patterns that could be disrupted by climate change, jeopardizing the world's food security. The amount of warming is anticipated to be greatest in the northern latitudes, but computer modeling suggests that the effect on crops is likely to be more uniformly severe in the southern latitudes (Harper, 2008, p.94).
▸ http://www.fao.org/newsroom/en/news/2007/1000646/index.html

• Climate change would reduce stream flows and increase pressure on groundwater while worsening the pollution discharge into smaller flows (Harper, 2008, p.95). This effect could exacerbate the world's existing water problems, and would have dire implications for food production, which accounts for 70% of global water use.
▸ http://www.southwestclimatechange.org/impacts/water/streamflow#impacts

• Warming can lead to **ecosystem collapse**, including vast **forest fires** (resulting in reduced transpiration and increased carbon emissions), grasslands turning to **dust bowls**, and the spread of tropical waterborne and insect-transmitted **diseases** (Harper, 2008, p.95). Climate change threatens forests in all biomes (MA, 2005, p.587).

• **Land degradation** in turn contributes to climate change. The **overexploitation of forests** has been at the expense of not only biodiversity, but natural regulation of water and climate.
▸ http://www.sciencedaily.com/releases/2007/05/070511100918.htm

• While the burning of fossil fuels has greatly disturbed the carbon cycle, **land-use change** has been responsible for about one-third of the increase in **atmospheric carbon dioxide** over the last 150 years, mainly through loss of **soil organic carbon** (GEO-4, 2007, p.100) http://www.eoearth.org/article/Soil_organic_carbon. **Deforestation** in the tropics has the greatest impact on the carbon cycle of any land use and land cover change (MA, 2005, p.606).

• "The global carbon cycle is by no means fully understood." The missing sink for 40% of known carbon dioxide emissions is generally thought to be **terrestrial ecosystems**, most notably forests and wetlands. Vast areas of peat and tundra are reservoirs of stored organic carbon (one-third of all terrestrial organic carbon is peat) and methane, and they continue to fix carbon. With climate change, there is risk of unexpected sudden increases in the atmospheric levels of carbon dioxide, if these sinks become saturated. The peat and tundra areas might transform from being a sink of carbon to become sources of greenhouse gas (GE0-4, 2007, p.111).
▸ http://www.sciencedaily.com/releases/2008/10/081028120951.htm

• **Forests and woodlands** play a significant role in the global carbon cycle, and, consequently, in accelerating or decelerating global climate change. Forests contain about 50% of the world's terrestrial organic carbon stocks, and forest biomass constitutes about 80% of terrestrial biomass. Forests contribute over two-thirds of global terrestrial net primary production. Slowing forest loss and restoring forest cover in deforested areas could thus help mitigate climate change (MA, 2005, p.587).
▸ http://www.sciencedaily.com/releases/2007/05/070511100918.htm

• Recently disturbed and regenerated forests usually lose carbon from both soil and remnant vegetation, whereas mature, undisturbed forests maintain an overall neutral carbon balance. The rate of carbon sequestration depends on age, site quality, species composition, and the style of forest management. Mature boreal forests in many cases actually serve as a net carbon sink (MA, 2005, p.606).
▸ http://www.wri.org/publication/content/8151

• Because climate change alters the spatial and temporal patterns of temperature and precipitation, it will cause geographical shifts in the ranges of individual species and vegetation zones.

• The Tropical Forest Foundation suggests that 50% less stem damage during operations would increase productivity on a given land base by 20% (MA, 2005, p.596).

Illustrative Facts & Statistics

• The climatic scenarios considered by the Third Assessment Report of the IPCC projects the increase in global annual average surface temperature by the year 2100 to be 1.4-5.8 degrees Celsius higher than the mean over the period 1990 to 2001 (MA, 2005, p.612).
• Estimates for the carbon stock in the world's forest ecosystems vary in the range of 352-536 billion tons (MA, 2005, p.605).
• It is reported that land use change (mostly deforestation) is the source of 1.6 (plus or minus 0.8) billion tons of carbon per year (MA, 2005, p.606).
• In the United States, economic analyses estimate that a 50 cm rise in sea level by the year 2100 would cost between $20.4 and $138 billion in lost property and damage to economic infrastructures (Harper, 2008, p.94).
• A one meter rise in sea level would flood most of New York City, including the entire subway system and all three major airports (Harper, 2008, p.94).
• A five degree Fahrenheit rise in average temperature would melt the Greenland ice cap, the world's largest mass of frozen water. Most of South Florida would disappear into the Atlantic (Harper, 2008, p.94-95).

► WATER

Documents to Consult

1) The Living Planet Report (LPR)

Web link: http://www.panda.org/about_our_earth/all_publications/living_planet_report/

• The Living Planet Report is the World Wildlife Fund's periodic update on the state of the earth's ecosystems. It details changing trends in global biodiversity and the impact of human resource consumption on the biosphere. The analysis is built around two indicators: The Living Planet Index (LPI), which reflects the health of the world's ecosystems, and the Ecological Footprint, which measures the extent of human demand on these ecosystems. These measures are tracked over several decades to reveal past trends, and then three scenarios explore what might lie ahead.

LPR 2004: http://assets.panda.org/downloads/lpr2004.pdf **OR** http://74.125.45.132/search?q=cache:hugaJM4T5dYJ:assets.panda.org/downloads/lpr2004.pdf+Living+Planet+Report+2004&cd=1&hl=en&ct=clnk&gl=ca
LPR 2006: http://assets.panda.org/downloads/living_planet_report.pdf **OR** http://74.125.47.132/search?q=cache:rbd-75cgHCMJ:assets.panda.org/downloads/living_planet_report.pdf+Living+Planet+Report+2006&cd=1&hl=en&ct=clnk&gl=ca

• The main feature of these documents regarding water is an outline of global trends (by country) in water withdrawals.

LPR 2008: http://assets.panda.org/downloads/living_planet_report_2008.pdf **OR** http://74.125.47.132/search?q=cache:OC9R87GlswAJ:assets.panda.org/downloads/living_planet_report_2008.pdf+Living+Planet+Report+2008&cd=3&hl=en&ct=clnk&gl=ca

• This report documents current levels of global water *consumption* by country. It introduces the term "water footprint" to describe the total volume of water used globally to produce the goods and services consumed by the inhabitants of a country, including water withdrawn from rivers, lakes, and aquifers that is used in agriculture, industry and for domestic purposes.

2) Global Environment Outlook (GEO)

Web link: http://www.unep.org/geo/

• The Global Environment Outlook is an initiative of the United Nations Environment Programme (UNEP) that analyzes environmental change, causes, impacts, and policy responses.

GEO-4 (2007): http://www.unep.org/geo/geo4/report/GEO-4_Report_Full_en.pdf

Chapter 3: Land: http://www.unep.org/geo/geo4/report/04_Water.pdf **OR** http://www.eoearth.org/article/Global_Environment_Outlook_(GEO-4):_Chapter_4

• The chapter on water (p. 147 – 188 of the report) assesses the state of the water environment - with emphasis on changes over the last twenty years - and its impacts on human well-being with respect to human health, safety and security; livelihoods; and socioeconomic development. The pressures causing these changes are explored within the context of global and regional drivers. The chapter focuses on water issues related to climate change, to patterns of water-use, and to the condition of the world's fisheries. It also outlines the measures that are being taken to address these issues.

3) Millennium Ecosystem Assessment (MA)

Web link: http://www.millenniumassessment.org/en/Reports.aspx

• The MA was initiated in 2001 and aims to assess the consequences of ecosystem change for human well-being and the scientific basis for action toward the conservation and sustainable use of these natural systems. The MA has synthesized the work of more than 1,360 experts across the globe, and their findings are presented in five technical volumes and six synthesis reports.

Current State and Trends Assessment:
http://www.millenniumassessment.org/en/Condition.aspx

• This report assesses the changing conditions of ecosystems and their services, the causes of these changes, and the consequences for human well-being. It considers terrestrial, freshwater and marine systems, and a range of ecosystem services, including food, timber, air quality regulation, nutrient cycling, detoxification, recreation and aesthetic services.

• Chapter 7 – Freshwater Ecosystem Services (p.165 – 207) – provide an account of the recent history and current state of global freshwater provisioning services, including a continental-scale assessment of major water quality issues, a comprehensive account of the drivers of change in provisioning services, and a discussion of "trade-offs" in the contemporary use of freshwater resources.

Key Issues and Stressors

• Water is the lifeblood of Earth. Not only is it a precious natural resource, it is a fundamental precondition for virtually all the biological processes that keep life going on this blue planet. The vast majority of both the earth's surface and the bodies of all living organisms are made up of water; all living systems need it. The principal sources of freshwater – lakes, rivers, wetlands and aquifers – make up but a tiny fraction (tenths of 1%) of all water on Earth. This relatively small supply must be shared between humanity and other living systems that require it; there must be a balance between the water we appropriate for our own use –for drinking, washing, and cooking -

and the water that we leave for freshwater ecosystems to function properly so they can thrive and continue to provide life on Earth with the other resources and services that we depend on.
▸ http://www.worldwatercouncil.org/index.php?id=5&L=0target%3D_black%22onf
▸ http://www.ec.gc.ca/water/en/nature/prop/e_prop.htm

• Natural systems largely depend on salt water as well, and we too rely on the oceans – for food, transportation, recreation, climate regulation, etc. Thus human practices ought not to compromise the integrity of marine systems, either.
▸ http://www.wwf.org.uk/what_we_do/safeguarding_the_natural_world/oceans/

• In general, issues that pertain to water are the result of a disruption in the delicate balance between the needs of a burgeoning human population and the needs of the planet at large. Due to human mismanagement of water resources and other harmful practices, the water on this planet is in a very precarious situation. The key issues and stressors are:

• ***Issue(s)***: Overconsumption and depletion of water resources
• ***Stressor(s)***: Size and growth rate of the human population, overconsumption of other goods/resources, industrial agriculture and industrial production in general, water subsidies

• ***Issue(s)***: Unequal distribution of water resources, water scarcity, and water-related disease
• ***Stressors(s)***: Size and growth rate of the human population, social inequality, poverty

• ***Issue(s)***: Pollution of water bodies
• ***Stressor(s)***: Size and growth rate of the human population, industrial agriculture and industrial production in general, overconsumption and waste

• ***Issue(s)***: Fundamental alterations in the hydrological cycle (paths of run-off and rivers, precipitation and evapotranspiration patterns, volume of water in streams, lakes, aquifers, and rivers, etc.)
• ***Stressor(s)***: Size and growth rate of the human population, overconsumption of water resources and other goods/resources, land use patterns and urban development, global climate change

• ***Issue(s)***: Warming of the oceans, melting polar ice caps, rising sea level
• ***Stressor(s)***: Global climate change

► Water Use Patterns

Key Online Resources:

• http://www.fao.org/nr/water/aquastat/main/index.stm
• http://www.waterfootprint.org/?page=files/home
• http://www.worldwatercouncil.org/
• http://www.unep.org/dewa/assessments/ecosystems/water/vitalwater/index.htm

• Water is not consumed in the same way as food or fuel, since it may be returned once used (albeit with a reduction in its quality). *Withdrawal use* is directly measurable as quantities of intake, discharge, and consumption. *Water consumption* refers to the difference between intake and discharge; it removes water from a river system and leaves it unavailable for further use downstream.
▸ http://www.ec.gc.ca/WATER/en/manage/use/e_wtdraw.htm

• Over the last few centuries, growth in global water use has been roughly exponential, and **water withdrawals are increasing at a faster rate than that of human population growth**.
▸ http://www.populationaction.org/Publications/Reports/Why_Population_Matters/Water.shtml

• Globally, **agriculture accounts for the most water use** (about **70%**).
▸ http://www.fao.org/nr/water/aquastat/water_use/index6.stm

• **Irrigation** represents **the most inefficient use** of water resources, or the largest *consumptive* use. **Evaporation** in large open water reservoirs and cooling ponds represents the second largest consumptive use, although it is difficult to measure.
▸ http://www.fao.org/nr/water/aquastat/water_use/index5.stm
▸ http://www.ec.gc.ca/WATER/en/manage/use/e_wtdraw.htm

• In terms of regional use, the **United States** has the largest per capita "**water footprint**."
▸ http://www.waterfootprint.org/Reports/ResearchData/Appendix%20XX.xls

• **Asia** is the single largest user of freshwater resources.
▸ http://www.unep.org/dewa/assessments/ecosystems/water/vitalwater/14.htm

• The water footprint of a nation refers to the total amount of water that is used to produce the goods and services consumed by the inhabitants of the nation. Food products in particular are said to contain a given amount of "**virtual water**"; for instance about 1,000 liters of water are "embedded" in one kilogram of wheat, since it takes about that much water to produce it.
▸ http://www.worldwatercouncil.org/index.php?id=866

• The total water footprint of a country includes two components: the part of the footprint that falls inside the country (internal water footprint) and the part of the footprint that presses on other countries in the world (external water footprint).
▸ http://www.waterfootprint.org/?page=cal/waterfootprintcalculator_national
To get an idea of how the water footprint is calculated, see
▸ http://www.waterfootprint.org/?page=cal/waterfootprintcalculator_indv_ext.

• **Water usage tripled since 1950**, and planners have met this growing demand by "so-called **water development projects**": dams, irrigation, and river diversion schemes (Harper, 2005, p. 49). Across the globe, this ever-expanding consumption has caused water tables to fall http://www.eoearth.org/article/Aquifer_depletion, lakes to shrink https://www.earth-policy.org/Updates/2005/Update47_data.htm, and wetlands to disappear http://www.nasa.gov/audience/foreducators/k-4/features/F_Disappearing_Wetlands.html.

• Despite rapidly increasing levels of water withdrawal and consumption, many parts of the world lack secure access to **water resources**, which are very **unevenly distributed** across the globe due to the variable nature of the hydrological cycle. While there is no global water scarcity as such, an increasing number of regions are chronically short of water. In fact, currently only about 15% of the world population lives with relative water abundance (MA, 2005, p.167), and there is "strong evidence that under a business-as-usual scenario there will not be enough water to produce the food needed to feed the world in 2050" (WWI, 2008, p.122). The **water crisis** is "a challenge of poverty, inequality, and unequal power relationships as much as it is about physical water scarcity" (WWI, 2008, p.112). **Water scarcity** leads to competition among people and between people and ecosystems, the use of non-sustainable supplies, pollution and public health problems (MA, 2005, p.191).
▸ http://www.fao.org/nr/water/issues/scarcity.html
▸ http://www.healthinternetwork.com/features/factfiles/water/en/index.html

• In general, a large portion of the human population does not have secure access to water resources, and those with access use it wastefully. This is largely attributable to the fact that water is highly **subsidized** in most countries; we have not been paying for it at its full value, and this has encouraged gross overuse. Thus, "getting the prices right" is one of the first steps toward the sustainable management of water supplies (WWI, 2008, p.118).
▸ http://www.ec.gc.ca/water/en/info/pubs/fs/e_FSA4.htm#granted

• Other imperatives include revolutionizing the agricultural sector to increase the efficiency of its water use http://www.fao.org/nr/water/what.html and lowering the demand for meat products, which are five or six times more water-intensive to produce than wheat http://eatkind.net.

Illustrative Facts & Statistics

▸ *Water use patterns*

• There was a fifteen fold increase in global water withdrawals between 1800 and 1980, when population increased by a factor of four. Over the twentieth century alone, water withdrawals increased by a factor greater than six – more than twice the rate of population growth (MA, 2005, p.174).
• From 1961 to 2001, global water use doubled, industrial use more than doubled, domestic use grew more than four-fold, and agricultural use grew by three-quarters (LPR, 2004, p.18)
• In 2001, world average water use was about 650,000 liters per person, ranging from around 1.9 million liters in North America to around 250,000 liters in Africa (LPR, 2004, p.18)
• The world average water footprint is 1.24 million liters per person per year, which is equivalent to half the volume of an Olympic swimming pool (LPR, 2008, p.21)
• The United States has the largest water footprint, nearly 2.5 million liters per person per year (LPR, 2008, p.18).

• Current water withdrawal is approximately 3,600 cubic kilometers per year globally, and the single largest user is Asia, which accounts for nearly half the world total. (MA, 2005, p.174)
• Agriculture accounts for the most water use, about 70% worldwide, and it is also the most inefficient use; it requires 4.2 million liters of water in a growing season to grow 1 hectare of corn. It is not uncommon for 70 to 80% of the water in irrigation systems to be lost by evaporation or to seep into the ground before reaching crops (Harper, 2008, p.49).
• Irretrievable losses from irrigation represent one-third of all water uses globally. Irrigation is very wasteful because much of this water is lost to evapotranspiration and lost in transit as well. Water input-to-crop output ratios vary from the hundreds to the thousands (MA, 2005, p.174).
• Meat, milk, leather and other livestock products account for 23% of global water use in agriculture, equivalent to more than 1,150 liters of water per person per day (LPR, 2008, p.21).
• Each kilogram of beef requires 15,500 liters of water (LPR, 2008, p.21); one kilogram of grain requires 1,000 – 2,000 liters of water (MA, 2005, p.185).
• Industrial processes, which include withdrawals for manufacturing, and thermoelectric cooling, today use about 20% of the total freshwater withdrawals, which has more than doubled between 1960 and 2000 (MA, 2005, p.190).
• It takes over 400,000 liters of water to produce an automobile, and industrial societies produce about 50 million cars every year (Harper, 2008, p.49).
• Unlike many resources, there are relatively fixed minimum requirements for water needs. To assure adequate health, people need a minimum of about 100 liters of water per day for drinking, cooking, and washing (Harper, 2008, p.49).
• It is estimated that between 1.5 billion and 3 billion people depend on groundwater supplies for drinking (MA, 2005, p.16).

►*Over-exploitation of water supplies*

• From 5% to possibly 25% of global freshwater use exceeds long-term accessible supply; all continents record overuse (MA, 2005, p.167).
• Worldwide, surface water and groundwater each supply about half of the needed freshwater, but the recharge rate for groundwater is very slow, about 1% a year (Harper, 2008, p.49).
• At present rates of consumption in the United States, much of the Ogallala aquifer will be barren, and production in the region that now supplies about 40% of the nation's beef and grain will drop sharply (Harper, 2008, p.50).
• Groundwater abstractions since the 1950s, with the advent of motorized drilling rigs and pumps, have increased from 100-150 cubic km per year to 950-1,000 cubic km (WWI, 2008, p.112).

►*Water scarcity and disease*

• By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity (GEO-4, 2007, p.116).
• About 95% of people in MDCs and 74% of people in LDCs now have access to clean drinking water. However, according to the World Health Organization, there are still about 1.4 billion people in LDCs without access to clean drinking water. The U.N. estimates that it would take $23 billion over about a decade to bring water and sanitation to those people. If the MDCs paid for half of that, it would amount to about $19 a year for each person in LDCs (Harper, 2008, p.71).

• 3.2 million people die each year from water-related diseases (6% of all deaths), including waterborne and water-based diseases (MA, 2005, p.195).
• 2.8 billion people live in basins with some level of water scarcity. Experts estimate that by 2025 over three quarters of the people in the world will face some degree of water scarcity (WWI, 2008, p.108).

► Consumption of Water Resources and Population

• Key Online Resources:

• http://www.populationaction.org/Publications/Reports/Why_Population_Matters/Water.shtml
• http://www.un.org/popin/fao/water.html
• http://www.aaas.org/international/ehn/fisheries/gleick.htm

• Our sheer numbers are putting immense pressure on virtually all natural resources, not just on water supplies. The **human population** increases **exponentially**, thus the amount of time it takes for our numbers to double is getting shorter and shorter: "If it takes the lily a year to fill the pond, it takes a full 364 days to fill half the pond" (PAI).
▸ http://216.146.209.72/Publications/Reports/People_in_the_Balance/Interactive/peopleinthebalance/pages/?s=1
▸ http://www.census.gov/ipc/www/idb/worldpopinfo.html
▸ http://www.populationaction.org/Publications/Reports/Why_Population_Matters/Population_-_Facts_and_Figures.shtml

• In addition, because people are **living longer** today – thanks to modern science, technology and medicine – the human population is simply exploding; it is possible that there are more people alive today than have ever existed.
▸ http://ecology.com/features/population/

•An expanding human population not only requires a greater supply of water for drinking, cooking, and washing; it necessitates an **increase** in the scale of **industrial production**, **agriculture**, **infrastructural development**, etc. These activities require vast amounts of water.
▸ http://www.un.org/popin/fao/water.html

•Over the last few centuries, growth in global **water use** has been roughly **exponential** and water withdrawals increased at more than *twice* the rate of population growth over the twentieth century (MA, 2005, p.174). Thus as our numbers swell, each of us, on average, is using more and more water.
▸ http://www.climate.org/topics/water.html

• There is "strong evidence that under a business-as-usual scenario there will not be enough water to produce the food needed to feed the world in 2050" (WWI, 2008, p.122). Currently, only about **15%** of the world population lives with **relative water abundance** (MA, 2005, p.167). Much of the world faces a **water crisis**, which is "a challenge of poverty, inequality, and unequal power relationships as much as it is about physical water scarcity" (WWI, 2008, p.112). **Water scarcity** leads to competition among people and between people and ecosystems, the use of non-sustainable supplies, pollution and public health problems (MA, 2005, p.191). In regions where water shortage is severe and worsening, high rates of population growth exacerbate the declining availability of renewable freshwater.
▸ http://216.146.209.72/Publications/Reports/People_in_the_Balance/Interactive/peopleinthebalance/pages/?s=2
▸ http://www.fao.org/nr/water/issues/scarcity.html,
▸ http://www.healthinternetwork.com/features/factfiles/water/en/index.html

• In general, a large portion of the human population does not have secure access to water resources, and those *with* access use it wastefully. This is largely attributable to the fact that water is highly **subsidized** in most countries; we have not been paying for it at its full value, and this has encouraged gross overuse. Thus, "getting the prices right" is one of the first steps toward the sustainable management of water supplies (WWI, 2008, p.118).
▸ http://www.ec.gc.ca/water/en/info/pubs/fs/e_FSA4.htm#granted

• Other imperatives include revolutionizing the agricultural sector to increase the efficiency of its water use http://www.fao.org/nr/water/what.html and lowering the demand for meat products, which are five or six times more water-intensive to produce than wheat http://eatkind.net.

• Improving the lives of those in the Global South is a crucial step towards slowing the growth rate of the human population.
▸ http://www.vhemt.org/
▸ http://www.populationaction.org/
▸ http://www.prb.org/Educators/TeachersGuides/HumanPopulation/Women/QuestionAnswer.aspx

Illustrative Facts & Statistics

• There was a fifteen fold increase in global water withdrawals between 1800 and 1980, when population increased by a factor of four. Over the twentieth century alone, water withdrawals increased by a factor greater than six – more than twice the rate of population growth (MA, 2005, p.174).
• From 1961 to 2001, global water use doubled, industrial use more than doubled, domestic use grew more than four-fold, and agricultural use grew by three-quarters (LPR, 2004, p.18). Over roughly the same time period (1959 to 1999), the world population doubled, increasing from 3 billion to 6 billion (United States Census Bureau).
• By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity (GEO-4, 2007, p.116).
• About 95% of people in MDCs and 74% of people in LDCs now have access to clean drinking water. However, according to the World Health Organization, there are still about 1.4 billion people in LDCs without access to clean drinking water. The U.N. estimates that it would take $23 billion over about a decade to bring water and sanitation to those people. If the MDCs paid for half of that, it would amount to about $19 a year for each person in LDCs.
• 3.2 million people die each year from water-related diseases (6% of all deaths), including waterborne and water-based diseases (MA, 2005, p.195).
• 2.8 billion people live in basins with some level of water scarcity. Experts estimate that by 2025 over three quarters of the people in the world will face some degree of water scarcity (WWI, 2008, p.108).

► Water, Land Use, and Development

• Humans are altering the hydrological cycle through our **infrastructural developments** and general **land use patterns**. In order to increase water security and effective management, storage and distribution of water supplies, we rely on "**water engineering**," including dams, reservoirs, irrigation schemes, water transfers, treatment facilities, etc (MA, 2005, p.182). These projects fracture and fragment aquatic ecosystems, interfere with the migratory patterns of important fisheries, and have compromised the capacity of inland water ecosystems to provide reliable, high-quality sources of water (p.183).

• The pattern and extent of cities, roads, agricultural land, and natural areas within a watershed influence infiltration properties, evapotranspiration rates, and runoff patterns, which in turn affect water quantity and quality (MA, 2005, p.188). For example, **deforesting** for urban development undermines the capacity of ecosystems and soils to absorb excess water and to evaporate it back into the atmosphere, creating conditions that are conducive to increased runoff and flooding (p.194).

• The geographic location of many large cities, such as those near coastal areas, and their rapid growth rates, has encouraged the over-exploitation of water resources that are not necessarily renewable, such as **coastal aquifers**. Groundwater over-exploitation in coastal areas can reverse the natural flow of groundwater into the ocean, causing salt water to intrude into in-land aquifers. Because of the high marine salt content, even low concentrations of seawater in an aquifer are enough to make groundwater supplies unfit for human consumption (MA, 2005, p.190).

Illustrative Facts & Statistics

►*Water resource management and infrastructure*

• Large reservoir construction has doubled or tripled the residence time of river water – that is, the average time that a drop of water takes to reach the sea, with the mouths of several large rivers showing delays on the order of many months to years (MA, 2005, p.183).
• Long-term trend analysis (more than 25 years) of 145 major world rivers indicated more than one fifth with declines in discharge to the ocean (MA, 2005, p.177).
• By 2015 nearly 55% of the world will live in urban areas. Because of the rapid rate of increase in cities around the world, water infrastructure is unable to keep apace, especially in megacities with more than 10 million people (MA, 2005, p.190).
• Worldwide, investments in dams have totaled $2 trillion. World Bank lending for irrigation and drainage averaged about $1.5 billion per year from 1960 to 2000 (MA, 2005, p.191).
• In the United States in 2000, private companies provided only 15% of municipal water supply and currently, over 80% of the world's investments in water, sanitation, and hydropower systems are publically owned bodies or international donors. (MA, 2008, p.194).

