DEDICATED TO MAKING A DIFFERENCE

Agricultural Ecosystems

Facts and Trends

World Business Council for Sustainable Development

IUCN

Foreword

The rapid increase in food prices in many countries has led to substantial media attention on agriculture. We hope that providing this Facts & Trends publication will help uncover some key trade-offs that mean extremely challenging decisions for governments, farmers, consumers and industry. This publication does not attempt to cover everything there is to know about agricultural ecosystems. Rather, it tries to present well-documented facts and figures to better understand the challenges facing the sustainable management of agricultural ecosystems.

We have used existing data from the World Resources Institute (WRI), the World Bank, the Food and Agriculture Organization of the United Nations (FAO), the Intergovernmental Panel on Climate Change (IPCC) and many other sources. We present it here in a simplified and condensed format to stimulate forward thinking and ongoing dialogue between business, civil society, government and other stakeholders.

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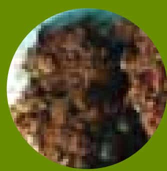


1. The context

Agriculture is a key motor of the global economy. It supports the livelihoods and subsistence of the largest number of people worldwide and is vital to rural development and poverty alleviation, as well as food and non-food production.

The main challenge for the agricultural sector is to simultaneously: secure enough high-quality agricultural production to meet demand; conserve biodiversity and manage natural resources; and improve human health and well-being, especially for the rural poor in developing countries.

As such, agricultural management needs to not only further increase the productivity of existing farmland to meet demand by adapting good and efficient management practices, but also embrace the three pillars of sustainability:

Environmental	Social	Economic
▪ Support biodiversity and ecosystem services ▪ Sustain productive agriculture, avoiding encroachment onto natural ecosystems ▪ Manage natural resources well.	▪ Foster healthy populations with the greatest chances of realizing their development potential ▪ Improve livelihoods by providing food, feed, fiber and fuel of high quality.	▪ Provide income to rural communities ▪ Increase the value of agricultural produce throughout the value chain.

There is no single, globally applicable sustainable management solution for agriculture. This is because agricultural practices depend on site-specific variables, such as climate, ecology, geography, demography, affluence and regulation. Nonetheless, sustainability principles can be applied across different management systems.

Key trends and questions that will influence the future of agriculture include:

Population growth

World population is projected to exceed 9 billion people in 2050 – how will we produce enough food to feed them?

Increasing urbanization, decreasing workforce

In 2007, for the first time in history, the urban population exceeded the rural one – how can shrinking rural populations feed increasing urban ones, as well as themselves?