► Water and Food

• Key Online Resources:

• ftp://ftp.fao.org/agl/aglw/docs/agricfoodwater.pdf
• http://www.davidsuzuki.org/Oceans/Aquaculture/Salmon/Pollution.asp
• http://www.panda.org/about_our_earth/blue_planet/problems/

• **Cultivation** both relies on and influences the provision of **fresh water**. Both the quantity and quality of water resources can be affected, as well as the timing and distribution of water flows in local catchments and large river basins. Impoundments for irrigation can regulate downstream flows, while seasonally bare soil and field drainage systems can accelerate runoff and reduce infiltration, resulting in more severe local flooding and decreased dry weather flows (MA, 2005, p.761).

• Given that **agriculture** (more specifically, irrigation) is the largest and most inefficient consumer of water supplies, increases in food production are largely responsible for the squandering and over-exploitation of these supplies, especially those in **non-replenishable aquifers**. Water tables are falling in scores of nations that contain more than half of the world's people, including China, India, and the U.S (Harper). There is "strong evidence that under a business-as-usual scenario there will not be enough water to produce the food needed to feed the world in 2050" (WWI, 2008, p.112).
▸ http://www.fao.org/nr/water/aquastat/water_use/index6.stm
▸ http://www.ec.gc.ca/WATER/en/manage/use/e_agri.htm
▸ http://www.eoearth.org/article/Aquifer_depletion

• Although irrigation is by far the largest global water user, the net rate of increase in **irrigated area** has decreased steadily in each of the four past decades and now stands at just under 1% annually. Expansion in irrigated area has slowed as unexploited fresh water resources have become more limited and more expensive to develop. There is also increasing competition for water from domestic and industrial users (MA, 2005, p.761).
▸ http://www.worldwatch.org/node/6186

• Many studies indicate that current water usage is now so far above sustainable levels that it is already hurting global farm output. Water has no alternative, making it a more final constraint on food supplies than that of oil or climate (Roberts, 2008, p.228). Already, water depletion is leading countries to curb their own farm production and instead to import their water indirectly, in the form of grain ("**virtual water**") purchased from the United States, Europe, Brazil, Argentina, and other big grain exporters (p.xix).

• **Industrial agriculture** is not only water-intensive, but extremely **polluting**. Overfertilization has long served as a form of crop insurance, and at the same time as farmers have been adding too much fertilizer, new farming methods have accelerated the tendency for those excess fertilizers to leave the soil. Many fields are now left bare between autumn harvest and spring planting (no longer use traditional cover crops in between). When uncovered soils are exposed to weather, soil nitrogen quickly converts into nitrate, a highly mobile chemical compound that is easily leached from the soils by rain. In addition, hundreds of millions of tons of nitrogen-rich manure accumulates in livestock feedlots and often leaks into surrounding water sources. In

rivers and lakes, all this wayward nitrogen causes extensive algal blooms, eutrophication, and potentially, fish-killing "dead zones" (Roberts, 2008, p.216).
▸ http://www.greenpeace.org/canada/en/recent/dead-zones
▸ http://disc.gsfc.nasa.gov/oceancolor/scifocus/oceanColor/dead_zones.shtml

• **Salinization** and **waterlogging** are two significant consequences of poor irrigation management and inadequate drainage. Salinization occurs through the accumulation of salts deposited when water is evaporated from the upper layers of soils and is especially important in irrigated arid areas where evaporation rates are high (MA, 2005, p.763) http://www.nm.nrcs.usda.gov/technical/handbooks/iwm/NM_IWM_Field_Manual/Section13-ProducerWorkshop/PW-83.pdf.

• One of the first steps toward the sustainable management of water supplies and the reduction of pollutants in the water system entails revolutionizing the agricultural sector to increase the efficiency of its water use http://www.fao.org/nr/water/what.html and lowering the demand for meat products, which are five or six times more water-intensive to produce than wheat, and even more polluting http://eatkind.net .

• The **overexploitation of fisheries** is a global problem. Of the world's 15 main fishing regions, four are depleted and nine are declining (FAO 2000).
▸ http://archive.greenpeace.org/comms/cbio/global.html
▸ http://www.fishing.hourston.co.uk/about7.html

• **Commercial fishing** and fish farms (aquaculture) in particular contribute substantially to ocean **pollution**; fish farms pollute coastal waters with massive amounts of fish feces, antibiotic-laden fish feed, and diseased fish carcasses. Since 1970, **aquaculture** – the cultivation of marine or freshwater food fish or shellfish – has become the fastest-growing food production sector in the world, increasing at an average rate of 9.2% per year – an outstanding rate compared to the 2.8% rate for land-based farmed meat products (MA, 2005, p.558).
▸ http://www.fishinghurts.com/EnvironmentalConcerns.asp
▸ http://www.fishinghurts.com/fishFarms.asp
▸ http://www.panda.org/about_our_earth/blue_planet/problems/aquaculture/pollution/
▸ http://www.davidsuzuki.org/Oceans/Aquaculture/Salmon/Pollution.asp

Illustrative Facts & Statistics

• Agriculture accounts for the most water use, about 70% worldwide, and it is also the most inefficient use; it requires 4.2 million liters of water in a growing season to grow 1 hectare of corn. It is not uncommon for 70 to 80% of the water in irrigation systems to be lost by evaporation or to seep into the ground before reaching crops (Harper, 2008, p.49).
• Water requirements for cultivation are large; it takes 500 liters, 900 liters, 1,400 liters, and 2,000 liters of transpired water to produce 1 kg of potatoes, wheat, maize, and rice respectively (MA, 2005, p.761).
• On average, every ton of grain we grow requires a thousand tons of water (Roberts, 2008, p.227).
• Irretrievable losses from irrigation represent one-third of all water uses globally. Irrigation is very wasteful because much of this water is lost to evapotranspiration and lost in transit as well. Water input-to-crop output ratios vary from the hundreds to the thousands (MA, 2005, p.174).

• Global estimates of irrigation efficiency vary but the average is around 43% (MA, 2005, p.762).
• Of the 9,000-12,500 cubic km of surface water estimated to be available globally for use each year, between 3,500 and 3,700 cubic km were withdrawn in 1995 (MA, 2005, p.761).
• The share of extracted water used for agriculture ranges from 87% in low-income countries to 74% in middle-income countries and 30% in high-income countries (MA, 2005, p.761).
• By 2002, there were 276 million hectares of irrigated cropland globally, five times more than at the beginning of the twentieth century. While this irrigated area represents only 18% of all croplands, irrigated agriculture provides about 40% of the global food supply (MA, 2005, p.761).
• Half of the developing world's grain crop is grown on irrigated acres, and the success of the Green Revolution in India and Southeast Asia wouldn't have been possible had the area of irrigated land not doubled since 1960 (Roberts, 2008, p.228).
• Each kilogram of beef requires 15,500 liters of water (LPR 2008); one kilogram of grain requires 1,000 – 2,000 liters of water (MA, 2005, p.185).
• Aquifers have been so heavily tapped that water tables are falling by up to twenty feet a year. In North Africa, water is being withdrawn from aquifers as much as 5 times faster than it can recharge, forcing farmers to drill their irrigation wells to depths of nearly a mile. Even in the rain-rich United States, the huge Ogallala Aquifer, which supplies one in five irrigated acres nation-wide, is being overdrawn at a rate of 170 million tons (3.1 trillion gallons) a year and is gradually forcing many farmers to either shift to new "dry land" crops or abandon agriculture altogether (Roberts, 2008, p.229).
• At present rates of consumption in the United States, much of the Ogallala aquifer will be barren, and production in the region that now supplies about 40% of the nation's beef and grain will drop sharply (Harper, 2008, p.50).
• In the 3-H region in China, water use now exceeds the sustainable flow by more than six hundred million tons a year. Water tables have fallen by up to 300 feet, ground levels are subsiding, and in coastal areas, freshwater wells are now sucking in seawater. China is now thought to be feeding perhaps 200 million people – around a sixth of its population – with water withdrawals that cannot be sustained (Roberts, 2008, p.229).
• It is estimated that around 45 million hectares, representing 20% of the world's total irrigated land, suffers from salinization or waterlogging. Losses amount to approximately 1.5 million hectares of irrigated land each year and about $11 billion annually from reduced productivity (MA, 2005, p.763).
• Micro-irrigation technologies such as drip irrigation and micro-sprinklers, often achieve efficiencies in excess of 95% compared with standard flood irrigation efficiencies of 60% or less (MA, 2005, p.762).
• In freshwater aquaculture alone, some 115 freshwater species of finfish, crustaceans, and mollusks were cultured in 2000. Over the period 1991-2000, carp and tilapia ranked first and second respectively in global freshwater fish production, accounting for 76-82% and 5-6% of the total respectively (MA, 2005, p.753).
• It is estimated that the fishing industry has eliminated 90% of the large fish in the ocean (WWI, 2008, p.63).
• There are nearly 150 dead zones worldwide, more than double the number in 1990 (Roberts, 2008, p.217).

► Water and Waste & Pollution

• Key Online Resources:

• http://www.panda.org/about_our_earth/blue_planet/problems/pollution/
• http://www.ec.gc.ca/water/en/manage/poll/e_poll.htm
• http://www.ec.gc.ca/water/en/info/pubs/primer/e_prim04.htm#a17
• ftp://ftp.fao.org/agl/aglw/docs/agricfoodwater.pdf

• Virtually everyone contributes to water pollution by virtue of the products we use and discard. If we don't flush them directly into the water system, they end up in a **landfill** where accumulated toxins and chemicals get washed away by rain into surface water (known as "**leachate**"), or they seep into groundwater.
▸ http://assets.panda.org/downloads/fact_sheet___phthalates_food.pdf
▸ http://www.ec.gc.ca/Water/en/manage/poll/e_howgrd.htm

• **Industrial agriculture** effects the pollution of groundwater, lakes, and rivers due to its heavy and inefficient use of inorganic chemicals and fertilizers. These substances, along with livestock and other waste, bleed nitrates and phosphates into the water system and thereby contribute to nutrient loading in lakes, which is in fact the most omnipresent freshwater quality problem (GEO-4, 2007, p.133). It results in **eutrophication**, a process whereby an excess of nutrients conduce to an explosion in aquatic plant life, such as algae and duckweed. Algal blooms not only reduce water quality, they deplete the oxygen in the water column and can result in "**dead zones**." For example, the fertilizers used to grow corn for animal feed in the Midwestern United States run off into surface water and eventually make their way down into the Gulf of Mexico, where they have created a dead zone the size of New Jersey (WWI, 2008, p.63).
▸ http://www.sciencedaily.com/articles/e/eutrophication.htm
▸ http://www.ec.gc.ca/water/en/manage/poll/e_plant.htm
▸ http://www.greenpeace.org/canada/en/recent/dead-zones
▸ http://disc.gsfc.nasa.gov/oceancolor/scifocus/oceanColor/dead_zones.shtml

• Given the massive amount of waste generated by livestock on large-scale factory farms, lowering the demand for meat products is an essential component of any initiative to reduce water pollution.
▸ http://eatkind.net

• **Industrial production** in general is a large contributor to water pollution. The disposal of industrial waste – chemicals, heavy metals, toxins – often leads to widespread groundwater contamination, especially when done at a site near sand and gravel aquifers.
▸ http://www.ec.gc.ca/Water/en/manage/poll/e_howgrd.htm
▸ http://www.sciencedaily.com/releases/2007/11/071110081909.htm

•In terms of **organic pollutants**, the most polluting industries are those whose products are based on organic raw materials, such as food and beverage, pulp and paper, and textile plants (MA).

• Power station electric generation is the largest source of **thermal water pollution**, but industrial cooling and reservoir operations also expel heat energy, affecting freshwater and

eventually marine ecosystems, whose organisms are sensitive to alterations in water temperature (MA, 2005, p.190).
▸ http://www.ec.gc.ca/water/en/info/pubs/primer/e_prim04.htm#a18

Illustrative Facts & Statistics

• It is estimated that water pollution/contamination denies close to 1.3 billion people (~ 20% of the global population in 2000) access to clean water supplies (UNEP).
• Over 80% of marine pollution comes from land-based activities (WWF).
• The health impacts of wastewater pollution on coastal waters have an economic cost of US$12 billion/year; contaminated water is the greatest single cause of human sickness and death on a global scale (GEO-4, 2007, p.131).
• Improved sanitation alone could reduce related deaths by up to 60% (GEO-4, 2007, p.151).
• In a medium-sized river basin like the Seine, over 100 different types of active molecules from pesticides can be found (MA, 2005, p.181).
• In developing countries, sewage treatment is still not commonplace, with 85-95% of sewage discharged directly into rivers, lakes, and coastal areas, some of which are also used for water supply (MA, 2005, p.180).
• In the United States, many medium to large lakes, and more than half of the large lakes near major population centers, suffer some degree of cultural eutrophication (Harper, 2008, p.67).

► Water and Climate Change

• Key Online Resources:

• http://www.ipcc.ch/ipccreports/tp-climate-change-water.htm
• http://www.davidsuzuki.org/Climate_Change/Impacts/water.asp
• http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg2/index.htm

• **Anthropogenic greenhouse gases** have significantly intensified the natural process whereby UV rays are reflected off the earth's surface and trapped in the atmosphere. This has created a net warming effect, with profound implications for the global water cycle.
▸ http://www.ec.gc.ca/cc/default.asp?lang=En&n=689C3F4B-1

• Climate change affects all aspects of the **hydrological cycle**, including **precipitation patterns** http://www.grida.no/publications/other/ipcc_tar/?src=/CLIMATE/IPCC_TAR/wg2/166.htm, http://www.wri.org/publication/content/7691, **evaporation patterns** http://www.grida.no/publications/other/ipcc_tar/?src=/CLIMATE/IPCC_TAR/wg2/166.htm, **soil moisture** http://www.grida.no/publications/other/ipcc_tar/?src=/CLIMATE/IPCC_TAR/wg2/166.htm, **water quality** http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg2/index.htm, **groundwater recharge** http://www.grida.no/publications/other/ipcc_tar/?src=/CLIMATE/IPCC_TAR/wg2/166.htm, **river flows** http://www.grida.no/publications/other/ipcc_tar/?src=/CLIMATE/IPCC_TAR/wg2/166.htm, http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg2/index.htm, **lakes** http://www.grida.no/publications/other/ipcc_tar/?src=/CLIMATE/IPCC_TAR/wg2/166.htm, **glaciers and snow melt** http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg2/index.htm, incidence of **hurricanes** http://www.wri.org/publication/content/7646, **floods** http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg2/index.htm, and **droughts** http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg2/index.htm.

• Climate change has profound implications for the world's **oceans**. **Sea levels** continue to **rise** as the waters expand with warmth http://www.grida.no/publications/vg/climate/page/3072.aspx, http://www.grida.no/publications/vg/climate/page/3077.aspx and as the **polar ice caps** melt away http://www.grida.no/publications/vg/climate/page/3082.aspx.

• The **acidity** of ocean waters is also impacted by climate change as the oceans absorb a massive amount of carbon dioxide http://www.scientificamerican.com/article.cfm?id=rising-acidity-in-the-ocean. Furthermore, the warming of the seas could potentially trigger the release of large quantities of carbon dioxide trapped on the ocean floor http://earthguide.ucsd.edu/virtualmuseum/climatechange1/06_1.shtml.

• The melting of the Arctic and Antarctic ice sheets will reduce the amount of solar energy reflected back into space and so increase the temperature further (**albedo effect**)
▸ http://maps.grida.no/go/graphic/climate-change-ice-and-snow-and-the-albedo-effect

• The oceans play a significant role in climate regulation. The **Great Ocean Conveyor** is driven primarily by the behavioral properties of water as it warms and cools. The implications of climate change could effect profound disruptions in this system, or even shut the conveyor belt off entirely. The consequences would be unimaginable, but among the possibilities is an ushering in of another ice age.
▸ http://www.davidsuzuki.org/Climate_Change/Science/Conveyor.asp
▸ http://www.grida.no/publications/vg/climate/page/3085.aspx

Illustrative Facts & Statistics

• Scientists estimate that globally, glaciers are losing 92 cubic kilometers of ice per year – that's as much water used by Canada's homes, farms and factories over six years (Suzuki).
• Sea-ice draft in the 1990s is over a meter thinner than two to four decades earlier. The main draft has decreased from over 3 meters to under 2 meters, and the volume is down by some 40% (UNEP/GRID-Arendal, 2008).
• The planet's seas quickly absorb 25 to 30 percent of humankind's CO_2 emissions and about 85 percent in the long run, as water and air mix at the ocean's surface. We have "disposed" of 530 billion tons of the gas in this way, and the rate worldwide is now one million tons per hour, faster than experienced on earth for tens of millions of years (Brewer and Barry, 2008)
• The ocean has been absorbing more than 80% of the heat added to the climate system (GEO-4, 2007, p.125)
• The global sea level rose at an average of 1.8 mm/year from 1961 to 2003 and 3.1 mm/year from 1993 to 2003 (GEO-4, 2007, p.125)
• It has been projected that many coral reefs will disappear by 2040 because of rising seawater temperatures (GEO-4, 2007, p.136)
• According to the latest World Disasters Report, on average 140 million people are affected by floods each year, more than all other natural or technological disasters combined (MA, 2005, p.194).

► FOOD

Documents to Consult

1) *The End of Food*

See: http://www.cbc.ca/consumer/story/2008/05/26/f-qanda-paulroberts.html

• Paul Roberts (2008) provides a comprehensive and carefully-researched account of the status of the modern food economy and details the ways in which the system entrusted to meet our most basic need is failing. Roberts lays out the stark economic realities behind modern food and shows how the system of making, marketing, and moving what we eat is growing less and less compatible with the billions of consumers that system was built to serve. At the heart of the narrative is a grim paradox: the rise of large-scale food production, though it generates more food more cheaply than at any time in history, has reached a point of dangerously diminishing returns.

2) Millennium Ecosystem Assessment (MA)

Web link: http://www.millenniumassessment.org/en/Reports.aspx

• The MA was initiated in 2001 and aims to assess the consequences of ecosystem change for human well-being and the scientific basis for action toward the conservation and sustainable use of these natural systems. The MA has synthesized the work of more than 1,360 experts across the globe, and their findings are presented in five technical volumes and six synthesis reports.

Current State and Trends Assessment:
http://www.millenniumassessment.org/en/Condition.aspx

• This report assesses the changing conditions of ecosystems and their services, the causes of these changes, and the consequences for human well-being. It considers terrestrial, freshwater and marine systems, and a range of ecosystem services, including food, timber, air quality regulation, nutrient cycling, detoxification, recreation and aesthetic services.

• Chapter 8 – Food Ecosystem Services (p.209 – 241) – provides insights into the structure and distribution of food provision, with particular emphasis on the relative contribution of various ecological systems. It examines trends in the core food sources (crops, livestock, and fisheries), some of the key linkages to ecosystems and ecosystem service provision, and drivers of those trends. Finally, the chapter addresses linkages between human well-being and food access and use. Topics such as the specific ways in which food is cultivated and harvested, and how those ways affect ecosystem capacity and the provision of other services, are covered in Chapters 26 (Cultivated Systems), 22 (Dryland Systems), 20 (Inland Water Systems), and 18 (Marine Systems). Key related

service chapters include Chapter 4 (Biodiversity), Chapter 7 (Freshwater Ecosystem Services), and Chapter 12 (Nutrient Cycling).

Key Issues and Stressors

• The initial use and subsequent transformation of ecosystems for the purpose of meeting human food needs has been a vital, long-standing, and for the most part, fruitful dimension of the human experience. The provision, preparation, and consumption of food are daily activities that for most societies represent an important part of their identity and culture (MA, 2005, p.212).

• However, the very meaning of food is being transformed: "food cultures that once treated cooking and eating as central elements in maintaining social structure and tradition are slowly being usurped by a global food culture, where cost and convenience are dominant, the social meal is obsolete, and the art of cooking is fetishized in coffee-table cookbooks and on television shows" (Roberts, 2008, p.xii).

• Once food began to be produced for profit rather than for subsistence, there was a treadmill effect associated with farming: the more bushels farmers were able to grow on each acre and the greater the volumes of grain they were able to put on the market, the lower that grain prices fell. In most other businesses, declining prices are a signal to companies to produce less. It's different for agriculture because the biggest and costliest input is land, which is a fixed cost over which farmers have very little control. Farmers thus compensate for falling grain prices by spreading their fixed costs (land, farm equipment, better seeds and chemicals) over more bushels (Roberts, 2008, p.26).
▸ http://www.ppi-ppic.org/ppiweb/agbrief.nsf/$webindex/F4A036AA534D7C928525690400692F68?opendocument&print=1

• Eventually, only huge industrial farms were able to make up in volume and efficiencies what they were losing in price. By the mid-1980s, the United States farm system had been so consolidated that more than two-thirds of the nation's entire agricultural output was now coming from less than one-third of the farms. In a food economy geared toward ever lower prices, selling convenience has become the food industry's most important means of making money (Roberts, 2008, p.31).
▸ http://www.fao.org/DOCREP/005/AC621E/ac621e05.htm

• Today's food crisis is ultimately economic in the sense that our food system can only be truly understood as an economic system. Agriculture gave rise to rudimentary economic organization and specialization, to accounting and management, to trade and speculation, and, ultimately, to an explicit economic paradigm – capitalism – which was likely invented on sixteenth-century sugar plantations (Roberts, 2008, p.xiii).
▸ http://www.ucalgary.ca/applied_history/tutor/eurvoya/Trade.html

• Later, when surging population growth in Europe exceeded existing production methods and threatened famine, the things that saved us – the move to more labor-saving technologies, the shift to larger production scales, and the creation of a global system of food trade – were precisely the sparks that ignited the subsequent Industrial Revolution (Roberts, 2008, p.xiii).
▸ http://www.wsu.edu/~dee/ENLIGHT/INDUSTRY.HTM

• Even as food production influenced the way we made everything else (Henry Ford invented his assembly line after watching a line of butchers methodically disassembling cattle in a

meatpacking plant), the way we made everything else began to influence the making of food. Farms came to be run like integrated factories, turning "inputs" of seed, feed, and chemicals into steady "outputs" of grain and meat. Individual shopkeepers such as the butcher, the baker, and the greengrocer were consolidated into huge, efficient, one-stop supermarkets, which were then merged into sprawling retail chains (Roberts, 2008, p.xiii).

• The source of most of the problems with the modern food economy is the paradox that for all that the food system has evolved like other economic sectors; food itself is fundamentally *not* an economic phenomenon http://www.globalonenessproject.org/videos/brahmahmadiclip1. Physically, food is so unsuited to mass production that we've had to re-engineer our plants and livestock to make them more readily harvested and processed (Roberts, 2008, p.xiv). The key issues and stressors associated with food are:

• ***Issue(s)***: Overexploitation/overconsumption of resources associated with food production, processing, and distribution
• ***Stressor(s)***: Size and growth of the human population; economic growth

• ***Issue(s)***: Global hunger and hunger-related disease, malnutrition
• ***Stressor(s)***: Size and growth of the human population; social and economic inequality

• ***Issue(s)***: Obesity and associated diseases
• ***Stressor(s)***: Economic growth, urbanization, industrial food production

• ***Issue(s)***: Prevalence of food-borne pathogens and disease
• ***Stressor(s)***: Industrial food production, urbanization

• ***Issue(s)***: Environmental impacts of global food system (pollution, loss of habitat and biodiversity, climate change)
• ***Stressor(s)***: Size and growth of the human population; industrial food production (large-scale, intensive agriculture, processing, global distribution networks)

► Patterns of Food Production and Consumption

Key Online Resources:

• http://fao.org
• http://www.who.int/nutrition/topics/3_foodconsumption/en/index.html

• Food production per capita has been increasing globally: from 1961 to 2003, global food production increased by 168%, or 1.7% per year, and as a result, average food production per capita increased by around 25% http://earthtrends.wri.org/text/agriculture-food/variable-180.html Fueling this output growth in many parts of the world were long-term investments in the generation and distribution of new seeds and other farming technologies, and in infrastructure such as irrigation systems and rural roads. This allowed farm productivity to increase and marketing margins to decrease, reducing the price of many foods (MA, 2005, p.211-212).

• Between 1961 and 2001 the **major driver** of growth in total food consumption was **population growth** (MA, 2005, p.224). Over the next forty years, demand for food will rise precipitously – both because global population will continue climbing and because the developing world, where most of that growth will occur, will continue to catch up with Western dietary patterns, particularly the love of **meat** (Roberts, 2008, p.xviii).
▸ http://www.grida.no/publications/rr/food-crisis/page/3559.aspx

• On average, it takes four pounds of grain to make a single pound of meat, which is why so much land must now be devoted to feed crops (Roberts, 2008, p.xviii). Livestock production is the **single largest user of land** either directly through grazing or indirectly through consumption of fodder and feed grains (MA, 2005, p.216).
▸ http://www.fao.org/ag/magazine/0612sp1.htm

• **Cows** themselves are inefficient. The modern cow needs at least seven pounds of feed to put on a pound of live weight – nearly twice that of pigs, and more than triple that of chickens. And because so much more of a cow's weight in inedible – 60% is bone, organ, and hide – than is the case with smaller livestock, beef's true conversion rate is actually far lower: it takes a full **twenty pounds of grain** to make a single pound of beef (compared to 4.5 and 7.3 for chicken and pigs) (Roberts, 2008, p.209-210). Furthermore, meat is one of the least efficient ways to obtain calories (p.xviii).
▸ http://www.vegansociety.com/environment/land/

• **Income** is the single most important factor determining the amount and quality of food consumption. At higher levels of income, high-value, more nutritious, or more culturally prestigious foods, such as fresh seafood or imported specialty foods, replace less-valued food sources http://74.125.95.132/search?q=cache:-OIfLDR3GD4J:www.unc.edu/depts/econ/papers/99-02.pdf+cereal+consumption+and+income&cd=1&hl=en&ct=clnk&gl=ca. The extra demand for meat is driving the **"Livestock Revolution"** (MA, 2005, p.225).
▸ http://www.fao.org/wairdocs/LEAD/X6115E/x6115e03.htm

• The accelerating demand for livestock products is increasingly being met by **intensive production systems**, especially for chicken and pigs, and especially in **Asia** (MA, 2005, p.211) http://www.ifpri.org/2020/BRIEFS/NUMBER41.HTM,

http://www.fao.org/Ag/Magazine/9812sp1.htm. Almost the entire expansion in output from poultry and pigs, globally, and from beef and milk cattle in industrial countries, has taken place in intensive, industrial production systems (p.218). In addition to putting increased pressure on cultivated systems to provide feed inputs and consequent increased demand for water and nitrogen fertilizer, intensified livestock production poses serious **waste problems** (p.211).
▸ http://www.fao.org/docrep/X5303E/x5303e0c.htm

• However, **cereals** provide almost half of the calories consumed directly by humans globally – 48% in 2001 – and will continue as the foundation of human food supply into the foreseeable future because of their high yields, nutrient density, and ease of cooking, transport, and storage compared with other staples such as root and starch crops (MA, 2005, p.216).
▸ http://www.pnas.org/content/96/11/5952.full

• Cereal consumption increases in proportion with incomes as they grow from low levels, but a reversal in this behavior is witnessed as incomes continue to rise and as basic energy and other dietary needs are met. At this stage most consumers tend to replace food staples like cereal with higher-value foods such as animal protein and fruits and vegetables. **Urbanization** often brings a shift in cereal preferences toward wheat and rice at the same time as an overall decline in the share of cereals in a more diverse diet (MA, 2005, p.216).

• Despite rising food production and falling food prices, more than 850 million people still suffer today from **chronic undernourishment**, and the absolute number of hungry people is rising (MA, 2005, p.212) http://www.fao.org/newsroom/en/news/2004/51809/index.html. **Sub-Saharan Africa**, the region with the largest share of undernourished people http://www.fao.org/economic/ess/food-security-statistics/fao-hunger-map/en/, is also the region where per capita food production has lagged the most http://www.fao.org/docrep/V6800E/V6800E0a.htm. Wild foods are locally important in many developing countries, often bridging the hunger gap created by stresses such as drought and civil unrest (p.211).

• **Average daily energy (caloric) intake** has declined recently in the poorest countries. People in these countries rely on starchy staples for energy, which leads to significant protein, vitamin, and mineral deficiencies http://www.fao.org/DOCREP/X8200E/x8200e03.htm. Nutritional status and children's growth rates improve with consumption of greater food diversity, particularly of fruits and vegetables (MA, 2005, p.211).
▸ http://docs.google.com/gview?a=v&q=cache:cUyxZh2VzIgJ:www.ifpri.org/divs/fcnd/dp/papers/fcnbr140.pdf+food+diversity+children+growth+rates&hl=en&gl=ca

• A global epidemic of **diet-related obesity** and non-communicable disease is emerging as increasingly urbanized people adopt diets that are higher in energy and lower in diversity in fruits and vegetables than traditional diets (known as the **nutrition transition**). Many countries now face the **double burden** of diet-related disease: the simultaneous challenges of significant incidence of acute, communicable diseases in undernourished populations and increasing incidence of chronic diseases associated with the overweight and obese (MA, 2005, p.211).
▸ http://www.who.int/nutrition/topics/2_background/en/index1.html
▸ http://www.fao.org/Ag/Magazine/0602sp1.htm

• An increasing number of people everywhere suffer from diseases caused by **contaminated food**. As the world eats more perishable foods such as meat, milk, fish, and eggs, the risk of food-borne disease illnesses is increasing. Food of animal origin poses health risks particularly when it is improperly prepared or inadequately refrigerated. Microbial contamination is of special concern in developing countries. Non-microbial contaminants include metals and persistent organic pollutants. Other growing health concerns related to food production are diseases passed from animals to humans, toxin-containing animal wastes, and overuse of antibiotics in livestock production that may cause allergies or render human antibiotics less effective (MA, 2005, p.211) http://www.sierraclub.org/factoryfarms/factsheets/antibiotics.asp

• Per capita **consumption of fish** is increasing http://www.who.int/nutrition/topics/3_foodconsumption/en/index5.html, and this growth is unsustainable with current practices. Total fish consumption has declined somewhat in industrial countries, while it has doubled in the developing world since 1973. Pressure on marine ecosystems is increasing to the point where a number of targeted stocks in all oceans are near or exceeding their maximum sustainable levels of exploitation, and world fish catches have been declining since the late 1980s due to overexploitation (MA, 2005, p.211).
▸ http://74.125.95.132/search?q=cache:6AHKOkXHsZ4J:www.fao.org/newsroom/common/ecg/1000505/en/stocks.pdf+fish+stocks+exploited+global&cd=1&hl=en&ct=clnk&gl=ca

• Inland water fisheries in the developing world are expanding slowly and will remain an important source of high-quality food for many of the world's poor, particularly in Africa and Asia; however, habitat modifications and water abstraction threaten the continued supply of freshwater fish. For the world as a whole, increases in the volume of fish consumed are made possible by **aquaculture** – the cultivation of marine or freshwater food fish or shellfish – which in 2002 is estimated to have contributed 27% of all fish harvested and 40% of the total amount of fish products consumed as food. Future growth of aquaculture will be constrained by development costs and by fishmeal and oil supplies, which are increasingly scarce (MA, 2005, p.211).
▸ http://www.wri.org/publication/content/8382

• As domestication of plant and animal species favored for food production has evolved, the **species base** supporting food provision has eroded (See ▸ **Food and Biodiversity**).

• By **subsidizing** food production and exports, while keeping in place high import tariffs, particularly on semi-processed or processed foods, OECD countries like the EU, the United States, and Japan drive down food prices on the world market, undercutting the potential profitability of developing-country producers in their own markets while simultaneously limiting their export opportunities (MA, 2005, p.226).
▸ http://www.fao.org/docrep/005/y4671e/y4671e08.htm
▸ http://www.globalpolicy.org/images/pdfs/10stopdumping.pdf

• Subsidized food production encourages farmers to **overproduce**, drawing proportionately more land, labor, and other resources into production and creating higher levels of agricultural pollution. While other factors such as increasing productivity have caused the net amount of agricultural land to grow more slowly or even to decline in some OECD countries, those effects would have been more significant in the absence of subsidies (MA, 2005, p.227).
▸ http://www.heritage.org/research/agriculture/bg2043.cfm

• **China**'s food economy is at a perilous tipping point. Population is still rising, and growth rates are expected to increase again as Beijing, fearful of supporting a massive army of retirees, relaxes the one-child policy to beef up the next generation of taxpayers http://www.npr.org/templates/story/story.php?storyId=87851165. The same economic liberalization that unleashed China's farming potential also touched off a domino effect of rising consumption and new food habits. That has meant more vegetable and produce, but also more prepared foods, and considerably more meat, which means more grain demand. And all this as China is still striving to develop as a food exporter. Even within China itself, the push for more meat has accelerated China's domestic demand for livestock feed beyond the country's domestic capacities (Roberts, 2008, p.138).
▸ http://www.usda.gov/oce/forum/2006_Speeches/PDF%20speech%20docs/Gale2906.pdf

• **Brazil**, with its **IMF-imposed restructuring**, has positioned itself to exploit China's new appetites (Roberts, 2008, p.139) http://www.nytimes.com/2007/04/05/business/worldbusiness/05iht-soy.4.5164446.html. Brazil now leads the world in sugar and coffee exports, while its 175 million cattle – nearly double that of the United States herd, and the largest in the world – allowed it to surpass American beef exports in 2004 and take an eighth of the entire beef market (p.140) http://www.usmef.org/TradeLibrary/News08_0215a.asp. Brazil's booming poultry industry, meanwhile, fed on cheap corn from neighboring Argentina, now exports more than two million tons of chicken, or roughly one in every five birds traded internationally. Within another decade, according to the FAO, Brazil's meat exports will be larger than those of the United States, Canada, Argentina, and Australia combined (p.140)
▸ http://www.ers.usda.gov/AmberWaves/April06/Findings/Brazil.htm

• There have been **two main direct drivers** of growth in food production: the increase in the area extent of cultivation, grazing, or fishing; and the intensity of production or exploitation within cultivated areas. For crops, it is intensification rather than area expansion that has mainly driven increased food output. While physical expansion in the area dedicated to food provision has been important in the past, rates of growth are now relatively low – and in some places in decline (e.g. in the EU and Australia). This slowdown reflects both the slowing growth in global food demand and the more limited opportunities for area expansion (MA, 2005, p.229) http://www.earth-policy.org/Books/Eco/EEch7_ss3.htm.

• Investments in agricultural research and the resulting flow of innovation have been key to the intensification process. Technical change and increased use of external inputs such as irrigation, fertilizer, and mechanical power contribute to changes in productivity http://www.wri.org/publication/content/8331. Increased productivity can also come from the introduction of less capital-intensive food-feed systems, whereby both the main crops as well as the introduction of legumes can enhance the cropping system (MA, 2005, p.229) http://www.fao.org/ag/AGP/AGPC/doc/Publicat/Gutt-shel/x5556e05.htm#legumes%20in%20agriculture.

• Nearly every credible forecast shows that if we're to have any chance of meeting future food demand in a sustainable fashion, **lowering our meat consumption** will be absolutely essential (Roberts, 2008, p.209).
▸ http://www.wellfedworld.org/PDF/CIWF%20Eat%20Less%20Meat.pdf

Illustrative Facts & Statistics

►*Extent and expansion of cropland*

• Globally, cultivated systems cover 36.6 million square kilometers, or approximately 27% of total land area (and a much higher share of habitable land [MA, 2005, p.221]). It is estimated that 74% of the world's population lives within the boundaries of cultivated systems (MA, 2005, p.754).
• Since 1700 cropland has increased by 1,200 million hectares (466%), including major expansion in North America and the former Soviet Union, with the greatest expansion occurring in the past 150 years (MA, 2005, p.749).
• Over the past 40 years cropland area has expanded globally by some 15% - from 1.3 billion to 1.5 billion hectares, the area of pasture has grown some 11% from 3.14 billion to 3.48 billion hectares, and practically all corners of the world's oceans are accessible to the world's fishing fleet (MA, 2005, p.229).
• Globally, agricultural land has expanded by around 130,000 square kilometers per year over the past 25 years, predominantly at the expense of natural forests and grasslands (MA, 2005, p.760).
• In the 1920s and 1930s there were more than 6 million farms of around 40 hectares each. By the late 1900s, there were fewer than 2 million farms and they averaged 200 hectares each (MA, 2005, p.228).
• Globally, 78% of the increase in crop output between 1961 and 1999 was attributable to yield increases and 22% to expansion of harvested area (MA, 2005, p.775).
• By 1950 all but two biomes – boreal forests and tundra – had lost substantial natural land cover to croplands and pasture (MA, 2005, p.109).
• More than 300 000 km^2 of land have been converted to agricultural use in the tropics alone (GEO-4, 2007, p.172).
• About 43% of tropical and subtropical dry and monsoon forests and 45% of temperate broadleaf and mixed forests globally have been converted to croplands (MA, 2005, p.221).
• About 43% of tropical and subtropical dry and monsoon forests and 45% of temperate broadleaf and mixed forests globally have been converted to croplands (MA, 2005, p.221).
• In Brazil, the area of land used for growing soybeans (most of which are exported to China) grew from 117,000 km^2 in 1994 to 210,000 km^2 in 2003. This was driven by a 52% increase in world consumption of soybeans and soybean products, and these figures continue to rise dramatically (GEO-4, 2007, p.173).
• Cropland in Latin America, Africa, Australia, and South and Southeast Asia expanded very gradually between 1700 and 1850, but subsequently expanded rapidly. Since 1950, cropland area in North America has stabilized, while it has decreased in Europe and China. In the 2 decades before 2000, the major areas of cropland expansion were located in Southeast Asia, parts of Asia, eastern Africa, and in the Amazon Basin. The major decreases of cropland occurred in the southeastern United States, eastern China, and parts of Brazil (MA, 2005, p.749).
• More than for any other crop (and excluding pastures), it is the global area expansion of oil crops over the past 40 years that has driven cropland expansion. Food use of oil and vegetable oil crops, expressed in oil equivalent, grew from 6.3 kg per capita per year in 1964/66 to 11.4 kg in 1997/99 (MA, 2005, p.214).

• Cereal production accounts for almost 60% of the world's harvested crop area and an often disproportionately larger share of the usage of fertilizer, water, energy, and other agrochemical inputs (MA, 2005, p.216).
• Between 1992 and 2001, the extent of organic cropland in the United States grew by over 200%, from about 163,000 hectares to 526,000 (MA, 2005, p.767).

►*Food output growth and consumption*

• From 1961 to 2003, food output increased by over 160%, or 1.7% per year. As a consequence, average food production per capita also increased by around 25% during the period (MA, 2005, p.212).
• Over the 40 years from 1964 to 2004, the total output of crops expanded by some 144% globally, an average increase of just over 2% per year, always keeping ahead of global population rates (MA, 2005, p.214).
• Dryland systems account for about 38% of total crop production, with forest and mountain ecosystems each accounting for about 25%, and coastal systems around 12% (MA, 2005, p.213).
•Food output in the transition countries fell by about 30% between 1990 and 1995 from its fairly stable level in the mid to late 1980s (MA, 2005, p.214).
• Globally, 78% of the increase in crop output between 1961 and 1999 was attributable to yield increases and 22% to expansion of harvested area (MA, 2005, p.775).
• On average, about 53% of food crops find their way into food and 21% are used for feed. The remaining 26% is categorized as used for seed, waste, or other industrial processing (MA, 2005, p.213).
• 90% of the grain that Americans consume is eaten in the form of meat or dairy (Roberts, 2008, p.210).
• Livestock and livestock products are estimated to make up over half of the total value of agricultural gross output in industrial countries, and about a third of the total in developing countries, but this share is rising rapidly (MA, 2005, p.216).
• In 1945, the average American ate around 125 pounds of meat a year; by 1980, per capita consumption had reached 195 pounds, an increase of nearly 60% (Roberts, 2008, p.24).
• The average American now eats around nine ounces of meat a day, nearly four times the government recommended intake for protein (Roberts, 2008, p.209).
• If the American level of meat consumption – about 217 pounds per person per year – were suddenly replicated worldwide, our total global grain harvest could support just 2.6 billion people – or less than 40% of the existing population, and barely a quarter of the ten billion expected by 2070 (Roberts, 2008, p.211).
• Between 1960 and 2002, per capita meat consumption in developing countries more than doubled, from 22 pounds to 56 pounds, and is on track to hit 74 pounds by 2030 (Roberts, 2008, p.211).
• The global growth rate of livestock product output is currently just over 2% per year and is declining over time, but there are regional disparities. While growth rates in industrial countries, where people already enjoy adequate supplies of animal protein, have remained at just over 1% for the past 30 years, growth rates in developing countries as a whole have been high and generally accelerating (MA, 2005, p.216-217).
• The trends in East Asia (and particularly China) are especially strong, with livestock product growth rates of over 7% a year over the last 30 years (MA, 2005, p.217).

• Over the last decade, bovine and ovine meat production increased by about 40%, pig meat production rose by nearly 60%, and poultry meat production doubled (MA, 2005, p.211).
• The 1961 global production of 344 million, 29 million, and 6 million tons of milk, beef, and mutton and goat meat, respectively, increased to 590 million, 59 million, and 11 million tons in 2001 (MA, 2005, p.218).
• Between 1990 and 2000, net imports of meat and milk to developing countries grew by more than 6% a year, while net imports of eggs declined by a little over 16% (MA, 2005, p.219).
• Milk production has risen faster in developing than in industrial countries, from 32 to 50 kg per capita per year, but still lies far below the 264 kg per capita per year of industrial countries (MA, 2005, p.218).
• In sub-Saharan Africa, milk production per animal has been declining since 1961, and in 2001, while production of beef per animal was about 65% of the world average, production of milk per animal was only 14% of the world average (MA, 2005, p.218).
• Annual per capita production of beef increased in developing countries from 4.6 to 6.2 kg between 1961 and 2001, while in industrial countries, despite the large-scale switch to poultry meat, annual per capita beef production edged up from 19.6 kg in 1961 to 22.4 in 2001 (MA, 2005, p.218).
• Global poultry meat production has expanded almost ninefold, from some 2.9 to 11.2 kg per capita per year between 1961 and 2001. In developing countries, this entailed a production expansion from 1.0 to 7.7 kg per capita per year as population in those countries increased from 2.1 billion to 4.8 billion. In industrial countries, the equivalent figure was from 6.7 to 24 kg as population increased from 980 million to 1.3 billion (MA, 2005, p.217).
• Pig and poultry meat each now account for about a third of all meat produced worldwide, and more than one-half of total pig production is in China (MA, 2005, p.218).
• Per capita production of both eggs and pork almost doubled between 1961 and 2001. Total production of eggs rose from 15.1 million to 57 million tons, and pork from 24.7 million to 91.3 million tons. In developing countries, annual per capita production of eggs and pork increased from 1.6 and 2.1 kg, respectively, in 1961 to 7.0 and 11.3 kg in 2001. In industrial countries, growth has been more modest, from 10.8 to 12.7 kg per capita in the case of eggs, and from 20.5 to 24.0 kg per capita in the case of pork during the same time period (MA, 2005, p.218).
• It is estimated that in 2002, aquaculture contributed 27% of all fish harvested and 40% of the total amount of fish products consumed as food (MA, 2005, p.211)
• In freshwater aquaculture alone, some 115 freshwater species of finfish, crustaceans, and mollusks were cultured in 2000. Over the period 1991-2000, carp and tilapia ranked first and second respectively in global freshwater fish production, accounting for 76-82% and 5-6% of the total respectively (MA, 2005, p.753).
• During the last four decades, the per capita consumption of fish as seafood increased from 9 to 16 kg per year (MA, 2005, p.220).
• 90% of full-time fishers conduct low-intensive fishing (a few tons per fisher per year), often in species-rich tropical waters of developing countries. Their counterparts in industrial countries generally produce several times that quantity of fishing output annually, but they are much fewer, probably numbering about 1 million in all, and their numbers are declining (MA, 2005, p.219).
• Nearly 40% of global fish production is traded internationally; most of this trade flows from developing to industrial countries (MA, 2005, p.219).

• Between 1974 and 1999, the number of fish stocks that had been overexploited and were in need of urgent action for rebuilding increased steadily and by 1999 stood at 28% of the world's stocks for which information is available (MA, 2005, p.219).
•Just over half of the wild marine fish stocks for which information is available are fully or moderately exploited, and the remaining quarter is either overexploited or significantly depleted (MA, 2005, p.219).
• It is estimated that the fishing industry has eliminated 90% of the large fish in the ocean (WWI, 2008, p.63).
• The Atlantic Ocean was the first area to be fully exploited and overfished, and fish stocks in the Pacific Ocean are almost all currently fully exploited (MA, 2005, p.219).
• The production of cereals has increased by about 130% over the past 42 years, but that is now growing more slowly (MA, 2005, p.211).
• Cereal and sugar crop production grew at an accelerated rate in the 1960s and 1970s, increasing their total per capita output by around 25% by 1980. The principal cereal crops, according to their 2001 production in million tons, are maize (615), paddy rice (598), wheat (591), barley (114), sorghum (60), millet (29), and oats (27) (MA, 2005, p.215)
• Between 1961 and 2001, there was a net increase in per capita cereal consumption globally from 135 to 155 kilograms per year, even though cereals now constitute a slightly lower proportion of total energy intake (down from 50% to 48%) (MA, 2005, p.216).
• Since 1987, cereal yields have increased by 17% in North America, 25% in Asia, 37% in West Asia, and by 40% in Latin America and the Caribbean (GEO-4, 2007, p.86).
• In industrial countries, per capita consumption of cereal as food fell from 148 to 130 kg per year, while in developing countries per capita consumption increased from 129 to 162 kg per year (MA, 2005, p.216).
• Growth in output of oil crops and vegetable oils between 1961 and 2001 was consistently strong at just over 4% per year, largely propelled by a rapid growth in palm oil (8.2% per year), rapeseed oil (6.9% per year), and soybeans (4.1% per year). The principal commodities included in this category and their global production quantities in million tons in 2001 are: soybeans (177), oil palm (128), coconuts (52), groundnuts (36), and rapeseed (36) (MA, 2005, p.214).
• More than for any other crop (and excluding pastures), it is the global area expansion of oil crops over the past 40 years that has driven cropland expansion. Food use of oil and vegetable oil crops, expressed in oil equivalent, grew from 6.3 kg per capita per year in 1964/66 to 11.4 kg in 1997/99 (MA, 2005, p.214).
• Fruit and vegetable production grew in line with population during the 1960s and 1970s, when growing demand lead to increased per capita output. The principal commodities in this category, and their 2001 production in million tons, are tomatoes (106), watermelons (81), bananas (65), cabbages (61), grapes (61), oranges (60), apples (58), and dry onions (51) (MA, 2005, p.214).
• Between 1961 and 2001, production of vegetables grew from 72 kg per capita on average per year to 126 kg, and that of fruits from 56 to 77 kg per year (MA, 2005, p.214).
• Some 1.5 billion people, about half of the world's total labor force and nearly one quarter of the global population, are employed in agriculture, or their livelihoods are directly linked to it, and women make up the majority of agricultural workers (GEO-4, 2007, p.172).
• Food manufacturers generate nearly $3.1 trillion in revenues a year (Roberts, 2008, p.31).
• China's two hundred million family farms produce 20% more output than do the United States' two million farmers, and on a land base less than three-quarters as big as America's (Roberts, 2005, p.125).

• Soybean farms in Brazil are expanding at the rate of around 4,000 square miles a year, and Brazilian soybean exports have soared from 8.2 million tons in 1998 to 25 million tons in 2006, with much of the increase going to China. Brazil is the world's second-largest soybean exporter, just behind the United States, and is expected to take the lead in the near future (Roberts, 2008, p.125).

►*Hunger*

• An estimated 852 million people were undernourished in 2000 – 02, up 37 million from the period 1997 – 99. Of this total, nearly 96% (815 million people, up by around 38 million from the 777 million in 1997 – 99, [MA, 2005, p.212]) live in developing countries (MA, 2005, p.211).
• In 1970 there were an estimated 959 million people suffering from hunger, or about one-quarter of the world's population. By 1998 that number had been reduced to 815 million, but progress has been slow (MA, 2005, p.212).
• In industrial countries, approximately 1.6% of children under five are underweight (MA, 2005, p.212).

►*Loss of variety*

• Of the estimated 10,000 – 15,000 edible plants known, only 7,000 have been used in agriculture and less than 2% are deemed to be economically important at a national level. Only 30 crops provide an estimated 90% of the world population's calorific requirements, with wheat, rice, and maize alone providing about half the calories consumed globally (MA, 2005, p.213).
• With regard to livestock, of the estimated 15,000 species of mammals and birds, only some 30-40 (0.25%) have been used for food production, with fewer than 14 species accounting for 90% of global livestock production (MA, 2005, p.214).
• FAO estimates that in Europe 50% of livestock breeds that existed 100 years ago have disappeared (MA, 2005, p.214).

►*Food subsidies*

• In 2002, some $235 billion of the over $300 spent by the OECD countries on their agricultural sectors (some six times the amount they allocate to overseas development aid) went to support agricultural producers. This support is paid for by higher domestic food prices and by taxes ($100 billion in the EU, $44 billion in Japan, and $31 billion in the United States) This support represents around 31% of average farm income (18% in the United States and 36% in the EU) (MA, 2005, p.226-227).

► Food and Population

• It is an ecological fact that the size and growth rate of a population of a given species is in part a function of the amount of food available to that population. **Malthus** believed that hunger would never be eradicated because any increase in food served only to make populations even larger. These larger populations then exceeded available food supplies, plunging humanity into famine and strife until scarcity sparked the next round of productivity increases, which then sparked yet another population surge. Malthus believed this vicious cycle would soon end: because crop yields can increase only linearly whereas population grows exponentially, he reasoned that population growth would soon outpace humankind's capacities to feed itself (Roberts, 2008, p.15).
▸ http://www.ucmp.berkeley.edu/history/malthus.html

• What staved off the end of humanity was the emergence of a **global food system**, built on railways, shipping routes, and new preservation technologies, and spurred by free trade that slowly began to connect the starving demand centers in Europe with distant suppliers in Australia, Argentina, and especially the United States. These countries not only possessed surplus land and small populations, but they were also just then undergoing industrial transformations of their food production (Roberts, 2008, p.17).

• The world's population is projected to increase from the current **6.5 billion** to over **9 billion** by 2050 http://www.un.org/apps/news/story.asp?NewsID=13451&Cr=population&Cr1, and will probably peak by 2070 at 9.5 billion (Roberts, 2008, p.206). To meet the Millennium Development Goals on hunger, a doubling of global food production will be required (GEO-4, 2007, p.110). Good nutrition reduces neonatal and **child mortality**, helping to slow population growth by increasing birth intervals and reducing demand for large families (MA, 2005, p.229) http://www.un.org/millenniumgoals/2008highlevel/pdf/newsroom/Goal%204%20FINAL.pdf

• If predicted technological breakthroughs fail to materialize, or don't come soon enough, the entire food economy could gradually slip back into a state of **demographic disequilibrium** where productivity is once again in a race with population growth and where the most heavily populated countries compete for access to large surpluses of grain and soybeans, just as the big industrialized nations now compete for oil (Roberts, 2008, p.208).

• Nearly every credible forecast shows that if we're to have any chance of meeting future food demand in a sustainable fashion, **lowering our meat consumption** will be absolutely essential (Roberts, 2008, p.209).
▸ http://www.wellfedworld.org/PDF/CIWF%20Eat%20Less%20Meat.pdf

• Recent trends reveal that ***per capita* food consumption** is on the rise – which means that while the number of individuals on the planet is increasing, the average amount of food consumed *per individual* is increasing as well.
▸ http://www.fao.org/docrep/004/y3557e/y3557e15.htm

• Population growth rates are declining, however, and currently stand at around 1.4% per year globally (MA, 2005, p.770). However, over the next forty years demand for food will rise precipitously both because global population will continue climbing – albeit at a slower rate –

and because the developing world, where most of that growth will occur, will continue to catch up with **Western dietary patterns**, particularly the love of **meat** (Roberts, 2008, p.xviii).
▸ http://www.grida.no/publications/rr/food-crisis/page/3559.aspx

• On average, it takes four pounds of grain to make a single pound of meat, which is why so much land must now be devoted to feed crops (Roberts, 2008, p.xviii). Livestock production is the **single largest user of land** either directly through grazing or indirectly through consumption of fodder and feed grains (MA, 2005, p.216).
▸ http://www.fao.org/ag/magazine/0612sp1.htm.

• While growth in overall crop output in **sub-Saharan Africa** has been relatively strong over the past two decades, beverage and fiber crops, predominantly for export, still represent a significant share of that production. Since food crop production has not grown as markedly, and **population growth rates remain high** http://www.unfpa.org/worldwide/africa.html, sub-Saharan Africa remains the only region in which per capita food production has not seen any sustained increase over the last three decades, and this has recently been in decline (MA, 2005, p.214).
▸ http://www.fao.org/english/newsroom/news/2003/20863-en.html

• Many middle-income and richer countries have seen a gradual slowing down in the growth of crop output in line with the deceleration of population growth and the attainment of generally satisfactory levels of food intake (MA, 2005, p.214).

• **China**'s food economy is at a perilous tipping point. Population is still rising, and growth rates are expected to increase again as Beijing, fearful of supporting a massive army of retirees, relaxes the **one-child policy** to beef up the next generation of taxpayers http://www.npr.org/templates/story/story.php?storyId=87851165. The same economic liberalization that unleashed China's farming potential also touched off a domino effect of rising consumption and new food habits. That has meant more vegetable and produce, but also more prepared foods, and considerably more meat, which means more grain demand. And all this as China is still striving to develop as a food exporter. Even within China itself, the push for more meat has accelerated China's domestic demand for livestock feed beyond the country's domestic capacities (Roberts, 2008, p.138).
▸ http://www.usda.gov/oce/forum/2006_Speeches/PDF%20speech%20docs/Gale2906.pdf

• The proportion those who live in cities is growing. **Urbanization** affects many dimensions of food demand. The food energy requirements of urban populations are generally less than those in rural areas because of more sedentary lifestyles. Urban consumers generally have **higher incomes** as well as access to a more diverse array of both domestic and imported foods. Urban lifestyles often mean less time at home, and more meals eaten away from home. Urban consumers eat more processed and convenience foods, which raises issues of food cost, quality, and safety in terms of the use of appropriate inputs, especially safe water in food processing (MA, 2005, p.225).
http://www.fao.org/ag/agn/nutrition/national_urbanization_en.stm

Illustrative Facts & Statistics

• Between 1960 and 1999, world population doubled to 6 billion, with an average growth rate of around 1.7% per year, while aggregate per capita food energy consumption grew at just over 0.5% per year (MA, 2005, p.770).
• Over the 40 years from 1964 to 2004, the total output of crops expanded by some 144% globally, an average increase of just over 2% per year, always keeping ahead of global population rates (MA, 2005, p.214).
• Population growth rates, which peaked at 2.1% per year in the late 1960s, had fallen to around 1.35% (or 78 million additional people) per year by the turn of the millennium. Approximately 90% of this increase is taking place in developing countries. Around half of the total population increase in developing countries will take place in sub-Saharan Africa and South Asia, where the incidence of hunger is already high and increasing in absolute terms (MA, 2005, p.224).
• In industrial as well as developing countries, 60-70% of the total increase in calories consumed between 1961 and 2002 was accounted for by population growth (MA, 2005, p.770).
• Developing countries now account for over 95% of global population growth and hence a correspondingly greater share of the pressure to expand food output from cultivated systems (MA, 2005, p.770).
• The proportion of those in developing countries who live in cities has doubled since 1960 from 22% to over 40%. This share is expected to grow to almost 60% by 2030 (MA, 2005, p.224-225).
• Developing countries now account for around 80% of the world's urban population. In 2001, 13 of the world's 17 "megacities" were in developing countries, and by 2015 it is expected that figure will have risen to 17 (MA, 2005, p.225).
• While population will probably peak by 2070 at 9.5 billion, global meat demand by that point will be somewhere between twice and three times its current level (Roberts, 2008, p.206-207).

► Food and Land & Soil

Key Online Resources:

•http://ngm.nationalgeographic.com/2008/09/soil/mann-text
•http://www.fao.org/docrep/006/y4683e/y4683e06.htm

• Humans are almost entirely dependent on the land for food: 98% of human food is produced on the land. Globally, **12%** of Earth's land surface is used for cultivating **food and fiber** crops, **24%** is **pasture** used **for grazing livestock** that produces meat and milk, and **31%** is covered by **forests**, which are largely exploited for fuel, lumber, paper, and other products. The remaining land, **less than one-third**, is desert, mountains, tundra, and other terrain **unsuitable for agriculture** (Harper, 2008, p.46).
▸http://www.ifpri.org/2020/BRIEFS/NUMBER18.HTM

• **Agriculture** first emerged about **10,000 years ago** in several different regions, including Mesopotamia, eastern China, meso-America, the Andes, and New Guinea (MA, 2005, p.749). **The Neolithic Revolution** was sparked by a number of changing climatic and social factors, which resulted in gradual demographic and geographic expansion. During this process of expansion, human societies depleted their local and regional natural environments, and were forced to change their mode of existence – from surviving off of wild food sources to cultivating plants and domesticating animals (Broswimmer, 2002, p.30).
▸http://www.bbc.co.uk/dna/h2g2/A2054675

• Swidden or **slash-and-burn agriculture** is one of the oldest forms of farming and consists of cropping on cleared plots of land, alternated with lengthy fallow periods. These systems are the dominant form of agriculture in tropical humid and sub-humid upland regions and are typically associated with tropical rain forests (MA, 2005, p.750).
▸http://www.eoearth.org/article/Slash_and_burn

• Human intervention has produced a "**net degradation of soil**" largely through **copious food production**, which overdraws and degrades natural resources to maximize production (Harper, 2008, p.46-47).

• From the beginning of agriculture until about 1950, nearly all the growth of food output came from expanding cultivated land area. Since 1950, at least four-fifths of the increase in food output came from increasing *productivity* (Harper, 2008, p.46-47).

• **Intensification** has involved improved technologies, such as plant breeding, fertilizers, pest and weed control, irrigation, and mechanization; global food security now depends to a large extent on **fertilizers** and **fossil fuels** (GEO-4, 2007, p.110). However, "fertilizer is not a substitute for fertile soil. It can only be applied up to certain levels before crop yields begin to decline" (Harper, 2008, p.46-47).
▸http://www.wri.org/publication/content/8331

• Most smallholders cannot afford fertilizers now, and the prices are being driven up by **rising energy costs** and the depletion of easily exploited stocks of phosphate. Food production is also constrained by the competing claims of other land uses, not least for maintenance of ecosystem services, and large areas may be reserved for conservation (GEO-4, 2007, p.110).

▸ http://www.postcarbon.org/even-giants-hurt-rising-energy-prices

• While modern intensive agriculture dramatically increased productivity, it all but destroyed the **traditional methods** of preserving soil productivity that farmers everywhere had learned to practice, such as terracing, contour plowing, crop rotation, fallowing, organic fertilizer, etc. (Harper, 2008, p.46).

• **Intensive agriculture** has encouraged continuous cropping of **monocultures** without rotation or fallow periods, cropping on hilly and **marginal land**, and **overgrazing** in confined pasturelands (Harper, 2008, p.46-47). Cropland expansion and intensification lead to a loss of habitat and biodiversity, soil salinization, soil erosion, and eutrophication, among other problems.
▸ http://www.cnr.berkeley.edu/~agroeco3/modern_agriculture.html

• Livestock production is the **single largest user of land** either directly through grazing or indirectly through consumption of fodder and feed grains (MA, 2005, p.216). Confined **livestock production systems** in industrial countries are the source of most of the world's poultry and pig meat production and hence of global meat supplies (p.752). Problems with these systems often arise in the disposal of large amounts of **manure** and slaughtering by-products. Soils can quickly become saturated with both **nitrogen and phosphorus** because it is too costly to transport manure long distances, given its relatively low nutrient concentration (p.752).
▸ http://www.fao.org/newsroom/en/news/2006/1000448/index.html

• The expansion of extensive **beef production systems**, primarily in South and Central America, has been associated with high rates of **deforestation** (MA, 2005, p.218).
▸ http://www.guardian.co.uk/uk/2005/oct/18/bse.foodanddrink

• The continued shift from cereal to animal products and the recent move towards **biofuels** will add to the demand for farm production (GEO-4, 2007, p.83) A major shift in agricultural production from food to biofuels presents an obvious conflict (p.110).
http://www.wri.org/stories/2008/08/food-or-fuel-the-bioenergy-dilemma

• The world's population is projected to increase to over 9 billion by 2050 http://www.un.org/apps/news/story.asp?NewsID=13451&Cr=population&Cr1. Thus, to meet the Millennium Development Goals on hunger, a doubling of global food production will be required (GEO-4, 2007, p.110).

• To feed a growing global population on increasingly degraded and expensive agricultural resources, we will need to increase the productive yield of agriculture while protecting the fertility of cropland soils (Harper, 2008, p.47), as well as strive to curb population growth http://vhemt.org/.

• Nearly every credible forecast shows that if we're to have any chance of meeting future food demand in a sustainable fashion, **lowering our meat consumption** will be absolutely essential (Roberts, 2008, p.209).
▸ http://www.wellfedworld.org/PDF/CIWF%20Eat%20Less%20Meat.pdf

• Some types of production systems, such as **multi-tiered, tree and crop-based farming systems**, can be very effective in building up soil nutrients, reducing soil erosion, enhancing

water-related, climate, and flood regulation services, and even promoting biodiversity (MA, 2005, p.755-756).
▸http://www.fao.org/docrep/x5672e/x5672e04.htm

• Many types of wild food remain important for the **poor and landless**, especially during times of famine and insecurity or conflict, when normal food supply mechanisms are disrupted and local or displaced populations have limited access to other forms of nutrition. Even in normal times, these **wild land-based foods** are important in complementing staple foods to provide a balanced diet, and plants growing as weeds may often be important in this respect (MA, 2005, p.219)
▸http://www.un.org/esa/forests/pdf/ECOSOC2007_Issues_Paper.pdf

• The loss of prime agricultural land is a consequence of urban expansion, often displacing food production onto less productive land elsewhere. **Urbanization** also leads to major changes in **nutrient flows** associated with the flow of food from rural to urban areas. Whereas organic matter residues were once recycled locally, this nutrient export from rural to urban areas can deplete soil nutrient content in the production areas and can concentrate nutrients in human wastes and other residues in and around cities (MA, 2005, p.225).

Illustrative Facts & Statistics

▸*Extent and expansion of cropland*

• Globally, cultivated systems cover 36.6 million square kilometers, or approximately 27% of total land area (and a much higher share of habitable land [MA, 2005, p.221]). It is estimated that 74% of the world's population lives within the boundaries of cultivated systems (MA, 2005, p.754).
• Cereal production accounts for almost 60% of the world's harvested crop area and an often disproportionately larger share of the usage of fertilizer, water, energy, and other agrochemical inputs (MA, 2005, p.216).
• Since 1700 cropland has increased by 1,200 million hectares (466%), including major expansion in North America and the former Soviet Union, with the greatest expansion occurring in the past 150 years (MA, 2005, p.749).
• Over the past 40 years cropland area has expanded globally by some 15% - from 1.3 billion to 1.5 billion hectares, the area of pasture has grown some 11% from 3.14 billion to 3.48 billion hectares, and practically all corners of the world's oceans are accessible to the world's fishing fleet (MA, 2005, p.229).
• Globally, agricultural land has expanded by around 130,000 square kilometers per year over the past 25 years, predominantly at the expense of natural forests and grasslands (MA, 2005, p.760).
• In the 1920s and 1930s there were more than 6 million farms of around 40 hectares each. By the late 1900s, there were fewer than 2 million farms and they averaged 200 hectares each (MA, 2005, p.228).
• Globally, 78% of the increase in crop output between 1961 and 1999 was attributable to yield increases and 22% to expansion of harvested area (MA, 2005, p.775).
• Agricultural land is expanding in 70% of countries, declining in 25% and static in 5%; forest area is decreasing in two-thirds of countries where agricultural land is expanding and forests are expanding in 60% of countries whose agricultural land is decreasing (MA, 2005, p.597).

• Cropland in Latin America, Africa, Australia, and South and Southeast Asia expanded very gradually between 1700 and 1850, but subsequently expanded rapidly. Since 1950, cropland area in North America has stabilized, while it has decreased in Europe and China. In the 2 decades before 2000, the major areas of cropland expansion were located in Southeast Asia, parts of Asia, eastern Africa, and in the Amazon Basin. The major decreases of cropland occurred in the southeastern United States, eastern China, and parts of Brazil (MA, 2005, p.749).
• More than for any other crop (and excluding pastures), it is the global area expansion of oil crops over the past 40 years that has driven cropland expansion. Food use of oil and vegetable oil crops, expressed in oil equivalent, grew from 6.3 kg per capita per year in 1964/66 to 11.4 kg in 1997/99 (MA, 2005, p.214).

►*Extent of various farming systems*

• Between 1992 and 2001, the extent of organic cropland in the United States grew by over 200%, from about 163,000 hectares to 526,000 (MA, 2005, p.767).
• Roughly 18% (250 million hectares) of total cultivated area is irrigated. Rain-fed agricultural systems account for the largest share (about 82%) of the total agricultural land area and exist in all regions of the world (MA, 2005, p.750).
• Slash-and-burn agriculture is practiced on about 22% of all agricultural land in the tropics and is the primary source of food and income for some 40 million people (MA, 2005, p.751).
• Mixed crop-livestock farming systems are the backbone of small-holder agriculture throughout the developing world, supporting an estimated 678 million rural poor (MA, 2005, p.751).

►*Environmental Impacts of Agriculture*

• The arrival of humans practicing agriculture increased the volume of soil and silt being carried into the ocean by at least two and a half times the original rate (Harper, 2008, p.46).
• Soil is eroding on approximately 38% of the world's cropland; soil erosion and degradation has reduced food production on about 16% of the world's cropland (Harper, 2008, p.47).
• It is estimated that American soils are eroding 16 times faster than it can from, and the Great Plains states have lost half their topsoils since agriculture began there (Harper, 2008, p.47).
• Worldwide, some 20% of irrigated land (450 000 km^2) is salt-affected, with 2,500 – 5,000 km^2 lost from production every year as a result of salinity (GEO-4, 2007, p.99-100).
• The soil of nearly a third of all arable land is so acid that it can't support high-yielding crops (Roberts, 2008, p.214).
• Half a billion people now live and farm on lands so hilly and erosion prone that further intensification won't be possible without a considerable cost, and, globally, erosion is so severe that, by 2050, the world may be trying to feed twice as many people with half as much topsoil (Roberts, 2008, p.214).
• Of the 230 pounds of synthetic nitrogen applied to the typical acre of United States corn, as much as 50 pounds will leave the soils and enter the surrounding environment (Roberts, 2008, p.216).
• In China, overgrazing transforms 1400 square miles of grasslands into desert each year (Roberts, 2008, p.221).

►*Intensity of food production*

• In the 1980s, globally, one farmer produced one ton of food, and one hectare of arable land produced 1.8 tons, annually on average. Today, one farmer produces 1.4 tons, and one hectare of

land produces 2.5 tons. The average amount of land cultivated per farmer remained the same, about 0.55 ha (GEO-4, 2007, p.86)

• Cereal production accounts for almost 60% of the world's harvested crop area and an often disproportionately larger share of the usage of fertilizer, water, energy, and other agrochemical inputs (MA, 2005, p.216).

• The roughly 18% (250 million hectares) of total cultivated area that is irrigated accounts for about 40% of crop production (MA, 2005, p.750).

• Today, the food security of two-thirds of the world's population depends on fertilizers, particularly nitrogen fertilizer (GEO-4, 2007, p.100).

• Three cereals – rice, wheat, and maize – receive 56% of all nitrogen fertilizer applied in agriculture (MA, 2005, p.753)

• Between 1992 and 2001, the extent of organic cropland in the United States grew by over 200%, from about 163,000 hectares to 526,000 (MA, 2005, p.767).

• Globally, 78% of the increase in crop output between 1961 and 1999 was attributable to yield increases and 22% to expansion of harvested area (MA, 2005, p.775).

• Most forecasts suggest that of the one billion tons of extra grain needed by 2030, four-fifths must come not by planting extra acres, but from intensification – getting more food from existing acres, largely because farmland is continually being lost to commercial and residential development, especially in the United States (Roberts, 2008, p.213).

► Food and Water

• Key Online Resources:

• ftp://ftp.fao.org/agl/aglw/docs/agricfoodwater.pdf
• http://www.davidsuzuki.org/Oceans/Aquaculture/Salmon/Pollution.asp
• http://www.panda.org/about_our_earth/blue_planet/problems/

• **Cultivation** both relies on and influences the provision of **fresh water**. Both the quantity and quality of water resources can be affected, as well as the timing and distribution of water flows in local catchments and large river basins. Impoundments for irrigation can regulate downstream flows, while seasonally bare soil and field drainage systems can accelerate runoff and reduce infiltration, resulting in more severe local flooding and decreased dry weather flows (MA, 2005, p.761).

• Given that **agriculture** (more specifically, irrigation) is the largest and most inefficient consumer of water supplies, increases in food production are largely responsible for the squandering and over-exploitation of these supplies, especially those in **non-replenishable aquifers**. Water tables are falling in scores of nations that contain more than half of the world's people, including China, India, and the U.S (Harper). There is "strong evidence that under a business-as-usual scenario there will not be enough water to produce the food needed to feed the world in 2050" (WWI, 2008, p.112).
▸ http://www.fao.org/nr/water/aquastat/water_use/index6.stm
▸ http://www.ec.gc.ca/WATER/en/manage/use/e_agri.htm
▸ http://www.eoearth.org/article/Aquifer_depletion

• Although irrigation is by far the largest global water user, the net rate of increase in **irrigated area** has decreased steadily in each of the four past decades and now stands at just under 1% annually. Expansion in irrigated area has slowed as unexploited fresh water resources have become more limited and more expensive to develop. There is also increasing competition for water from domestic and industrial users (MA, 2005, p.761).
▸ http://www.worldwatch.org/node/6186

• Many studies indicate that current water usage is now so far above sustainable levels that it is already hurting global farm output. Water has no alternative, making it a more final constraint on food supplies than that of oil or climate (Roberts, 2008, p.228). Already, water depletion is leading countries to curb their own farm production and instead to import their water indirectly, in the form of grain ("**virtual water**") purchased from the United States, Europe, Brazil, Argentina, and other big grain exporters (p.xix).

• **Industrial agriculture** is not only water-intensive, but extremely **polluting**. Overfertilization has long served as a form of crop insurance, and at the same time as farmers have been adding too much fertilizer, new farming methods have accelerated the tendency for those excess fertilizers to leave the soil. Many fields are now left bare between autumn harvest and spring planting (no longer use traditional cover crops in between). When uncovered soils are exposed to weather, soil nitrogen quickly converts into nitrate, a highly mobile chemical compound that is easily leached from the soils by rain. In addition, hundreds of millions of tons of nitrogen-rich manure accumulates in livestock feedlots and often leaks into surrounding water sources. In

rivers and lakes, all this wayward nitrogen causes extensive algal blooms, eutrophication, and potentially, fish-killing "dead zones" (Roberts, 2008, p.216).
▸ http://www.greenpeace.org/canada/en/recent/dead-zones
▸ http://disc.gsfc.nasa.gov/oceancolor/scifocus/oceanColor/dead_zones.shtml

• **Salinization** and **waterlogging** are two significant consequences of poor irrigation management and inadequate drainage. Salinization occurs through the accumulation of salts deposited when water is evaporated from the upper layers of soils and is especially important in irrigated arid areas where evaporation rates are high (MA, 2005, p.763) http://www.nm.nrcs.usda.gov/technical/handbooks/iwm/NM_IWM_Field_Manual/Section13-ProducerWorkshop/PW-83.pdf.

• One of the first steps toward the sustainable management of water supplies and the reduction of pollutants in the water system entails revolutionizing the agricultural sector to increase the efficiency of its water use http://www.fao.org/nr/water/what.html and lowering the demand for meat products, which are five or six times more water-intensive to produce than wheat, and even more polluting http://eatkind.net .

• The **overexploitation of fisheries** is a global problem. Of the world's 15 main fishing regions, four are depleted and nine are declining (FAO 2000).
▸ http://archive.greenpeace.org/comms/cbio/global.html
▸ http://www.fishing.hourston.co.uk/about7.html

• **Commercial fishing** and fish farms (aquaculture) in particular contribute substantially to ocean **pollution**; fish farms pollute coastal waters with massive amounts of fish feces, antibiotic-laden fish feed, and diseased fish carcasses. Since 1970, **aquaculture** – the cultivation of marine or freshwater food fish or shellfish – has become the fastest-growing food production sector in the world, increasing at an average rate of 9.2% per year – an outstanding rate compared to the 2.8% rate for land-based farmed meat products (MA, 2005, p.558).
▸ http://www.fishinghurts.com/EnvironmentalConcerns.asp
▸ http://www.fishinghurts.com/fishFarms.asp
▸ http://www.panda.org/about_our_earth/blue_planet/problems/aquaculture/pollution/
▸ http://www.davidsuzuki.org/Oceans/Aquaculture/Salmon/Pollution.asp

Illustrative Facts & Statistics

• Agriculture accounts for the most water use, about 70% worldwide, and it is also the most inefficient use; it requires 4.2 million liters of water in a growing season to grow 1 hectare of corn. It is not uncommon for 70 to 80% of the water in irrigation systems to be lost by evaporation or to seep into the ground before reaching crops (Harper, 2008, p.49).
• Water requirements for cultivation are large; it takes 500 liters, 900 liters, 1,400 liters, and 2,000 liters of transpired water to produce 1 kg of potatoes, wheat, maize, and rice respectively (MA, 2005, p.761).
• On average, every ton of grain we grow requires a thousand tons of water (Roberts, 2008, p.227).
• Irretrievable losses from irrigation represent one-third of all water uses globally. Irrigation is very wasteful because much of this water is lost to evapotranspiration and lost in transit as well. Water input-to-crop output ratios vary from the hundreds to the thousands (MA, 2005, p.174).

• Global estimates of irrigation efficiency vary but the average is around 43% (MA, 2005, p.762).
• Of the 9,000-12,500 cubic km of surface water estimated to be available globally for use each year, between 3,500 and 3,700 cubic km were withdrawn in 1995 (MA, 2005, p.761).
• The share of extracted water used for agriculture ranges from 87% in low-income countries to 74% in middle-income countries and 30% in high-income countries (MA, 2005, p.761).
• By 2002, there were 276 million hectares of irrigated cropland globally, five times more than at the beginning of the twentieth century. While this irrigated area represents only 18% of all croplands, irrigated agriculture provides about 40% of the global food supply (MA, 2005, p.761).
• Half of the developing world's grain crop is grown on irrigated acres, and the success of the Green Revolution in India and Southeast Asia wouldn't have been possible had the area of irrigated land not doubled since 1960 (Roberts, 2008, p.228).
• Each kilogram of beef requires 15,500 liters of water (LPR 2008); one kilogram of grain requires 1,000 – 2,000 liters of water (MA, 2005, p.185).
• Aquifers have been so heavily tapped that water tables are falling by up to twenty feet a year. In North Africa, water is being withdrawn from aquifers as much as 5 times faster than it can recharge, forcing farmers to drill their irrigation wells to depths of nearly a mile. Even in the rain-rich United States, the huge Ogallala Aquifer, which supplies one in five irrigated acres nation-wide, is being overdrawn at a rate of 170 million tons (3.1 trillion gallons) a year and is gradually forcing many farmers to either shift to new "dry land" crops or abandon agriculture altogether (Roberts, 2008, p.229).
• At present rates of consumption in the United States, much of the Ogallala aquifer will be barren, and production in the region that now supplies about 40% of the nation's beef and grain will drop sharply (Harper, 2008, p.50).
• In the 3-H region in China, water use now exceeds the sustainable flow by more than six hundred million tons a year. Water tables have fallen by up to 300 feet, ground levels are subsiding, and in coastal areas, freshwater wells are now sucking in seawater. China is now thought to be feeding perhaps 200 million people – around a sixth of its population – with water withdrawals that cannot be sustained (Roberts, 2008, p.229).
• It is estimated that around 45 million hectares, representing 20% of the world's total irrigated land, suffers from salinization or waterlogging. Losses amount to approximately 1.5 million hectares of irrigated land each year and about $11 billion annually from reduced productivity (MA, 2005, p.763).
• Micro-irrigation technologies such as drip irrigation and micro-sprinklers, often achieve efficiencies in excess of 95% compared with standard flood irrigation efficiencies of 60% or less (MA, 2005, p.762).
• In freshwater aquaculture alone, some 115 freshwater species of finfish, crustaceans, and mollusks were cultured in 2000. Over the period 1991-2000, carp and tilapia ranked first and second respectively in global freshwater fish production, accounting for 76-82% and 5-6% of the total respectively (MA, 2005, p.753).
• It is estimated that the fishing industry has eliminated 90% of the large fish in the ocean (WWI, 2008, p.63).
• There are nearly 150 dead zones worldwide, more than double the number in 1990 (Roberts, 2008, p.217).

► Food and Energy

• Nearly everything about the way our food system has developed over the last half-century – from our ability to manufacture fertility to our capacity to move food to import-dependent nations – could not have occurred without **cheap energy**, and the degree to which that system can continue in a world of high energy prices is a frightening unknown (Roberts, 2008, p.xix).
▸ http://www.energybulletin.net/node/5045
▸ http://www.feasta.org/events/foodconf/food_conference.htm

• Cheap oil has enabled a faster pace of food transportation. As speed increases linearly, fuel use climbs exponentially: going twice as fast requires much more than twice the energy. Our sprawling just-in-time global food economy, the very foundation of year-round produce and seafood, has effectively locked us into **massive oil consumption** – consumption that was feasible when oil was cheap but may be unsustainable in a world of two-hundred-dollar oil (Roberts, 2008, p.224).
▸ http://www.energybulletin.net/node/6052

• **Petroleum** is perhaps the single most important input in modern food production; it serves both as a **fuel** for tractors and food transportation and as the **chemical base** for fertilizers and pesticides http://www.energybulletin.net/node/12158. It is gradually becoming so scarce and expensive that many of the assumptions underlying a global industrial food system are now in question (Roberts, 2008, p.xix)
http://www.acore.org/files/pdfs/Renewable_Energy_Pressure_Relief_Valve.pdf?q=pdfs/Renewable_Energy_Pressure_Relief_Valve.pdf. In fact, the most visible driver transforming the food economy will probably be the **rising price of oil**. Oil demand is now being fuelled by massive emerging Asia and oil supplies are being depleted (Roberts, 2008, p.222).

• Synthetic nitrogen is made from **natural gas**, the price of which has more than tripled since 2002. Supplies of natural gas are already tight, even in the United States, one of the largest natural gas producers in the world (Roberts, 2008, p.215).
▸ http://www.rff.org/Publications/Resources/Documents/156/RFF_Resources_156_gas.pdf

• **Food processing** and **packaging** are incredibly energy intensive. The energy needed to make a pound of breakfast cereal from wheat is about 32 times the amount needed to make a pound of flour from the same wheat, and in many cases, companies use more energy packaging the food than making the food itself (Roberts, 2008, p.223).
▸ http://www.earth-policy.org/Books/Seg/PB3ch02_ss3.htm

• Food production is now so inextricably linked to fossil fuels that a peak in oil output, and the subsequent decline in food supplies, would shrink the global population by several billion over the next two decades (Roberts, 2008, p.304).

• The recent move towards **biofuels** will add to the demand for farm production (GEO-4, 2007, p.83). A major shift in agricultural production from food to biofuels presents an obvious conflict (p.110).
▸ http://www.wri.org/stories/2008/08/food-or-fuel-the-bioenergy-dilemma

• **Ethanol refineries** consume nearly 30% of the United States corn crop, up from just 10% in 2002 (Roberts, 2008, p.206). Corn is among the **least efficient crops** to make into fuel.
▸ http://www.earth-policy.org/Updates/2005/Update49.htm

Illustrative Facts & Statistics

• Since September 2001, crude-oil prices have jumped from around $26 a barrel to well over $90 a barrel in 2007 (Roberts, 2008, p.222).
• The emerging biofuels industry now claims nearly a third of the entire United States corn supply (Roberts, 2008, p.xviii).
• It takes 2,200 calories of hydrocarbon energy to produce a can of soda that contains just 200 calories of food energy. It's no wonder that food production accounts for nearly a fifth of the United States' total energy bill (Roberts, 2008, p.223).
• The 33,000 cubic feet of natural gas needed to make a ton of nitrogen fertilizer could be used instead to generate 9,671 kilowatts of electricity, enough to run the average United States home for ten and a half months (Roberts, 2008, p.215).

► Food and Biodiversity

Key Online Resources:

• http://69.28.176.224/article/Global_Environment_Outlook_(GEO-4)~_Chapter_5#Managing_energy_demand_and_biodiversity_impacts

• Biodiversity provides a **diverse range of edible plants and animal species** that have been and continue to be used as **wild sources of food**, including plants (leafy vegetables, fruits, and nuts), fungi, bushmeat, insects and other arthropods, and fish (including mollusks and crustaceans as well as finfish). The capacity of ecosystems to provide wild food sources is generally declining, as natural habitats worldwide are under increasing pressure and as wild plant and animal populations are exploited for food at unsustainable levels (MA, 2005, p.219).
http://www.undp.org/biodiversity/biodiversitycd/bioImport.htm

• There are several dimensions to biodiversity in **cultivated systems**. These systems contain cultivated or **"planned" biodiversity**, the diversity of plants sown as crops and animals used for livestock or aquaculture (MA, 2005, p.756). Since the origins of agriculture, farmers – and, more recently, professional plant and animal breeders – have developed a diverse range of varieties and breeds that contain a high level of genetic diversity within the major species used for food (p.214). There are many breeds of livestock that originate from a single species and for some crop species there are thousands of distinct varieties (p.214). Of some 270,000 known species of higher plants about 10,000–15,000 are edible, and about 7,000 of them are used in agriculture (GEO-4, 2007, p.171).
▸http://www.pfaf.org/leaflets/edible_uses.php

• Agricultural biodiversity also includes the biodiversity that **supports agricultural production** through pollination, nutrient cycling, and pest control (MA, 2005, p.756). For example, earthworms and other soil fauna and microorganisms, together with plant root systems, maintain soil structure and facilitate nutrient cycling, and insects, spiders, and other arthropods often act as natural enemies of crop pests (p.759).
▸http://www.grida.no/publications/rr/food-crisis/page/3569.aspx

•The most direct impact of food provision on biodiversity has been through **habitat conversion**, which typically leads to reductions in native biodiversity. The major locations of agricultural expansion have frequently coincided with remnants of natural habitats with high biodiversity value (MA, 2005, p.221).
▸http://www.greenfacts.org/en/biodiversity/l-3/3-extinction-endangered-species.htm

• The rapid rate of population decline in tropical species reflects the loss of natural habitat to cropland or pasture in the tropics between 1950 and 1990, **agricultural conversion** being the main driver. In temperate ecosystems, the conversion of natural habitat to farmland took place before 1950, when populations of temperate species are likely to have declined, before stabilizing. The majority of natural forests and grasslands in temperate regions was lost prior to 1970, whereas in the tropics the loss of natural habitat is a relatively recent and on-going phenomenon (LPR, 2006, p.8).
▸http://earthtrends.wri.org/features/view_feature.php?theme=7&fid=34

• The **globalization of agriculture** and **inappropriate agricultural policies** have emerged as the leading indirect drivers influencing the loss of species and ecosystem services. Globalization is leading to major changes in where, how and who produces food and other agricultural commodities. Global market demand for high value commodities such as soybeans, coffee, cotton, oil palm, horticultural crops and biofuels has resulted in substantial habitat conversion and ecosystem degradation. This has replaced diverse small-holder farms with larger **monoculture** enterprises (GEO-4, 2007, p.167).
▸http://www.fao.org/DOCREP/005/Y4671E/y4671e0c.htm

• The steep decline in grassland species coincides with a rise in the **grazing land** component of the ecological footprint; the grazing land footprint doubled between 1970 and 2000, while the forest footprint increased by about 30% (LPR, 2004, p.6).

• Over the past two decades, many of the world's most important agricultural crops have lost **genetic diversity** due to changes in agricultural practices (GEO-4, 2007, p.165). As larger and larger areas are planted with a smaller and smaller number of crop varieties – most major staple crops are grown in **monoculture** – and as livestock systems are intensified, many varieties and breeds are at risk of being lost in production systems and are increasingly found only in ex situ collections (MA, 2005, p.214). The continued loss of genetic diversity of such crops may have major implications on food security
▸http://www.fao.org/SD/EPdirect/EPre0040.htm

• Increased **globalization** threatens to diminish the varieties that are traditionally used in most agricultural systems. Despite its crucial importance in supporting societies, agriculture remains the largest (indirect) driver of **genetic erosion**, species loss and conversion of natural habitats around the world (GEO-4, 2007, p.171).
▸http://www.fao.org/docrep/x0262e/x0262e02.htm

• **Genetically-engineered organisms (GEOs)**, **or living modified organisms (LMOs),** are a relatively recent phenomenon. They are created through a kind of **biotechnology** that involves direct manipulation of an organism's genes in order to provide new attributes in different crops and breeds (MA, 2005, p.173). The technology has been used in the area of medicine for years and has more recently pervaded the food system. Breeders promise varieties of staple crops tailored to the constraints of future food production: plants bred to tolerate heat and drought and salty soils, for example. **Monsanto** is one of the leading players in the booming transgenic market. Critics warn that transgenic plants and animals may contain novel substances that could harm humans or intermingle with and destroy native species (Roberts, 2008, p.240). There are also concerns about how the technology will affect poor people, whose livelihoods depend primarily on traditional low input agricultural practices. Increased research, monitoring and regulation are needed to ensure these negative impacts are avoided as this technology is developed (MA, 2005, p.173).
▸http://www.wri.org/publication/content/8213
▸http://www.safe-food.org/-issue/ge.html
▸http://www.greenpeace.org/international/campaigns/genetic-engineering
▸http://74.125.47.132/search?q=cache:wew2VN8EOgUJ:www.greenpeace.org/raw/content/international/press/reports/executive-summary-monsanto.pdf+%22genetic+engineering%22+Monsanto&cd=6&hl=en&ct=clnk&gl=ca

• Food provision affects wild biodiversity through its demand for **water and nutrients**, and through the **pollution of ecosystems** with pesticides and excess nutrients. Irrigated agriculture is a major user of fresh water, which, together with the direct loss of wetland habitats from conversion and the pollution of inland waters with excess nutrients, has a major negative impact on inland water biodiversity (MA, 2005, p.221).

• Of the **pesticides** in widespread use, the most important effects on biodiversity are from persistent organic pollutants, since these have effects on large spatial and temporal scales (MA, 2005, p.221).
▸http://www.cep.unep.org/publications-and-resources/marine-and-coastal-issues-links/persistent-organic-pollutants-pops-and-pesticides

• Changes in production practices and loss of diversity in agro-ecosystems can undermine the ecosystem services necessary to sustain agriculture. For example, **pollinator diversity** and numbers are affected by habitat fragmentation, agricultural practices, the land-use matrix surrounding agricultural areas, and other land-use changes. Although some of the crops that supply a significant proportion of the world's major staples do not require animal pollination (such as rice and maize), the decline of pollinators has long-term consequences for those crop species that serve as crucial sources of micronutrients and minerals (such as fruit trees and vegetables) in many parts of the world (MA, 2005, p.173).
▸http://www.fao.org/Ag/Magazine/0512sp1.htm

• Genetic erosion, loss of local populations of species, and loss of cultural traditions are often intimately intertwined. While rates of genetic erosion are poorly known, they generally accompany the transition from traditional to commercially developed varieties. In crop and livestock production systems throughout the developing world, genetic erosion reduces smallholder farmer options for mitigating impacts of environmental change and reducing vulnerability, especially in marginal habitats or agricultural systems that are predisposed to extreme weather conditions (such as arid and semi-arid lands of Africa and India) (MA, 2005, p.173).

• Meeting global food needs poses increasing challenges, and will require either **intensification** or extensification to increase agricultural productivity. Intensified systems tend to be dominated by only a few varieties. This approach is usually associated with higher levels of inputs, including technology, agrochemicals, energy and water use. The latter three, at least, have serious negative impacts on biodiversity (GEO-4, 2007, p.173).
▸http://www.fao.org/docrep/007/j0902e/j0902e03.htm

• **Extensification** relies on lower inputs, and generally on more land being used, often through habitat conversion. In many parts of the world, agricultural extensification involves converting more land for the cultivation of major commodities such as soybeans (Latin America and the Caribbean), oil palm and rubber (Asia and the Pacific), and coffee (Africa, Latin America and Asia), and it is exacerbated by the emergence of new markets for export (GEO-4, 2007, p.173).
▸http://www.eoearth.org/article/Global_Environment_Outlook_(GEO-4)~_Chapter_5

• There is the trend of **growing more trees** in agricultural landscapes for a wide variety of purposes. Trees stabilize and enhance soils, contribute in themselves to biodiversity, but also play host to a variety of birds and insects. Management practices can have major impacts on such

biodiversity and the services it provides for nutrient cycling, pest control, and pollination, with positive spillovers for agricultural production (MA, 2005, p.222)
▸http://www.agric.wa.gov.au/PC_92523.html

• The **deep sea** is increasingly recognized as a major reservoir of biodiversity, comparable to the biodiversity associated with tropical rain forests and shallow-water coral reefs. It has been estimated that the number of species inhabiting the deep sea may be as high as 10 million (GEO-4, 2007, p.163).
▸http://74.125.95.132/search?q=cache:49ApREhIy-MJ:www.greenpeace.org/raw/content/canada/en/documents-and-links/publications/high-seas-bottom-trawl-fisheri.pdf+fishing+biodiversity+trawling&cd=1&hl=en&ct=clnk&gl=ca

• **Fishing** is one of the major direct anthropogenic forces that has an impact on the structure, function, and biodiversity of the oceans today (MA, 2005, p.489). **Overexploitation** has been implicated as the leading threat to the world's marine fishes and has led to a decline in the average trophic level of catches. High-impact fishing (including bottom trawling, long-lining, gill netting, and dynamite fishing) causes damage to the biodiversity of sensitive habitats, such as cold-water reefs, tropical coral reefs, and seamounts, and to migratory seabirds (p.222). The biggest threat to deep-sea **coral reefs** comes from **trawling activities** (p.489).
▸http://news.nationalgeographic.com/news/2004/02/0219_040219_seacorals.html

• Most industrial **fisheries** are either fully or overexploited (MA, 2005, p.481). http://www.greenfacts.org/en/fisheries/. The FAO's *State of the World's Fisheries and Aquaculture* Report shows that the percentage of underexploited stocks has declined steadily since 1974, while the proportion of stocks exploited beyond maximum sustainable yield levels has increased steadily. If these data are representative of fisheries as a whole, they indicate an overall declining trend in spawning stock biomass for commercially important fish species since 1974 (MA, 2005, p.103).
▸http://www.fao.org/docrep/009/a0699e/A0699E00.HTM

• The world's demand for food and animal feed over the last 50 years has resulted in such strong fishing pressure that the biomass of some targeting species, such as the larger, higher-valued species and those caught incidentally (**by-catch**; e.g. small cetaceans such as dolphins) http://www.greenpeace.org/international/campaigns/oceans/bycatch, has been reduced over much of the world by a factor of 10 relative to levels prior to the onset of industrial fishing (MA, 2005, p.481).

• In addition, with fleets now targeting the more abundant fish at **lower trophic levels**, it would be expected that global catches should be increasing rather than stagnating or decreasing, as is actually occurring (MA, 2005, p.482).
▸http://www.seafriends.org.nz/issues/fishing/pauly1.htm

• Since 1970, **aquaculture** has become the fastest-growing food production sector in the world, increasing at an average rate of 9.2% per year – an outstanding rate compared to the 2.8% rate for land-based farmed meat products (MA, 2005, p.558).
▸http://www.umbi.umd.edu/comb/research-programs/recirculating/marine-aquaculture.php

• **Infectious disease** is currently a serious problem in aquaculture, both for farmed fish and wild stocks. When infected farmed fish escape from aquaculture facilities, they can transmit these

parasites and diseases to wild stock (e.g. Atlantic salmon), as well as disrupt the native aquatic life through **invasion damage** http://oceania.wetlands.org/NEWS/tabid/469/articleType/ArticleView/articleId/1773/Default.aspx. Human reliance on farmed fish and shellfish is significant and growing (MA, 2005, p.98).

• Along with conversion to agriculture, salt pans, and urban and industrial development, an important cause of **loss of mangrove area** is the aquaculture industry, typically through conversion of mangrove wetlands to shrimp or prawn farms (MA, 2005, p.521).
►http://www.fao.org/fishery/topic/14894/en

• Annual fish stock assessments are conducted in Canada's **Great Lakes** for commercially important salmonoid species (e.g. lake trout and Pacific salmon) and for their prey species (such as rainbow smelt and lake herring). With the exception of Lake Superior, populations of prey species in the other four lakes are all decreasing. Many native predator species, such as lake trout and sturgeon, are found in vastly reduced numbers and have been replaced by introduced species (MA, 2005, p.103).
►http://www.glsc.usgs.gov/main.php?content=research_lamprey&title=Invasive%20Fish0&menu=research_invasive_fish

• Longer-term catch and status information is available for Pacific and Atlantic salmon in North America, fisheries of the Rhine and Danube Rivers in Europe, and fisheries of the Pearl River in China; all have declined to just a fraction of their former levels due to overexploitation, river alteration, and habitat loss, putting some of these species at serious risk of extinction (MA, 2005, p.103).

• Even fisheries that until recently were reasonably well managed, such as the caviar-producing sturgeons in the Caspian Sea http://www.blueoceaninstitute.org/seafood/species/104.html, and fisheries from relatively intact rivers such as the Mekong in Southeast Asia are rapidly declining http://www.fao.org/docrep/005/y3994e/y3994e13.htm. Major sturgeon populations have already declined by up to 70% (MA, 2005, p.103).

Illustrative Facts & Statistics

►*Wild food sources*

• Historically, many terrestrial species have become extinct due to hunting, and there are currently 250 mammal species, 262 bird species, and 72 amphibian species listed as threatened due to overexploitation for food (MA, 2005, p.222)
• Some 40% of known species of fish inhabit inland waters – more than 10,000 species out of 25,000 species globally – and about 25-30% of all vertebrate species diversity is concentrated close to or in inland waters (MA, 2005, p.561).
• It is estimated that the fishing industry has eliminated 90% of the large fish in the ocean (WWI, 2008, p.63).

►*Agriculture*

• Of the estimated 10,000 – 15,000 edible plants known, only 7,000 have been used in agriculture and less than 2% are deemed to be economically important at a national level. Only 30 crops provide an estimated 90% of the world population's calorific requirements, with wheat, rice, and maize alone providing about half the calories consumed globally (MA, 2005, p.213).

• About 7,000 species of plants and several hundred species of animals have been used for human food at one time or another. Some indigenous and traditional communities use 200 or more species for food (MA, 2005, p.219).
• Globally, there are over 6,500 breeds of domesticated animals. A third of these are under near-future threat of extinction due to their very small population size. Over the past century, it is believed that 5,000 domesticated animal and bird breeds have been lost (MA, 2005, p.758).
• Of the estimated 15,000 species of mammals and birds, only some 30-40 (0.25%) have been used for food production, with fewer than 14 species accounting for 90% of global livestock production (MA, 2005, p.214).
• FAO estimates that in Europe 50% of livestock breeds that existed 100 years ago have disappeared (MA, 2005, p.214).
• The global production of genetically modified crops (mainly maize, soybean and cotton) was estimated to cover more than 900,000 km^2 in 2005 (GEO-4, 2007, p.173).
• Only 14 animal species currently account for 90% of all livestock production, and only 30 crops dominate global agriculture, providing an estimated 90% of the calories consumed by the world's population (GEO-4, 2007, p.171).
• Over three-quarters of the major world crops rely on animal pollinators. Approximately 73% of the world's cultivated crops are pollinated by bee species, 19% by flies, 6.5% by bats, 5% by wasps, 5% by beetles, 4% by birds, and 4% by butterflies and moths. The services of wild pollinators are estimated to be worth $4.1 billion a year to United States agriculture alone (MA, 2005, p.759).

►*Aquaculture and fishing*

• Some 40% of known species of fish inhabit inland waters – more than 10,000 species out of 25,000 species globally – and about 25-30% of all vertebrate species diversity is concentrated close to or in inland waters (MA, 2005, p.561).
• 75% of the world's fish stocks are fully or overexploited (GEO-4, 2007, p.164).
• 28% of fish stocks assessed have declined to levels below which a maximum sustainable yield can be taken, a further 47% require stringent management to prevent decline into a similar situation (MA, 2005, p.103).
•WWF (2002) suggest that 30-50% of the deep-water corals along the Norwegian coast have already been lost due to bottom trawling, marine pollution, and oil and gas extraction (MA, 2005, p.489).
• It is estimated that approximately 20% of the world's known coral reefs have been destroyed and a further 20% have been badly degraded (MA, 2005, p.523).

►*Biotechnology*

• Transgenic crops account for more than a quarter of total corn acreage and more than half of soybean acreage worldwide (Roberts, 2008, p.240).
• Herbicide-tolerant seeds now account for half of all corn and more than 93% of all soybean acreage in the United States (Roberts, 2008, p.243)
• Monsanto owns 90% of the transgenic traits sold worldwide (Roberts, 2008, p.260).

► Food and Climate Change

• Food production is a very climate-sensitive enterprise. Even subtle changes in climate can have dramatic impacts on food production and on food procurement in general, as history has shown.

• Between 3 million and 2.4 million years ago, **Australopithecus** – a diminutive ancestor who lived in the prehistoric African forest and survived on a largely plant-based diet – got a shove: the climate began to cool and dry out, and the primeval jungle fragmented into a mosaic of forest and grasslands, which forced our ancestors out of the trees and into a radically new food strategy. In this more open environment, early humans would have found far less in the way of fruits and vegetables but far more in the way of animals (Roberts, 2008, p.5).
►http://www.ecotao.com/holism/hu_austral.htm

• By around 180,000 years ago, as the first of four **ice ages** began, animal foods dominated and defined the human food strategy. Both **Neanderthals** and later, **Cro-Magnons**, relied heavily on the mastodon, bison, woolly rhinoceros, and other arctic megafauna that had been driven southward into human territory by expanding **glaciers** (Roberts, 2008, p.8).
►http://www.ecotao.com/holism/hu_neand.htm

• By 11,000 years ago, a **warming climate** had drawn the big, cold-weather game back northward, away from human settlement. In their place came smaller, faster species (e.g. gazelle), which required new hunting skills and weapons. Yet ultimately, new technologies couldn't save the hunting life. As hunting success faltered, tribes had to supplement hunting with gathering. (Roberts, 2008, p.8-9).

• The **Neolithic Revolution** was sparked by a number of changing climatic and social factors, which resulted in gradual demographic and **geographic expansion**. During this process of expansion, human societies depleted their local and regional natural environments, and were forced to change their mode of existence (Broswimmer, 2002, p.30).
►http://www.bbc.co.uk/dna/h2g2/A2054675

• More recently, forecasters have begun to tabulate just how damaging even a minor change in global climate will be to the modern food system, which is built on the assumption of stable temperatures and consistent rainfall (Roberts, 2008, p.208).
►http://www.ciesin.org/docs/004-138/004-138.html

• Even by conservative estimates, the combination of rising temperatures and shifting patterns **in** rainfall and storm frequency will push down total global food output, and this while demand is rising (Roberts, 2008, p.xix).
►http://www.fao.org/newsroom/en/news/2006/1000436/index.html

• Crops bred for a particular level of rainfall or a particular range of temperatures will see dramatic changes in yields in **hotter, drier weather**. Most climate models envision more frequent **extreme weather events** of all kinds – droughts, severe rainstorms, hailstorms, and flash floods, which can be just as damaging to crop yields http://www.worldwildlife.org/who/media/press/2008/WWFPresitem9361.html. Higher temperatures boost **pest populations** and allow insects, fungi, weeds, and other pests to migrate into farming regions that were previously uninfested, leading to substantial crop damage http://www.fao.org/climatechange/media/16606/1/0/. Higher temperatures also stimulate **soil**

bacteria and **fungi**, which accelerates the decay of soil organic matter and thus reduces the soil's capacity to store and transport nutrients and water. Such soils will not only erode more easily, they will also need more fertilizers to maintain yields; yet because they have less organic matter to retain those fertilizers, they will simply surrender more of that added nitrogen into groundwater (Roberts, 2008, p.226).

• Industrial food production is in turn a culprit implicated in global climate change, largely through its contribution in many ways to changes in atmospheric concentrations of carbon dioxide, nitrous oxide, and methane. **Agricultural systems** emit carbon dioxide through the direct use of **fossil fuels** in field operations (such as tillage, harvesting, irrigation pumping, transport, and grain drying), the indirect use of embodied energy in inputs that require the combustion of fossil fuels in their production, and the decomposition of soil organic matter and crop residues (MA, 2005, p.768) http://www.foodandwaterwatch.org/food/factoryfarms/dairy-and-meat-factories/climate-change/greenhouse-gas-industrial-agriculture. However, cultivated systems play a relatively small role in total CO_2 emissions, and some systems have the potential to **sequester carbon** by use of improved crop and soil management practices, thus becoming a sink for carbon dioxide (p.769) http://www.epa.gov/sequestration/faq.html.

• **Burning crop residues** releases a number of **greenhouse gases (GHG)**, including carbon dioxide, methane, carbon monoxide, nitrous oxide, and oxides of nitrogen (MA, 2005, p.768).
▸http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex9318/

• An additional impact of cultivation on GHG concentrations occurs from **erosion**. While some of the organic carbon transported to depositional sites and aquatic ecosystems is buried and sequestered, a large fraction may be emitted into the atmosphere (MA, 2005, p.768).

• Agriculture is the largest source of anthropogenic **methane** (CH_4) (MA, 2005, p.769). The concentration of methane in the atmosphere has more than doubled over the last two centuries, with **enteric fermentation** in domestic **livestock** http://www.fao.org/newsroom/en/news/2006/1000448/index.html, manure management, rice cultivation, and field burning of agricultural crop wastes as the main causes (p.768). Several other agricultural activities, such as irrigation and tillage practices, may also contribute to methane emissions (p.769).
▸http://www.epa.gov/methane/sources.html

• Applying **manure** to agricultural land can lead to **groundwater contamination** by nitrates after nitrification of the ammonium nitrogen present and to emissions of ammonia, methane, and N_2O – all of which contribute to climate change (MA, 2005, p.769).

• Agriculture is the main source of **nitrous oxide**, a chemically active GHG, accounting for about 70% of anthropogenic emissions. The release of nitrous oxide has increased in recent years due to more **intensive agricultural practices**, in particular land conversion and application of nitrogen fertilizer (MA, 2005, p.769).
▸http://www.epa.gov/nitrousoxide/sources.html

• **Global-scale cyclical weather patterns** have strongly influenced food production, including the impact of the El-Nino-Southern Oscillation http://www.sciencemag.org/cgi/content/abstract/1057969 and the North-Atlantic Oscillation http://www.sciencedaily.com/releases/2009/01/090113101200.htm (MA, 2005, p.229).

Illustrative Facts & Statistics

• Agriculture may be contributing about 20% of current annual GHG-forcing potential (MA, 2005, p.769).
• Agriculture contributes 50% of total anthropogenic methane emissions, and 70% of the nitrous oxide emissions (MA, 2005, p.768).
• Rice fields account for as much as one-third of total anthropogenic methane emissions. Global methane emissions from rice fields are estimated to be 37 teragrams per year, while N_2O emissions are much lower, at 1.8-5.3 teragrams per year, although N_2O is a much more potent GHG (MA, 2005, p.769).
• About 80% of methane from agricultural sources is produced biologically (MA, 2005, p.769).
• Atmospheric concentration of N_2O is increasing at a rate of 0.22 plus or minus .02% per year (MA, 2005, p.769).
• Annual emissions of nitrogen due to N_2O emissions from agricultural systems amount to 6.3 teragrams (MA, 2005, p.769).
• Erosion-induced emission of CO_2 into the atmosphere may be about 1 billion tons of carbon a year (MA, 2005, p.768).
• Estimates of the potential to sequester carbon in cultivated systems on a global basis range from 400 million to 800 million tons per year (MA, 2005, p.768).
• It has been suggested that United States corn and soybean yields could drop by as much as 17% for each degree that the growing season warms (MA, 2005, p.228).

► Food and Human Well-Being

• The most direct and tangible benefit of food is its role in enabling individuals to pursue healthy, active, productive lives as a consequence of **adequate nutrition**. For these reasons, access to adequate, safe food has been recognized as a **basic human right** (MA, 2005, p.229).
►http://www.fao.org/newsroom/en/news/2007/1000680/index.html

• "A diverse diet, with sufficient protein, oils and fats, micronutrients, and other dietary factors is as important for well-being as access to and consumption of sufficient calories" (p.211). Our scientifically bred produce grows so quickly that it contains measurably fewer nutrients and **micronutrients** http://www.time.com/time/health/article/0,8599,1880145,00.html. Our **processed foods** are often packed with large quantities of salt, fat, and sweeteners, and hundreds of chemical additives, some of which are linked to medical problems (Roberts, 2008, p.83) http://news.bbc.co.uk/2/hi/health/2814253.stm. **Deficiencies** in Vitamin A, zinc, iron, and folate as well as other micronutrients are responsible for a substantial proportion of malaria morbidity and mortality (MA, 2005, p.233) http://www.who.int/nutrition/topics/vad/en/index.html.

• Good nutrition reduces neonatal and child mortality, helping to slow population growth by increasing birth intervals and reducing demand for large families (MA, 2005, p.229ish?). Malnutrition is associated with disease and poor health, which places a further burden on households as well as health care systems (p.230).
►http://www.un.org/millenniumgoals/2008highlevel/pdf/newsroom/Goal%204%20FINAL.pdf

• Campbell (2006), who directed the most comprehensive study of diet, lifestyle and disease ever done with humans in the history of biomedical research (p.7), documents that **plant-based diets** are the healthiest in terms of disease prevention *and* treatment. For example, it was found that increased intakes of animal protein enhance the production of insulin-like growth factor, which enhances cancer cell growth (p.367). It was also found that eating plant protein has even greater power to lower cholesterol levels than reducing fat or cholesterol intake (p.119).
►http://www.eatveg.com/intro.htm
►http://www.veganhealth.org/articles/dailyrecs/

• **Urbanization** and **socioeconomic changes** have resulted in diets that are higher in energy and lower in diversity of fruits and vegetables than those consumed historically. As a consequence, many countries now face a **"double burden"** of diet-related disease: the simultaneous challenges of significant incidence of acute, communicable diseases in undernourished populations and increasing incidence of chronic diseases associated with the overweight and obese (MA, 2005, p.211) http://www.who.int/nutrition/topics/2_background/en/index1.html, http://www.fao.org/Ag/Magazine/0602sp1.htm. The pathway from traditional rural diets to those of increasingly urban and affluent societies and its attendant implications for nutrition and health has been dubbed the nutrition/**diet transition** http://www.fao.org/FOCUS/E/obesity/obes2.htm.

• Rising rates of obesity and overweight are due to both reduced physical activity and increased consumption of more energy-dense, nutrient-poor foods with high levels of sugar and saturated fats (MA, 2005, p.234). Obesity is one of the more visible illustrations of food's poor fit as an economic phenomenon: "although consumers can consume as many DVDs or sneakers as their credit card companies will allow," the same cannot be said for food, no matter how cheap it becomes (Roberts, 2008, p.xvi).

▸http://www.who.int/dietphysicalactivity/publications/facts/obesity/en/

• **Poorer consumers** tend to be more obese than consumers at higher income levels are: cheaper foods tend to be more caloric. Poor neighborhoods tend to have more fast-food restaurants and more convenience stores and fewer grocery stores, than wealthier, whiter neighborhoods have (Roberts, 2008, p.96).
▸http://opa.yale.edu/news/article.aspx?id=6011

• Not only do we **cook** less than we used to, but more of us eat alone – at our desks, in our cars, standing at our kitchen counters. In America, the average family shares a meal fewer than five times a week (Roberts, 2008, p.xviii).
▸http://www.jamieoliver.com/jamies-ministry-of-food

• **Food contaminants** can occur naturally or as a result of poor or inadequate production, storage, and handling (MA, 2005, p.235) http://ec.europa.eu/food/food/chemicalsafety/contaminants/index_en.htm. The modern food system is geared toward high volume, low costs, and rapid, worldwide distribution (Roberts, 2008, p.178). High-speed distribution means contaminated food can be in consumers' homes, and stomachs, long before contamination is detected. The risk of **food-borne disease** is escalating most rapidly in developing countries http://www.who.int/mediacentre/factsheets/fs124/en/

• The new high-speed mechanized processing in **meat plants**, so critical for the high-volume, low-margin business, significantly raised the risk of contamination: mechanical handling routinely punctured animal intestines, coating carcasses and equipment with bacteria-loaded feces. And once contamination had entered the food supply, the industry's increasingly centralized structure assured that pathogen of the widest distribution. Hamburger, for example, which was once ground locally, is now made in huge batches, using meat trimmings from multiple carcasses purchased from multiple suppliers. Finished products typically contain meat from dozens or even hundreds of animals (Roberts, 2008, p.179-180).

• Decades of heavy **antibiotic** use by livestock producers, which now accounts for nearly half of all antibiotics used worldwide, has produced numerous new strains of bacteria that are immune to entire classes of antibiotics (Roberts, 2008, p.185).
▸http://www.sierraclub.org/factoryfarms/factsheets/antibiotics.asp

• **Organophosphates** are complex molecules that serve as the base of many modern insecticides and fungicides (Roberts, 2008, p.217). The German military tested them as a **human nerve agent** in the 1920s because they are very dangerous to humans (p.218).
▸http://www.panna.org/ops

• The world's population is projected to increase from the current **6.5 billion** to over **9 billion** by 2050 http://www.un.org/apps/news/story.asp?NewsID=13451&Cr=population&Cr1, and will probably peak by 2070 at 9.5 billion (Roberts, 2008, p.206). To meet the Millennium Development Goals on hunger, a doubling of global food production will be required (GEO-4, 2007, p.110). To feed a growing global population on increasingly degraded and expensive agricultural resources, we will need to increase the productive yield of agriculture while protecting the fertility of cropland soils (Harper, 2008, p.47), as well as strive to curb population growth http://vhemt.org/. Lowering our demand for livestock products will also be essential,

given how resource-intensive and inefficient livestock production is.
http://www.wellfedworld.org/PDF/CIWF%20Eat%20Less%20Meat.pdf

• **Local food production** is critical to eliminating hunger and promoting rural development in areas where the poor do not have the capacity to purchase food from elsewhere. The number of food-insecure people is growing fastest in developing regions, where underdeveloped market infrastructures and limited access to resources prevent food needs from being satisfied by international trade alone. Rural households gain income and employment from engaging in food production enterprises. In sub-Saharan Africa, two-thirds of the population relies on agriculture or agriculture-related activities for their livelihoods (MA, 2005, p.211).
►http://www.unesco.org/education/tlsf/TLSF/theme_a/mod02/www.worldgame.org/wwwproject/what01.shtml

Illustrative Facts & Statistics

►*Hunger/malnourishment*

• Globally, nine hundred million people – one-seventh of the population – are malnourished, and another one billion suffer chronic and often destructive deficiencies in micronutrients – statistics that, given the fact that food is cheaper and easier to get now that at any time in history, offers the most dramatic proof that the modern food economy is ailing catastrophically (Roberts, 2008, p.146).
• It is estimated that 852 million people worldwide did not have enough food to meet their basic daily energy needs in 2000 – 2002, including 9 million in industrial countries, 28 million in countries in transition, and 815 million in developing countries (MA, 2005, p.233).
• Some 519 million hungry people live in Asia and the Pacific and 204 million in sub-Saharan Africa, around 60% and 24% respectively of the global total of undernourished people (MA, 2005, p.233).
• The two most populous countries in the world – China and India – alone account for almost 43% of the global total of hunger, but the highest incidence rates, ranging from 40% to 55% of the population, are found in Eastern, Southern, and Central Africa (MA, 2005, p.230?).
• Every twelve months across sub-Saharan Africa, malnutrition kills more than ten million people (Roberts, 2008, p.146).
• Even in the United States, the wealthiest country in the world, one child in six still suffers from inadequate nutrition (Roberts, 2008, p.146).
• An estimated 55% of the nearly 12 million deaths each year among children under five in the developing world are associated with malnutrition (MA, 2005, p.229).
• It is estimated that 4-5 billion people worldwide, many of them women of reproductive age and children under 12, are affected by iron-deficiency-induced anemia (MA, 2005, p.232).
• Iodine deficiency is the world's most prevalent – yet easily preventable – cause of brain damage. It affects over 740 million people, 13% of the world's population (MA, 2005, p.232).
• Overall, inadequate nutrition is estimated to cause losses of between 0.23% and 4.7% per year in per capita GDP growth rates worldwide (MA, 2005, p.237).
• Improvements in Vitamin A status have been demonstrated to lead to a 23% reduction in mortality among children aged one to five (MA, 2005, p.232).
• Up to 2.7 million lives could potentially be saved each year with sufficient global fruit and vegetable consumption (235).

►*Obesity*

• Obesity has become a global epidemic. At present over 1 billion adults are overweight, with at least 300 million considered clinically obese, up from 200 million in 1995 (MA, 2005, p.233).
• Obesity rates have tripled or more since 1980 in some areas of North America, the U.K., Eastern Europe, the Middle East, the Pacific Islands, Australasia, and China (MA, 2005, p.235).
• Almost 65% of Americans are overweight and around one quarter are obese (MA, 2005, p.235).
• By 2000, the percentage of obese American adults had jumped to 31% and the percentage of overweight was at 16% (Roberts, 2008, p.89).
• In 1960, almost no children had been classified as obese; in 2000, the number was one in seven (Roberts, 2008, p.89).
• Each year, complications from obesity and related problems, cause 112,000 premature deaths and account for $75 billion in extra medical costs in the United States. Obesity afflicts a billion people worldwide, or roughly the same number as those who are underfed (Roberts, 2008, p.84).

►*Food-related disease*

• In industrial countries, up to 30% of people reportedly suffer from food-borne diseases each year. In the United States, around 76 million cases of food-borne diseases, resulting in 325,000 hospitalizations and 5,000 deaths, are estimated to occur each year (MA, 2005, p.235).
• Despite dramatic advances in food production, preservation, and packaging, food-borne diseases continue to strike some seventy-six million Americans – one in four – each year, and 325,000 require hospitalization, and of these, 5,000 to 9,000 die (Roberts, 2008, p.177).
• Salmonella sickens well over a million Americans, 600 of them fatally, every year and is the most common cause of food-borne deaths (Roberts, 2008, p.186).
• In 2000 alone, 2.1 million people died from diarrheal diseases, and it is estimated that 70% of the 1.5 billion global episodes of diarrhea are due to biologically contaminated food (MA, 2005, p.235).
• Dietary factors account for about 30% of all cancers in western countries and up to 40% in developing countries (MA, 2005, p.235).
• Atrazine, one of the most widely used herbicides in the United States, is linked to heart and lung congestion, muscle spasms, degeneration of the retina, and cancer, and it remains the second most frequently detected herbicide in drinking-water wells (Roberts, 2008, p.185?).
• Food safety is a huge concern, even in the United States: the FDA currently examines less than 2% of the food shipments entering the country, and even when they are examined, each cargo gets an average of thirty seconds' scrutiny (Roberts, 2008, p.185).
• Half of Americans have a health problem that requires taking a prescription drug every week, and over 100 million Americans have high cholesterol (Campbell, 2006, p.3)
• In 2002, United States health agencies reported some 97,000 cases of organophosphate exposure, more than half of them in children under six (Roberts, 2008, p.218).

► BIODIVERSITY

Documents to Consult

1) The Living Planet Report (LPR)

Web link: http://www.panda.org/about_our_earth/all_publications/living_planet_report/

• The Living Planet Report is the World Wildlife Fund's periodic update on the state of the earth's ecosystems. It details changing trends in global biodiversity and the impact of human resource consumption on the biosphere. The analysis is built around two indicators: The Living Planet Index (LPI), which reflects the health of the world's ecosystems, and the Ecological Footprint, which measures the extent of human demand on these ecosystems. These measures are tracked over several decades to reveal past trends, and then three scenarios explore what might lie ahead.

LPR 2004: http://assets.panda.org/downloads/lpr2004.pdf **OR** http://74.125.45.132/search?q=cache:hugaJM4T5dYJ:assets.panda.org/downloads/lpr2004.pdf+Living+Planet+Report+2004&cd=1&hl=en&ct=clnk&gl=ca
LPR 2006: http://assets.panda.org/downloads/living_planet_report.pdf **OR** http://74.125.47.132/search?q=cache:rbd-75cgHCMJ:assets.panda.org/downloads/living_planet_report.pdf+Living+Planet+Report+2006&cd=1&hl=en&ct=clnk&gl=ca
LPR 2008: http://assets.panda.org/downloads/living_planet_report_2008.pdf **OR** http://74.125.47.132/search?q=cache:OC9R87GlswAJ:assets.panda.org/downloads/living_planet_report_2008.pdf+Living+Planet+Report+2008&cd=3&hl=en&ct=clnk&gl=ca

• The Living Planet Index (LPI) measures overall trends in populations of wild species around the world. It examines the planet's natural wealth of vertebrate species over time and, as such, provides an indicator of the state of the earth's environment.

2) Global Environment Outlook (GEO)

Web link: http://www.unep.org/geo/

• The Global Environment Outlook is an initiative of the United Nations Environment Programme (UNEP) that analyzes environmental change, causes, impacts, and policy responses.

GEO-4 (2007): http://www.unep.org/geo/geo4/report/GEO-4_Report_Full_en.pdf

Chapter 5: Biodiversity: http://www.unep.org/geo/geo4/report/05_Biodiversity.pdf **OR** http://www.eoearth.org/article/Global_Environment_Outlook_(GEO-4)~_Chapter_5

• The chapter on biodiversity (p. 157 – 192) provides a synthesis of the latest information on the state and trends of global biodiversity, linking these trends to the consequences for sustainable development in a number of key areas. The pressures impacting biodiversity are explored along with the associated effects on ecosystem services and human well-being.

3) Millennium Ecosystem Assessment (MA)

Web link: http://www.millenniumassessment.org/en/Reports.aspx

• The MA was initiated in 2001 and aims to assess the consequences of ecosystem change for human well-being and the scientific basis for action toward the conservation and sustainable use of these natural systems. The MA has synthesized the work of more than 1,360 experts across the globe, and their findings are presented in five technical volumes and six synthesis reports.

Current State and Trends Assessment:
http://www.millenniumassessment.org/en/Condition.aspx

• This report assesses the changing conditions of ecosystems and their services, the causes of these changes, and the consequences for human well-being. It considers terrestrial, freshwater and marine systems, and a range of ecosystem services, including food, timber, air quality regulation, nutrient cycling, detoxification, recreation and aesthetic services.

• Chapter 4 describes what is known about biodiversity on a global scale, the nature of biodiversity and its measurement, the main drivers of change, and the observed trends in distribution, variation, and abundance of biodiversity. The focus is on the fundamental aspects of biodiversity that underpin all ecosystem processes and that are valued in their own right. Biodiversity relevant to particular services is documented in chapters 7 through 17, while biodiversity as one element in the management of particular ecosystems for the delivery of services is discussed in Chapters 18 through 27.

Key Issues and Stressors

• Biodiversity is the diversity among living organisms in terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part. It is the diversity of genes, populations, species, communities, and ecosystems (MA, 2005, p.80).
▸ http://www.ciel.org/Biodiversity/WhatIsBiodiversity.html
▸ http://www.wri.org/publication/content/8515
▸ http://www.wri.org/publication/content/8514

• Biodiversity provides the basis for ecosystems and the services they provide, upon which all people fundamentally depend (GEO-4, 2007, p.158). Direct benefits such as food crops, clean water, clean air, and aesthetic pleasures all depend on biodiversity, as does the persistence, stability, and productivity of natural systems (MA, 2005, p.79). Bacteria and microbes transform waste into usable products; insects pollinate crops and flowers; and biologically diverse

landscapes provide inspiration and enjoyment around the world. Such ecosystem services, or the benefits derived from biodiversity, are ultimately dependent on functioning ecosystems (GEO-4, 2007, p.162).

• Biotic factors such as the abundance, distribution, dynamics and functional variation among biodiversity components of ecosystems regulate the magnitude and variability of ecosystem processes, such as production or decomposition. Together, biotic and abiotic factors (e.g. climate) determine the specific properties of an ecosystem, such as its stability, fertility, or susceptibility to invasion. They also determine the type of ecosystem found, such as drylands, forest, or inland waters (MA, 2005, p.80).

• Knowledge of biodiversity is uneven, with strong biases toward the species level, large animals, temperate systems, and components of biodiversity used by people. The most appropriate measures and indicators of biodiversity depend on the value or service being assessed and involve a consideration of components of biodiversity that are involved (populations, genes, etc.) and the service that is being delivered (MA, 2005, p.79).
▸ http://www.cbin.ec.gc.ca/enjeux-issues/indicateurs-indicators.cfm?lang=eng

• Species richness, family richness, and species endemism are all highest in tropical forests (MA, 2005, p.79).
▸ http://www.blueplanetbiomes.org/rainforest.htm

• Most estimates of the total number of species on Earth are between 5 and 30 million and of those only about 2 million have been formally described (MA, 2005, p.79).
▸ http://www.bmb.psu.edu/courses/bisc002_summer04/biodiversity.pdf
▸ http://www.wri.org/publication/content/8202

• In general, human activities have caused a substantial decline in global biodiversity. The key issues and stressors are:

• ***Issue(s)***: Species extinction and endangerment
• ***Stressor(s)***: Direct drivers – unsustainable land use patterns and habitat destruction, overexploitation of resources, invasive species, disease, pollution, climate change; Indirect drivers – size and growth of the human population, overconsumption, economic development, urbanization, industrial agriculture and industrial production in general.

• ***Issue(s)***: Habitat change, loss and degradation
• ***Stressor(s)***: Size and growth of the human population, unsustainable land use patterns, industrial agriculture and industrial production in general, economic and infrastructural development, urbanization.

• ***Issue(s)***: Loss of genetic diversity
• ***Stressor(s)***: Industrial agriculture, economic growth and development, size and growth of the human population

► Trends and Changes in Biodiversity

Key Online Resources:

• http://www.millenniumassessment.org/documents/document.273.aspx.pdf
• http://69.28.176.224/article/Global_Environment_Outlook_(GEO-4)~_Chapter_5#Managing_energy_demand_and_biodiversity_impacts
• http://www.greenfacts.org/en/index.htm
• http://www.wri.org/

• Biodiversity is commonly measured at the levels of **genes**, **species** or **ecosystems**. At each of these levels, measures may represent one or many of: variety, quality and quantity, and distribution. In practice, the relevant measure and attribute depends on the role being assessed, but ultimately, long-term sustainability of many services depends on the maintenance of genetic variability (MA, 2005, p.80).
▸ http://www.wri.org/publication/content/8515
▸ http://www.businessandbiodiversity.org/what_is_measuring.html

• In general, variability is more significant at the genetic and species levels, whereas quantity and distribution are more significant at the population and ecosystem levels. For most ecosystem services, local loss of biodiversity (population reduction or local extinction) is most significant; but for future option values, global loss is the primary consideration (MA, 2005, p.81).

• Over geological time there has been a net excess of speciation over extinction that has resulted in the diversity of life experienced today. However, the high number of recent extinctions suggests that the world might be now facing a **rapid net loss of biodiversity** (MA, 2005, p.104).
▸ http://www.wri.org/publication/content/8184
▸ http://www.wri.org/publication/content/8192
▸ http://www.greenfacts.org/en/global-biodiversity-outlook/index.htm#1

Biogeographic Realms

• There are eight **biogeographic realm**s – large spatial regions within which ecosystems share a broadly similar biota – and they map roughly onto the world's continents. Each realm contains a range of major habitat types or biomes. There is substantial variation in the extent of change and degradation to biodiversity among the biogeographic realms, and they face different combinations of drivers of change (MA, 2005, p.82).
▸ http://www.greenfacts.org/en/biodiversity/figtableboxes/1013-biomes-map.htm

• Among terrestrial realms, net primary productivity and biomass values are highest in the **Neotropics**, which is by far the most species-rich realm, has the greatest number of endemic species, and has more than twice as many freshwater fish families as the Nearctic and Palearctic (MA, 2005, p.82).

• All realms have experienced at least 10% **habitat conversion** and the Indo-Malayan realm has the largest percentage of agricultural and urban lands (54%) (MA, 2005, p.83). In all realms, at least a quarter of the area had been converted to other land uses by 1950 (MA, 2005, p.110).
▸ http://www.greenfacts.org/en/biodiversity/l-3/3-extinction-endangered-species.htm

• Over 25% of the species in Oceania are threatened, more than twice the percentage of any other realm, likely due to high rates of endemism, severe range restriction, and vulnerability to introduced predators and competitors (MA, 2005, p.111).

• Based on species threat levels, we can expect a larger absolute change in biodiversity (measured as expected species extinctions) in the tropical continents, but the highest rates of extinction on tropical islands (MA, 2005, p.111).

Biomes

• There are 14 **biomes,** which represent broad habitat and vegetation types and span across biogeographic realms; they are useful units for assessing global biodiversity and ecosystem services because they stratify the globe into ecologically meaningful and contrasting classes (MA, 2005, p.85).
▸http://www.greenfacts.org/en/biodiversity/figtableboxes/1013-biomes-map.htm

• In general, no marine biome classification scheme has successfully covered the wide range of oceanic depths and addressed the lack of regional uniformity, thus complicating a global assessment of marine biodiversity (MA, 2005, p.86).
▸http://www.wri.org/publication/content/8516

• In over half the biomes, 20-50% of land area has been converted to human use (MA, 2005, p.86). However, patterns of human conversion among biomes have generally remained similar over at least the last century (MA, 2005, p.109).
▸http://www.greenfacts.org/en/biodiversity/l-3/3-extinction-endangered-species.htm

• By 1950 all but two biomes – boreal forests and tundra – had lost substantial natural land cover to croplands and pasture. Mediterranean forests and temperate grassland biomes had experienced the most extensive conversion, with roughly only 30% of native vegetation cover remaining in 1950 (MA, 2005, p.109).
▸http://www.greenfacts.org/en/biodiversity/l-3/3-extinction-endangered-species.htm

• The majority of biomes have been greatly modified by humans. Almost half of the tropical dry forest biome's native habitats have been replaced with cultivated lands. Three other biomes – temperate grasslands, temperate broadleaf forests, and Mediterranean forests – have experienced at least 35% conversion (MA, 2005, p.79).
▸http://www.greenfacts.org/en/biodiversity/l-3/3-extinction-endangered-species.htm

• Coastal ecosystems – coastal lands, areas where freshwater and salt water mix – and nearshore marine areas – are among the most productive yet highly threatened systems in the world (MA, 2005, p.515).
▸http://archive.wri.org/page.cfm?id=799&z=?

Species

• A species may be defined as a group of organisms capable of interbreeding freely with each other but not with members of other species.
▸http://www.wri.org/publication/content/8522

• Using a conservative estimate of 5 million as the total number of species on the planet, and given that studies of the marine fossil record indicate that individual species persisted for periods ranging from 1 to 10 million years, we would expect anywhere between 5 extinctions a year to roughly one extinction every 2 years. Among birds, mammals and amphibians alone, over the past 100 years about 100 species have gone extinct (these groups represent about 1% of described species) (MA, 2005, p.105).
▸http://www.greenfacts.org/en/biodiversity/l-3/3-extinction-endangered-species.htm

• Over the past few hundred years humans may have increased the rate of **species extinction** by as much as three orders of magnitude (MA, 2005, p.79).

• The majority of species among a range of higher taxa are declining in range or number. Species that are increasing have benefited from management interventions such as protection in reserves (MA, 2005, p.79).
▸http://www.greenfacts.org/en/biodiversity/l-3/3-extinction-endangered-species.htm

• The **IUCN 2004 Red List of Threatened Species** is the most extensive global dataset on species richness, based on assessments of 38,047 species. It reveals the following: Levels of threat are lowest among **birds**, with 12% of species threatened http://www.birdlife.org/action/science/species/global_species_programme/red_list.html; 23% of **mammalian species** are globally threatened http://www.iucnredlist.org/mammals/key_findings; 25% of **conifer species** are globally threatened http://intranet.iucn.org/webfiles/doc/SSC/SSCwebsite/Act_Plans/Executive_Summary_Conifers_Action_Plan.pdf; 32% of **amphibian species** are globally threatened http://www.iucnredlist.org/amphibians/key_findings; and 52% of **cycad species** are globally threatened (MA, 2005, p.105).

• Some species represent much more **evolutionary history** than others. If extinctions were randomly distributed across the tree of life, little evolutionary history would be lost. There is a clear trend for higher levels of threat among the larger species, especially those that are flightless, ground-dwelling, particularly vulnerable to alien predators, and edible or economically valuable (MA, 2005, p.105). **Ecological traits** demonstrated to be associated with high extinction risk include high trophic level, low population density, slow life history (i.e. low fertility), and small geographical range (MA, 2005, p.107).
▸http://www.greenfacts.org/en/biodiversity/l-3/3-extinction-endangered-species.htm
▸http://www.endangeredspecieshandbook.org/vanishing_what_traits.php

• 72% of recorded extinctions in five animal groups (mammals, birds, amphibians, reptiles and mollusks) were of **island species**, as they were especially vulnerable to the human-assisted introduction of predators, competitors and diseases (MA, 2005, p.107).

• The majority of threatened species are concentrated in tropical and warm temperate endemic-rich "**hot-spots**." In regional assessments, taxonomic groups with the highest proportion of threatened species tended to be those that rely on freshwater habitats (LPR, 2004, p.7).
▸http://www.biodiversityhotspots.org/Pages/default.aspx

• **Mammal extinctions** are concentrated in the Caribbean and Australia, which in both cases are thought to be second waves of human-induced extinction, following the over-exploitation of the Pleistocene (MA, 2005, p.107).

▸http://www.endangeredspecieshandbook.org/dinos_mammal.php

• **Avian extinctions** are overwhelmingly concentrated on oceanic islands, especially Hawaii and New Zealand. With few exceptions, oceanic island avifaunas have lost most of their endemic species over the last 1,000 years (MA, 2005, p.108).
▸http://74.125.47.132/search?q=cache:9U3aPQygPbEJ:www.birdlife.org/news/news/2006/06/possibly_extinct_paper.pdf+avian+extinction+Hawaii+New+Zealand&cd=14&hl=en&ct=clnk&gl=ca

• The current wave of **amphibian extinction** is concentrated in montane areas from Honduras south to northern Peru, in the Caribbean islands, in eastern Australia, and perhaps in the Atlantic Forest of Southern Brazil (MA, 2005, p.108).
▸http://74.125.47.132/search?q=cache:voI-wc_udcwJ:www.natureserve.org/library/amphibian_fact_sheet.pdf+amphibian+extinction+montane+areas&cd=24&hl=en&ct=clnk&gl=ca

• One consequence of the global patterns of extinction and invasion is biotic **homogenization** – a process whereby species assemblages become increasingly dominated by a small number of widespread, human-adapted species (MA, 2005, p.79). The many species that are declining as a result of human activities tend to be replaced by a much smaller number of expanding species that thrive in human-altered environments (MA, 2005, p.109).
▸http://news.nationalgeographic.com/news/2005/11/1111_051111_globalization.html
▸http://74.125.47.132/search?q=cache:ZuT-_avX-GwJ:www.botany.wisc.edu/waller/publicationspdfs/Odon%26Rooney.pdf+biotic+homogenization&cd=6&hl=en&ct=clnk&gl=ca

• Species extinctions represent the final point in a series of **population** extinctions (MA, 2005, p.105).

Populations

• A population is defined as "a group of individuals of the same species, occupying a defined area and usually isolated to some degree from other similar groups." Populations are dynamic and are continually changing due to variation in births and deaths, immigration and emigration (MA, 2005, p.93).
▸http://www.wri.org/publication/content/8521

• Change in the status of populations provides insight into the status of genetic diversity, as the extinction of a population may represent the loss of unique genetic material, and populations are also the level at which we can best observe the relationship between biodiversity and ecosystem functioning (MA, 2005, p.93).

• Most of the services provided by ecosystems require a large number of local populations. For example, **erosion control** requires a number of local plant populations (MA, 2005, p.93).

• The best available estimate of global trends in populations is the **Living Planet Index (LPI)** (MA, 2005, p.100), which is the average of three separate indices measuring changes in abundance of 555 terrestrial species (mammals, birds, reptiles), 323 freshwater species (vertebrates found in rivers, lakes and wetlands), and 267 marine species (mammals, birds,

reptiles and fish in ocean and coastal ecosystems) around the world. The LPI declined by about 40% from 1970 to 2000 http://www.panda.org/about_our_earth/all_publications/living_planet_report/living_planet_index/, as humanity's global **ecological footprint** grew by 70% over the same time period (LPR, 2004, p.4) http://www.panda.org/about_our_earth/all_publications/living_planet_report/footprint/.

• Even **fisheries** that until recently were reasonably well managed, such as the caviar-producing sturgeons in the Caspian Sea http://www.blueoceaninstitute.org/seafood/species/104.html, and fisheries from relatively intact rivers such as the Mekong in Southeast Asia are rapidly declining http://www.fao.org/docrep/005/y3994e/y3994e13.htm. Major sturgeon populations have already declined by up to 70% (MA, 2005, p.103).

• With the exception of Lake Superior, populations of prey species in the other four **Great Lakes** are all decreasing. Many native predator species, such as lake trout and sturgeon, are found in vastly reduced numbers and have been replaced by introduced species (MA, 2005, p.103).
▸http://www.glsc.usgs.gov/main.php?content=research_lamprey&title=Invasive%20Fish0&menu=research_invasive_fish

Genes and Genomes

• Biodiversity at the within-species level is usually measured by **genetic diversity**, which refers to the variety of alleles and genotypes present in a species. This diversity allows populations to evolve by means of changing relative frequency of different alleles to cope with environmental changes, including new pests, diseases, parasites, competitors and predators, pollution, and global change (MA, 2005, p.93-94).
▸http://www.wri.org/publication/content/8515
▸http://cnx.org/content/m12158/latest/
▸http://www.wri.org/publication/content/8213

• Species lacking genetic diversity usually have difficulty adapting to environmental change and face increased risk of extinction because any environmental change that harms one individual is likely to harm others to a similar extent (MA, 2005, p.94).

• The plentiful genetic diversity in many plant and animal species has been exploited extensively by humans through **artificial selection** to generate numerous breeds specialized in providing various service products such as meat, eggs, milk, fiber, hunting, companion, and aesthetics (MA, 2005, p.94).

• **Genetically-engineered organisms** are a relatively recent phenomenon. They are created through a kind of **biotechnology** that involves direct manipulation of an organism's genes in order to implant it with a favorable trait. The technology has been used in the area of medicine for years and has more recently pervaded the food system.
▸http://www.wri.org/publication/content/8213
▸http://www.safe-food.org/-issue/ge.html
▸http://www.greenpeace.org/international/campaigns/genetic-engineering
▸http://74.125.47.132/search?q=cache:wew2VN8EOgUJ:www.greenpeace.org/raw/content/international/press/reports/executive-summary-monsanto.pdf+%22genetic+engineering%22+Monsanto&cd=6&hl=en&ct=clnk&gl=ca

• The most important direct impacts on biodiversity are habitat destruction, introduction of alien species, overexploitation, disease, pollution, and climate change (MA, 2005, p.96). Many, if not all, of these immediate causal factors are driven primarily by population growth and unsustainable consumption patterns, which lead to increased demand for ecosystem services and energy, as well as increased waste and pollution. Virtually all of the factors leading to the accelerating loss of biodiversity are linked to the development of and increasing demand for energy by society (GEO-4, 2007, p.167). (See ▸ **Biodiversity and Energy**).
▸http://www.wri.org/publication/content/8195

• While disease and climate change will likely play a bigger role in the near future, **habitat change** is currently the most pervasive direct driver. When high levels of human activity and land transformation interface with areas of high species diversity, the result is negative implications for biodiversity. Loss of habitat area through clearing or degradation is currently the primary cause of range declines in species and populations (MA, 2005, p.96).
▸http://www.globalchange.umich.edu/globalchange2/current/lectures/biodiversity/biodiversity.html

• The main causes of species extinction are changing from a historical trend of introductions and overexploitation affecting island species to present-day habitat loss and degradation affecting **continental species** (MA, 2005, p.79).

• The **globalization of agriculture** and **inappropriate agricultural policies** have emerged as the leading indirect drivers influencing the loss of species and ecosystem services. Globalization is leading to major changes in where, how and who produces food and other agricultural commodities. Global market demand for high value commodities such as soybeans, coffee, cotton, oil palm, horticultural crops and biofuels has resulted in substantial habitat conversion and ecosystem degradation. This has replaced diverse small-holder farms with larger **monoculture** enterprises (GEO-4, 2007, p.167).
▸http://www.fao.org/DOCREP/005/Y4671E/y4671e0c.htm

• The rapid rate of population decline in tropical species reflects the loss of natural habitat to cropland or pasture in the tropics between 1950 and 1990, **agricultural conversion** being the main driver. In temperate ecosystems, the conversion of natural habitat to farmland took place before 1950, when populations of temperate species are likely to have declined, before stabilizing. The majority of natural forests and grasslands in temperate regions was lost prior to 1970, whereas in the tropics the loss of natural habitat is a relatively recent and on-going phenomenon (LPR, 2006, p.8).
▸http://earthtrends.wri.org/features/view_feature.php?theme=7&fid=34

• Temperate, tropical, and flooded grasslands, Mediterranean woodlands, temperate broadleaf forests, and tropical dry forests have all lost more than half their estimated original habitat cover. The biomes least transformed by agricultural conversion are boreal forests and tundra (LPR, 2006, p.8).
▸http://www.greenfacts.org/en/biodiversity/l-3/3-extinction-endangered-species.htm

• **Habitat fragmentation** – the clearing of natural vegetation for agriculture or road construction (MA, 2005, p.96), for example – typically accompanies land use change and endangers species by isolating populations in small patches of remaining habitat, rendering them more susceptible

to genetic and demographic risks as well as natural disasters (p.110). Overall, Europe has experienced the most human-caused fragmentation and South America the least (p.96).
▸http://www.greenfacts.org/en/biodiversity/l-3/4-causes-desertification.htm#4p1
▸http://www.globalchange.umich.edu/globalchange2/current/lectures/biodiversity/biodiversity.html

• Species that disappear most quickly from fragmented terrestrial landscapes often have large area requirements and are primary-habitat specialists that avoid the modified habitats. Some species are also particularly vulnerable to edge-effects, where the edge of the habitat is less suitable for them (MA, 2005, p.96).
▸http://www.for.gov.bc.ca/hfd/pubs/docs/En/En21.pdf

• 60% of the world's large rivers are highly or moderately fragmented. Waterfalls, rapids, riparian vegetation, and wetlands are some of the habitats that disappear when rivers are regulated or impounded. Fragmentation has also affected 90% of the water volume in these rivers. The only remaining large free-flowing rivers in the world are found in the tundra regions of North America and Russia and in smaller coastal basins in Africa and Latin America (MA, 2005, p.97).
▸http://maps.grida.no/go/graphic/level-of-river-fragmentation-and-flow-regulation

• Humans have introduced animals and plants to new areas for thousands of years, but with improvements in transportation and the globalization of trade, the **introduction of non-native species** to new habitats or ecosystems has greatly increased. Invasive alien species may threaten native species as direct predators or competitors, as vectors of disease, or by modifying the habitat or altering native species dynamics (MA, 2005, p.97).
▸http://oceania.wetlands.org/NEWS/tabid/469/articleType/ArticleView/articleId/1773/Default.aspx

• Invasive alien species have been a major cause of homogenization and extinction, especially on islands and in freshwater habitat, in which the introduction of alien species is the second leading cause of extinction (MA, 2005, p.97).
▸http://www.greenfacts.org/en/biodiversity/l-3/4-causes-desertification.htm#4p2
▸http://74.125.47.132/search?q=cache:WDexQv1yF4MJ:ec.europa.eu/environment/nature/invasivealien/docs/ias_discussion_paper.pdf+Invasive+alien+species+freshwater+habitat&cd=7&hl=en&ct=clnk&gl=ca

• **Estuarine systems** are among the most invaded ecosystems in the world, with exotic introduced species causing major ecological changes. Often introduced organisms change the structure of coastal habitat by physically displacing native vegetation (MA, 2005, p.520).

• **Globalization** has facilitated the **spread of pathogens**; and pathogens are assisted by an increase in the conditions under which pathogens thrive, such as very high population densities in domestic plants or animals, or species living in suboptimal conditions due to rapid environmental change. When diseases become established in a population, **chronic population declines** increase the species' vulnerability to extinction (MA, 2005, p.98).

• Over the last decade, numerous pathogens introduced directly or indirectly by human activities have caused large-scale declines in several wildlife species (e.g. lion population in Tanzania) (MA, 2005, p.98).

▸http://www1.umn.edu/umnnews/Feature_Stories2/Lions_caught_in_the_crossfire.html

• Infectious disease is currently a serious problem in **aquaculture**, both for farmed fish and wild stocks. When infected farmed fish escape from aquaculture facilities, they can transmit these parasites and diseases to wild stock (e.g. Atlantic salmon) (MA, 2005, p.98).
▸http://www.ncrac.org/NR/rdonlyres/2C878A92-8D58-4DCB-AAE0-C88A2F3A1152/96237/FS115Biosecurity.pdf

• Among the most commonly **overexploited species** or groups of species are marine fish and invertebrates, trees, animals hunted for bushmeat (wild meat taken from the forests by locals for income or subsistence), and plants and animals harvested for the medicinal and pet trade (MA, 2005, p.98).
▸http://www.greenfacts.org/en/biodiversity/l-3/4-causes-desertification.htm#4p3

• Most industrial **fisheries** are either fully or overexploited http://www.greenfacts.org/en/fisheries/. The world's demand for food and animal feed over the last 50 years has resulted in such strong fishing pressure that the biomass of some targeting species, such as the larger, higher-valued species and those caught incidentally (by-catch) http://www.greenpeace.org/international/campaigns/oceans/bycatch, has been reduced over much of the world by a factor of 10 relative to levels prior to the onset of industrial fishing (MA, 2005, p.481).

• Unsustainable levels of **hunting** are believed to be of great concern for a large number of target species (e.g. elephants, gorillas) (MA, 2005, p.98).
▸http://www.worldwatch.org/node/124

• Modern **climate change** may have been a contributing factor in the extinction of at least once species, the **golden toad**, and evidence suggests strong and persistent effects of such change on both plants and animals, evidenced by substantial changes to the phenology and distribution of many taxa (MA, 2005, p.99).
▸http://news.bbc.co.uk/2/hi/science/nature/328776.stm

• Certain species or communities will be more prone to extinction than others due to the direct or underlying effects of climate change, and risk of extinction will increase especially for those species that are already vulnerable (i.e. either have limited climatic ranges, restricted habitat requirements, reduced mobility, or isolated or small populations) (MA, 2005, p.99).
▸http://www.nies.go.jp/social/aim/india0210/papers/ipccreports/workinggroup2/218.htm

• Some scenarios indicate that as many as 30% of species will be lost as a consequence of climate change (MA, 2005, p.99).

Illustrative Facts & Statistics

▸*Species endangerment and extinction*

• At a global level, nearly 850 species have been recorded as becoming extinct or at least extinct in the wild since 1500 (MA, 2005, p.105).
• Approximately 50% of extinctions over the past 20 years occurred on continents (MA, 2005, p.79).

• Rates of species extinction are 100 times higher than the baseline rate shown by the fossil record (GEO-4, 2007, p.162).
• 12 of the 27 documented global extinctions over the past 20 years have been plants (MA, 2005, p.104).
• It is estimated that in the last few decades, more than 20% of the world's 10,000 described freshwater fish species have become threatened or endangered or are listed as extinct (MA, 2005, p.563).
• Between 12-52% of species with well-studied higher taxa are threatened with extinction, according to the IUCN Red List (MA, 2005, p.79).
• It is estimated that 16 million populations are being lost per year in tropical forests alone (MA, 2005, p.100).
• The terrestrial species index indicates that populations of terrestrial species declined by approximately 30% between 1970 and 2000; the temperate species declined by more than 10% while the tropical species fell by about 65%; the grassland, savannah, desert and tundra species index declined by more than 60%; temperate grassland species populations declined by more than 10% while tropical grassland species populations by about 80% over the same period (LPR 2004, p.6). Over three-quarters of known species are terrestrial (MA, Inland, p.11).
• The freshwater species index fell by about 50% from 1970 to 2000; temperate freshwater species declined by about 50% from 1970 to 2000 while tropical freshwater species declined by about 50% from 1970 to 1995; 91 species of freshwater fish are listed as extinct in the wild in the 2000 IUCN Red List (LPR, 2004, p.8).
• The marine species index indicates that populations of 267 species of marine mammal, bird, reptile, and fish declined by about 30% between 1970 and 2000; the average trophic level of fish catches in the Northwest and Western Central Atlantic declined by about 12% and in the Northeast Atlantic by about 3% between 1970 and 1994 (LPR, 2004, p.10).
• From 1970 to 2000, the global ecological footprint grew by about 70 per cent and the world's human population grew by 65 per cent. (LPR, 2004, p.4).
• According to NatureServe, based on an assessment of 20,439 species, one-third of United States' flora and fauna appears to be of conservation concern (MA, 2005, p.106).
• At the global level, 41% of known waterbird populations are in decline, 36% are stable, and 19% are increasing (MA, 2005, p.100).
• Shorebirds are declining worldwide: of populations with a known trend, 48% are declining in contrast to just 16% increasing (MA, 2005, p.565).
• IUCN (2003) reports 130 freshwater species of aquatic insects, 275 species of freshwater crustacean, and 420 freshwater mollusks as globally threatened (MA, 2005, p.562).
• Of the 200 species of freshwater turtles, 51% of the species with known status have been assessed as globally threatened, and the number of critically endangered freshwater turtles more than doubled in the four years preceding 2000 (MA, 2005, p.564).
• The recent Global Amphibian Assessment shows that nearly one-third (1,856 species) of the world's amphibian species are threatened with extinction, a large portion of which (964 species) are freshwater (MA, 2005, p.564).
• Population trends are available for 260 species of cycads (288 species in total). Of these, 79.6% are declining and 20.4% are stable, none are increasing (MA, 2005, p.104).
• On some sub-Antarctic islands, exotic species account for more than 50% of vascular plant diversity, and exotic grasses may outcompete native species (MA, 2005, p.724).

• 20 species of Arctic plants are considered globally threatened, 21 species of Arctic mammal are considered globally threatened (MA, 2005, p.724).

►*Habitat change, loss and degradation*

• Globally, over 50% of the temperate broadleaf and mixed forest biome and nearly 25% of the tropical rain forest biome have been fragmented or removed by humans, as opposed to only 4% of the boreal forest (MA, 2005, p.96).
• Tropical forest cover decreased by about 7% from 1990 to 2000 while temperate forest cover increased by about 1%
• Agricultural land is expanding in about 70% of countries, declining in 25%, and roughly static in 5% (MA, 2005, p.96).
• Approximately 35% of mangrove area has been lost or converted at the rate of 2,834 km^2 per year. Coastal wetland loss in some places has reached 20% annually (MA, 2005, p.515).
• During the past 20 years, the number of protected areas grew by over 22,000 and currently stands at more than 115,000 (GEO-4, 2007, p.166).
• Roughly 12% of the world's land surface is included within some kind of protected area, but less than 1% of the world's marine ecosystems are protected, with the Great Barrier Reef and the northwestern Hawaiian islands making up one-third the area of all marine protected areas (GEO-4, 2007, p.166).
• As of 2003, around 1,500 dams over 60 meters are planned or under construction around the world (e.g. 46 dams are planned for the Yangtze River in China) (MA, 2005, p.97).
• The number of dams in the world has increased from 5,000 in 1950 to more than 45,000 at present. These reservoirs provide water for 30-40% of irrigated agriculture and generate 19% of global electricity supplies (MA, 2005, p.560).
• The cost of mangrove degradation in Pakistan is US$20 million in fishing losses, US$500 000 in timber losses, and US$1.5 million in feed and pasture losses (regulating provisioning services) (GEO-4, 2007, p.161).
• The cost of the Newfoundland cod fishery collapse is US$2 billion and tens of thousands of jobs (provisioning service) (GEO-4, 2007, p.161).

►*Value of biodiversity*

• The trade in wild plants and animals and their derivatives is estimated at nearly $160 billion (GEO-4, 2007, p.161).
• The economic value of the annual world fish catch is US$58 billion (provisioning service) (GEO-4, 2007, p.161).
• The economic value of anti-cancer agents from marine organisms is up to US$1 billion/year (provisioning service) (GEO-4, 2007, p.161).
• The economic value of the global herbal medicine market was roughly US$43 billion in 2001 (provisioning service) (GEO-4, 2007, p.161).
• The economic value of honeybees as pollinators for agriculture crops is US$2–8 billion/year (regulating service) (GEO-4, 2007, p.161).
• The economic value of coral reefs for fisheries and tourism is US$30 billion/year (cultural service) (GEO-4, 2007, p.161).

► Biodiversity and Population

• Further pressure on biodiversity will result from the continuing increase in the global human population, which is predicted to reach 8 billion by 2025. All will require access to food and water, leading to an unavoidable increase in stresses on natural resources (GEO-4, 2007, p.168). The land use requirements of our growing population translate into very high levels of habitat conversion (MA, 2005, p.96). The increased infrastructure required to support such a global population of more than 8 billion people will likely have particular effects on biodiversity in the future (GEO-4, 2007, p.168).
▸ http://74.125.95.132/search?q=cache:a1Aegssyhr8J:www.unep.org/geo/geo4/media/fact_sheets/Fact_Sheet_7_Biodiversity_and_Human_Wellbeing.pdf+biodiversity+pressure+human+population&cd=15&hl=en&ct=clnk&gl=ca

• The increased need for agricultural production to feed the population will likely be met largely by commercial **intensification** ▸http://www.fao.org/docrep/007/j0902e/j0902e03.htm, with negative consequences for the genetic diversity of agricultural crops and livestock. **Extensification** will also help to meet the need, with a predicted additional 120 million hectares required by 2030 in developing countries, including lands of high biodiversity value (GEO-4, 2007, p.168) http://www.eoearth.org/article/Global_Environment_Outlook_(GEO-4)~_Chapter_5.

Illustrative Facts & Statistics

• From 1970 to 2000, the terrestrial index fell by about 30%, the freshwater index by about 50%, and the marine index by about 30%. During this same time period, the global ecological footprint grew by about 70% and the world's human population grew by 65% (LPR, 2004, p.4)

► Biodiversity and Land & Soil

• The greatest threat to biodiversity is the **destruction and fragmentation of habitat**, most notably deforestation (Harper, 2008, p.57). **Forest** ecosystems are extremely important refuges for terrestrial biodiversity. Biodiversity is essential for the continued health and functioning of these ecosystems, and underpins the various services that forests provide (MA, 2005, p.587).
▸ http://www.wri.org/publication/content/8150
▸ http://www.wri.org/publication/content/8152

• **Tropical deforestation** is the greatest eliminator of species, followed by the **destruction of coral reefs and wetlands**. Tropical forests alone cover only about 5% of the earth's surface, but contain more than 50% of all terrestrial species (Harper, 2008, p.57).
▸ http://earthobservatory.nasa.gov/Features/Deforestation/

• **Modern agriculture** is another major cause of declining biodiversity. **Cropland expansion** and **intensification** contribute to the destruction and fragmentation of habitat, but modern agriculture reduces biodiversity in a much more direct and intentional way, through the increasingly prevalent cultivation of **monoculture** crops.

• People have historically used over 7,000 plant species for food, now reduced to largely twenty species around the world, mainly wheat, corn, millet, rye, and rice. These plants are now **selectively bred** into a few strains with greatly reduced genetic variability (Harper, 2008, p.57).
▸ http://www.newcastle.edu.au/Resources/Research%20Centres/TFI/Publications/26%20Simon%20Lubinski.pdf

• A variety of human actions have reduced biodiversity, including overfishing, commercial hunting and poaching, predator and pest control, and invasive species (Harper, 2008, p.57).

Illustrative Facts & Statistics

• IUCN estimates that 12.5% of the world's species of plants, 44% of birds, 57% of amphibians, 87% of reptiles, and 75% of mammals are threatened by forest decline (MA, 2005, p.601).
• Between 1990 and 2005, deforestation in the tropics continued at an annual rate of 130 000 km^2 (GEO-4, 2007, p.82).
• It is estimated that the current rate of species disappearance from tropical forests is about 4,000 to 6,000 species per year, which is about 10,000 times greater than the natural "background" rate of extinction before humans arrived (Harper, 2008, p.57).
• In Sri Lanka, farmers cultivated some 2,000 varieties of rice as late as 1959. Today only five principal varieties are grown. India once had 30,000 varieties of rice; today most production comes from only 10 (Harper, 2008, p.57).

► Biodiversity and Food

Key Online Resources:

• http://69.28.176.224/article/Global_Environment_Outlook_(GEO-4)~_Chapter_5#Managing_energy_demand_and_biodiversity_impacts

• Biodiversity provides a **diverse range of edible plants and animal species** that have been and continue to be used as **wild sources of food**, including plants (leafy vegetables, fruits, and nuts), fungi, bushmeat, insects and other arthropods, and fish (including mollusks and crustaceans as well as finfish). The capacity of ecosystems to provide wild food sources is generally declining, as natural habitats worldwide are under increasing pressure and as wild plant and animal populations are exploited for food at unsustainable levels (MA, 2005, p.219).
http://www.undp.org/biodiversity/biodiversitycd/bioImport.htm

• There are several dimensions to biodiversity in **cultivated systems**. These systems contain cultivated or **"planned" biodiversity**, the diversity of plants sown as crops and animals used for livestock or aquaculture (MA, 2005, p.756). Since the origins of agriculture, farmers – and, more recently, professional plant and animal breeders – have developed a diverse range of varieties and breeds that contain a high level of genetic diversity within the major species used for food (p.214). There are many breeds of livestock that originate from a single species and for some crop species there are thousands of distinct varieties (p.214). Of some 270,000 known species of higher plants about 10,000–15,000 are edible, and about 7,000 of them are used in agriculture (GEO-4, 2007, p.171).
▸http://www.pfaf.org/leaflets/edible_uses.php

• Agricultural biodiversity also includes the biodiversity that **supports agricultural production** through pollination, nutrient cycling, and pest control (MA, 2005, p.756). For example, earthworms and other soil fauna and microorganisms, together with plant root systems, maintain soil structure and facilitate nutrient cycling, and insects, spiders, and other arthropods often act as natural enemies of crop pests (p.759).
▸http://www.grida.no/publications/rr/food-crisis/page/3569.aspx

•The most direct impact of food provision on biodiversity has been through **habitat conversion**, which typically leads to reductions in native biodiversity. The major locations of agricultural expansion have frequently coincided with remnants of natural habitats with high biodiversity value (MA, 2005, p.221).
▸http://www.greenfacts.org/en/biodiversity/l-3/3-extinction-endangered-species.htm

• The rapid rate of population decline in tropical species reflects the loss of natural habitat to cropland or pasture in the tropics between 1950 and 1990, **agricultural conversion** being the main driver. In temperate ecosystems, the conversion of natural habitat to farmland took place before 1950, when populations of temperate species are likely to have declined, before stabilizing. The majority of natural forests and grasslands in temperate regions was lost prior to 1970, whereas in the tropics the loss of natural habitat is a relatively recent and on-going phenomenon (LPR, 2006, p.8).
▸http://earthtrends.wri.org/features/view_feature.php?theme=7&fid=34

• The **globalization of agriculture** and **inappropriate agricultural policies** have emerged as the leading indirect drivers influencing the loss of species and ecosystem services. Globalization is leading to major changes in where, how and who produces food and other agricultural commodities. Global market demand for high value commodities such as soybeans, coffee, cotton, oil palm, horticultural crops and biofuels has resulted in substantial habitat conversion and ecosystem degradation. This has replaced diverse small-holder farms with larger **monoculture** enterprises (GEO-4, 2007, p.167).
▸http://www.fao.org/DOCREP/005/Y4671E/y4671e0c.htm

• The steep decline in grassland species coincides with a rise in the **grazing land** component of the ecological footprint; the grazing land footprint doubled between 1970 and 2000, while the forest footprint increased by about 30% (LPR, 2004, p.6).

• Over the past two decades, many of the world's most important agricultural crops have lost **genetic diversity** due to changes in agricultural practices (GEO-4, 2007, p.165). As larger and larger areas are planted with a smaller and smaller number of crop varieties – most major staple crops are grown in **monoculture** – and as livestock systems are intensified, many varieties and breeds are at risk of being lost in production systems and are increasingly found only in ex situ collections (MA, 2005, p.214). The continued loss of genetic diversity of such crops may have major implications on food security
▸http://www.fao.org/SD/EPdirect/EPre0040.htm

• Increased **globalization** threatens to diminish the varieties that are traditionally used in most agricultural systems. Despite its crucial importance in supporting societies, agriculture remains the largest (indirect) driver of **genetic erosion**, species loss and conversion of natural habitats around the world (GEO-4, 2007, p.171).
▸http://www.fao.org/docrep/x0262e/x0262e02.htm

• **Genetically-engineered organisms (GEOs)**, **or living modified organisms (LMOs),** are a relatively recent phenomenon. They are created through a kind of **biotechnology** that involves direct manipulation of an organism's genes in order to provide new attributes in different crops and breeds (MA, 2005, p.173). The technology has been used in the area of medicine for years and has more recently pervaded the food system. Breeders promise varieties of staple crops tailored to the constraints of future food production: plants bred to tolerate heat and drought and salty soils, for example. **Monsanto** is one of the leading players in the booming transgenic market. Critics warn that transgenic plants and animals may contain novel substances that could harm humans or intermingle with and destroy native species (Roberts, 2008, p.240). There are also concerns about how the technology will affect poor people, whose livelihoods depend primarily on traditional low input agricultural practices. Increased research, monitoring and regulation are needed to ensure these negative impacts are avoided as this technology is developed (MA, 2005, p.173).
▸http://www.wri.org/publication/content/8213
▸http://www.safe-food.org/-issue/ge.html
▸http://www.greenpeace.org/international/campaigns/genetic-engineering
▸http://74.125.47.132/search?q=cache:wew2VN8EOgUJ:www.greenpeace.org/raw/content/international/press/reports/executive-summary-monsanto.pdf+%22genetic+engineering%22+Monsanto&cd=6&hl=en&ct=clnk&gl=ca

• Food provision affects wild biodiversity through its demand for **water and nutrients**, and through the **pollution of ecosystems** with pesticides and excess nutrients. Irrigated agriculture is a major user of fresh water, which, together with the direct loss of wetland habitats from conversion and the pollution of inland waters with excess nutrients, has a major negative impact on inland water biodiversity (MA, 2005, p.221).

• Of the **pesticides** in widespread use, the most important effects on biodiversity are from persistent organic pollutants, since these have effects on large spatial and temporal scales (MA, 2005, p.221).
▸http://www.cep.unep.org/publications-and-resources/marine-and-coastal-issues-links/persistent-organic-pollutants-pops-and-pesticides

• Changes in production practices and loss of diversity in agro-ecosystems can undermine the ecosystem services necessary to sustain agriculture. For example, **pollinator diversity** and numbers are affected by habitat fragmentation, agricultural practices, the land-use matrix surrounding agricultural areas, and other land-use changes. Although some of the crops that supply a significant proportion of the world's major staples do not require animal pollination (such as rice and maize), the decline of pollinators has long-term consequences for those crop species that serve as crucial sources of micronutrients and minerals (such as fruit trees and vegetables) in many parts of the world (MA, 2005, p.173).
▸http://www.fao.org/Ag/Magazine/0512sp1.htm

• Genetic erosion, loss of local populations of species, and loss of cultural traditions are often intimately intertwined. While rates of genetic erosion are poorly known, they generally accompany the transition from traditional to commercially developed varieties. In crop and livestock production systems throughout the developing world, genetic erosion reduces smallholder farmer options for mitigating impacts of environmental change and reducing vulnerability, especially in marginal habitats or agricultural systems that are predisposed to extreme weather conditions (such as arid and semi-arid lands of Africa and India) (MA, 2005, p.173).

• Meeting global food needs poses increasing challenges, and will require either **intensification** or extensification to increase agricultural productivity. Intensified systems tend to be dominated by only a few varieties. This approach is usually associated with higher levels of inputs, including technology, agrochemicals, energy and water use. The latter three, at least, have serious negative impacts on biodiversity (GEO-4, 2007, p.173).
▸http://www.fao.org/docrep/007/j0902e/j0902e03.htm

• **Extensification** relies on lower inputs, and generally on more land being used, often through habitat conversion. In many parts of the world, agricultural extensification involves converting more land for the cultivation of major commodities such as soybeans (Latin America and the Caribbean), oil palm and rubber (Asia and the Pacific), and coffee (Africa, Latin America and Asia), and it is exacerbated by the emergence of new markets for export (GEO-4, 2007, p.173).
▸http://www.eoearth.org/article/Global_Environment_Outlook_(GEO-4)~_Chapter_5

• There is the trend of **growing more trees** in agricultural landscapes for a wide variety of purposes. Trees stabilize and enhance soils, contribute in themselves to biodiversity, but also play host to a variety of birds and insects. Management practices can have major impacts on such

biodiversity and the services it provides for nutrient cycling, pest control, and pollination, with positive spillovers for agricultural production (MA, 2005, p.222)
▸http://www.agric.wa.gov.au/PC_92523.html

• The **deep sea** is increasingly recognized as a major reservoir of biodiversity, comparable to the biodiversity associated with tropical rain forests and shallow-water coral reefs. It has been estimated that the number of species inhabiting the deep sea may be as high as 10 million (GEO-4, 2007, p.163).
▸http://74.125.95.132/search?q=cache:49ApREhIy-MJ:www.greenpeace.org/raw/content/canada/en/documents-and-links/publications/high-seas-bottom-trawl-fisheri.pdf+fishing+biodiversity+trawling&cd=1&hl=en&ct=clnk&gl=ca

• **Fishing** is one of the major direct anthropogenic forces that has an impact on the structure, function, and biodiversity of the oceans today (MA, 2005, p.489). **Overexploitation** has been implicated as the leading threat to the world's marine fishes and has led to a decline in the average trophic level of catches. High-impact fishing (including bottom trawling, long-lining, gill netting, and dynamite fishing) causes damage to the biodiversity of sensitive habitats, such as cold-water reefs, tropical coral reefs, and seamounts, and to migratory seabirds (p.222). The biggest threat to deep-sea **coral reefs** comes from **trawling activities** (p.489).
▸http://news.nationalgeographic.com/news/2004/02/0219_040219_seacorals.html

• Most industrial **fisheries** are either fully or overexploited (MA, 2005, p.481). http://www.greenfacts.org/en/fisheries/. The FAO's *State of the World's Fisheries and Aquaculture* Report shows that the percentage of underexploited stocks has declined steadily since 1974, while the proportion of stocks exploited beyond maximum sustainable yield levels has increased steadily. If these data are representative of fisheries as a whole, they indicate an overall declining trend in spawning stock biomass for commercially important fish species since 1974 (MA, 2005, p.103).
▸http://www.fao.org/docrep/009/a0699e/A0699E00.HTM

• The world's demand for food and animal feed over the last 50 years has resulted in such strong fishing pressure that the biomass of some targeting species, such as the larger, higher-valued species and those caught incidentally (**by-catch**; e.g. small cetaceans such as dolphins) http://www.greenpeace.org/international/campaigns/oceans/bycatch, has been reduced over much of the world by a factor of 10 relative to levels prior to the onset of industrial fishing (MA, 2005, p.481).

• In addition, with fleets now targeting the more abundant fish at **lower trophic levels**, it would be expected that global catches should be increasing rather than stagnating or decreasing, as is actually occurring (MA, 2005, p.482).
▸http://www.seafriends.org.nz/issues/fishing/pauly1.htm

• Since 1970, **aquaculture** has become the fastest-growing food production sector in the world, increasing at an average rate of 9.2% per year – an outstanding rate compared to the 2.8% rate for land-based farmed meat products (MA, 2005, p.558).
▸http://www.umbi.umd.edu/comb/research-programs/recirculating/marine-aquaculture.php

• **Infectious disease** is currently a serious problem in aquaculture, both for farmed fish and wild stocks. When infected farmed fish escape from aquaculture facilities, they can transmit these

parasites and diseases to wild stock (e.g. Atlantic salmon), as well as disrupt the native aquatic life through **invasion damage** http://oceania.wetlands.org/NEWS/tabid/469/articleType/ArticleView/articleId/1773/Default.aspx. Human reliance on farmed fish and shellfish is significant and growing (MA, 2005, p.98).

• Along with conversion to agriculture, salt pans, and urban and industrial development, an important cause of **loss of mangrove area** is the aquaculture industry, typically through conversion of mangrove wetlands to shrimp or prawn farms (MA, 2005, p.521).
►http://www.fao.org/fishery/topic/14894/en

• Annual fish stock assessments are conducted in Canada's **Great Lakes** for commercially important salmonoid species (e.g. lake trout and Pacific salmon) and for their prey species (such as rainbow smelt and lake herring). With the exception of Lake Superior, populations of prey species in the other four lakes are all decreasing. Many native predator species, such as lake trout and sturgeon, are found in vastly reduced numbers and have been replaced by introduced species (MA, 2005, p.103).
►http://www.glsc.usgs.gov/main.php?content=research_lamprey&title=Invasive%20Fish0&menu=research_invasive_fish

• Longer-term catch and status information is available for Pacific and Atlantic salmon in North America, fisheries of the Rhine and Danube Rivers in Europe, and fisheries of the Pearl River in China; all have declined to just a fraction of their former levels due to overexploitation, river alteration, and habitat loss, putting some of these species at serious risk of extinction (MA, 2005, p.103).

• Even fisheries that until recently were reasonably well managed, such as the caviar-producing sturgeons in the Caspian Sea http://www.blueoceaninstitute.org/seafood/species/104.html, and fisheries from relatively intact rivers such as the Mekong in Southeast Asia are rapidly declining http://www.fao.org/docrep/005/y3994e/y3994e13.htm. Major sturgeon populations have already declined by up to 70% (MA, 2005, p.103).

Illustrative Facts & Statistics

►*Wild food sources*

• Historically, many terrestrial species have become extinct due to hunting, and there are currently 250 mammal species, 262 bird species, and 72 amphibian species listed as threatened due to overexploitation for food (MA, 2005, p.222)
• Some 40% of known species of fish inhabit inland waters – more than 10,000 species out of 25,000 species globally – and about 25-30% of all vertebrate species diversity is concentrated close to or in inland waters (MA, 2005, p.561).
• It is estimated that the fishing industry has eliminated 90% of the large fish in the ocean (WWI, 2008, p.63).

►*Agriculture*

• Of the estimated 10,000 – 15,000 edible plants known, only 7,000 have been used in agriculture and less than 2% are deemed to be economically important at a national level. Only

30 crops provide an estimated 90% of the world population's calorific requirements, with wheat, rice, and maize alone providing about half the calories consumed globally (MA, 2005, p.213).
• About 7,000 species of plants and several hundred species of animals have been used for human food at one time or another. Some indigenous and traditional communities use 200 or more species for food (MA, 2005, p.219).
• Globally, there are over 6,500 breeds of domesticated animals. A third of these are under near-future threat of extinction due to their very small population size. Over the past century, it is believed that 5,000 domesticated animal and bird breeds have been lost (MA, 2005, p.758).
• Of the estimated 15,000 species of mammals and birds, only some 30-40 (0.25%) have been used for food production, with fewer than 14 species accounting for 90% of global livestock production (MA, 2005, p.214).
• FAO estimates that in Europe 50% of livestock breeds that existed 100 years ago have disappeared (MA, 2005, p.214).
• The global production of genetically modified crops (mainly maize, soybean and cotton) was estimated to cover more than 900,000 km^2 in 2005 (GEO-4, 2007, p.173).
• Only 14 animal species currently account for 90% of all livestock production, and only 30 crops dominate global agriculture, providing an estimated 90% of the calories consumed by the world's population (GEO-4, 2007, p.171).
• Over three-quarters of the major world crops rely on animal pollinators. Approximately 73% of the world's cultivated crops are pollinated by bee species, 19% by flies, 6.5% by bats, 5% by wasps, 5% by beetles, 4% by birds, and 4% by butterflies and moths. The services of wild pollinators are estimated to be worth $4.1 billion a year to United States agriculture alone (MA, 2005, p.759).

►*Aquaculture and fishing*

• Some 40% of known species of fish inhabit inland waters – more than 10,000 species out of 25,000 species globally – and about 25-30% of all vertebrate species diversity is concentrated close to or in inland waters (MA, 2005, p.561).
• 75% of the world's fish stocks are fully or overexploited (GEO-4, 2007, p.164).
• 28% of fish stocks assessed have declined to levels below which a maximum sustainable yield can be taken, a further 47% require stringent management to prevent decline into a similar situation (MA, 2005, p.103).
•WWF (2002) suggest that 30-50% of the deep-water corals along the Norwegian coast have already been lost due to bottom trawling, marine pollution, and oil and gas extraction (MA, 2005, p.489).
• It is estimated that approximately 20% of the world's known coral reefs have been destroyed and a further 20% have been badly degraded (MA, 2005, p.523).

►*Biotechnology*

• Transgenic crops account for more than a quarter of total corn acreage and more than half of soybean acreage worldwide (Roberts, 2008, p.240).
• Herbicide-tolerant seeds now account for half of all corn and more than 93% of all soybean acreage in the United States (Roberts, 2008, p.243)
• Monsanto owns 90% of the transgenic traits sold worldwide (Roberts, 2008, p.260).

► Biodiversity and Energy

Key Online Resources:

• http://69.28.176.224/article/Global_Environment_Outlook_(GEO-4)~_Chapter_5#Managing_energy_demand_and_biodiversity_impacts

• Virtually all of the factors leading to the accelerating loss of biodiversity are linked to the development of and increasing demand for energy by society. Of particular importance are the high levels of per capita energy use in the **developed world**, and the potential growth in energy use in the large emerging economies (GEO-4, 2007, p.167).

• Many forms of energy are the result of a service provided by ecosystems, now or laid down in the form of **fossil fuels** far in the past (GEO-4, 2007, p.176). Biodiversity – based energy sources include both traditional **biomass** and modern **biofuels.** The former is relatively inexpensive and accessible, and therefore has a vital role to play in supporting **poor populations**. If these resources are threatened, as is the case in some countries with extreme **deforestation**, poverty reduction will be an even greater challenge. Use of fuelwood can cause deforestation, but demand for fuelwood can also encourage tree planting, as occurs, for example, in Kenya, Mali and several other developing countries (p.177).

• Society's growing requirements for energy are resulting in significant changes in the very ecosystems that supply the fuel (GEO-4, 2007, p.176); the rapid increase in demand for energy has profound impacts on biodiversity at two levels: impacts from the **production and distribution of energy**, and those resulting from the **use of energy** (p.167).

• Exploration for hydrocarbons, pipeline construction, uranium and coal mining, hydroelectric dam construction, harvesting for fuel wood and, increasingly, biofuel plantations can all lead to significant biodiversity loss, both on land and at sea (GEO-4, 2007, p.167).

• Demand for energy is projected to grow by at least 53% by 2030. Energy from biomass and waste is projected to supply about 10% of global demand until 2030. However, this assumes that adequate fossil fuels will be available to address the majority of the increase in demand, and this may not be realistic. Energy-related **carbon dioxide emissions** are expected to increase slightly faster than energy use by 2030 (GEO-4, 2007, p.176).

• Energy use has impacts at local, national and global levels. **Pollution** from burning fossil fuels and the associated effects of **acid rain** have been a problem for European and North American forests, lakes and soils. While emission controls in Europe and North America led to a reversal of acidification trends, there is now a risk of acidification in other areas of the world, particularly Asia (GEO-4, 2007, p.176).

• Use of **thermal and nuclear power** results in waste disposal problems, as do solar cells, which can result in soil contamination by heavy metals. **Desertification** in the Sahel and elsewhere in sub-Saharan Africa has been linked in part to fuel demand from biomass. Indirect effects of energy use include both overexploitation of natural resources and greatly facilitated spread of invasive alien species through global trade, both made possible through cheap and easily-available energy for transport (GEO-4, 2007, p.176).

• **Climate change** results largely from energy use. As a result of climate change, species ranges and behavior are changing, with consequences for human well-being, including changing patterns of human disease distribution, and increased opportunities for invasive alien species. Species most likely to be affected include those that already are rare or threatened, migratory species, polar species, genetically impoverished species, peripheral populations and specialized species, including those restricted to alpine areas and islands. Some amphibian species extinctions have already been linked with climate change, and a recent global study estimated that 15–37% of regional endemic species could be committed to extinction by 2050 (GEO-4, 2007, p.176).

• **Climate change** is also having impacts at ecosystem scales. Mediterranean-type ecosystems found in the Mediterranean basin, California, Chile, South Africa and Western Australia are expected to be strongly affected by climate change (GEO-4, 2007, p.177).

► Biodiversity and Waste & Pollution

• Pollution impacts biodiversity in several ways. It results in **higher mortality rates**, **nutrient loading**, and **acidification**. In addition, it potentially leads to decreased resilience and productivity of ecosystem services, loss of coastal protection due to degradation of reefs and mangroves, eutrophication, and anoxic water bodies leading to loss of fisheries (GEO-4, 2007, p.169).
▸ http://www.epa.gov/bioindicators/aquatic/pollution.html

• Increasing levels of chemical pollution and marine debris in the marine environment are likely having impacts on most marine mammal species through ingestion of pollution and floating plastic debris or entanglement. Various health problems in marine mammals have been associated with high levels of accumulated pollutants that have been found in many species of predatory marine mammals (MA, 2005, p.526).

Illustrative Facts & Statistics

• Thousands of turtles die from eating or becoming entangled in non-degradable debris each year (MA, 2005, p.526).
• Over 90% of land in the EU-25 countries in Europe is affected by nitrogen pollution greater than the calculated critical loads. This triggers eutrophication, and the associated increases in algal blooms and impacts on biodiversity, fisheries, and aquaculture (GEO-4, 2007, p.169).

► Biodiversity and Climate Change

• Climate change culminates in **species extinctions**, expansion or contraction of species ranges, and changes in species compositions and interactions. In addition, it potentially leads to changes in resource availability, the spread of diseases to new ranges, changes in the characteristics of protected areas, and changes in the resilience of ecosystems (GEO-4, 2007, p.169).
►http://www.panda.org/about_our_earth/aboutcc/problems/impacts/species/
►http://www.sciencedaily.com/releases/2008/10/081013142545.htm

• Modern climate change may have been a contributing factor in the extinction of at least once species, the **golden toad**, and evidence suggests strong and persistent effects of such change on both plants and animals, evidenced by substantial changes to the phenology and distribution of many taxa (MA, 2005, p.99).
►http://news.bbc.co.uk/2/hi/science/nature/328776.stm

• Certain species or communities will be more prone to extinction than others due to the direct or underlying effects of climate change, and risk of extinction will increase especially for those species that are already vulnerable (MA, 2005, p.99). Such species include those that are already rare or threatened, those with limited climatic ranges, restricted habitat requirements, or reduced mobility; isolated or small populations, migratory species, polar species, genetically impoverished species, peripheral populations and specialized species, including those restricted to alpine areas and islands. Some amphibian species extinctions have already been linked with climate change, and a recent global study estimated that 15–37% of regional endemic species could be committed to extinction by 2050 (GEO-4, 2007, p.176).
►http://www.eoearth.org/article/Global_Environment_Outlook_(GEO-4)~_Chapter_5

• Climate change contributes to **habitat change** and is becoming the dominant driver of change in biodiversity, particularly in **vulnerable habitats**. Under climate change, endemic montane, island, and peninsula species are especially vulnerable; and coastal habitats such as mangroves, coral reefs and coastal wetlands are especially at risk from resulting sea level rise http://www.ipcc.ch/ipccreports/tar/wg2/292.htm. Both recent empirical evidence and predictive modeling studies suggest that climate change will increase population losses. In some regions there may be an increase in local biodiversity – usually as a result of species introductions, the long-term consequences of which are hard to foresee (MA, 2005, p.79).

• Of all the world's ecosystems, **coral reefs** may be the most vulnerable to the effects of Climate Change. Warming seawater triggers coral bleaching, which sometimes causes coral mortality. Rising CO_2 levels change the pH of the water, reducing calcium carbonate deposition (reef-building) by corals. Climate change also facilitates the **spread of pathogens** leading to the spread of coral diseases. One estimate suggests that all current coral reefs will disappear by 2040 due to warming sea temperatures (MA, 2005, p.523).
►http://www.panda.org/about_our_earth/aboutcc/problems/impacts/coral_reefs/
►http://www.marinebiology.org/coralbleaching.htm

• **Polar marine ecosystems** are very sensitive to climate change, because a small increase in temperature changes the thickness and amount of sea ice on which many species depend. The livelihoods of indigenous human populations living in subarctic environments and subsisting on

marine mammals are threatened, since the exploration of marine resources is directly linked to the seasonality of sea ice (GEO-4, 2007, p.169).

• Climate change will also have impacts on biodiversity through changes in **species distributions and relative abundances** as their preferred climates move towards the poles and higher altitudes, leaving those endemic to polar and high mountain regions most at risk (GEO-4, 2007, p.168).
▸http://www.panda.org/about_our_earth/aboutcc/problems/impacts/species/

Illustrative Facts & Statistics

• Some scenarios indicate that as many as 30% of species will be lost as a consequence of climate change (MA, 2005, p.99).
• By 2000, 27% of the world's coral reefs had been degraded in part by increased water temperatures, with the largest single cause being the climate-related coral bleaching event of 1998 (GEO-4, 2007, p.177).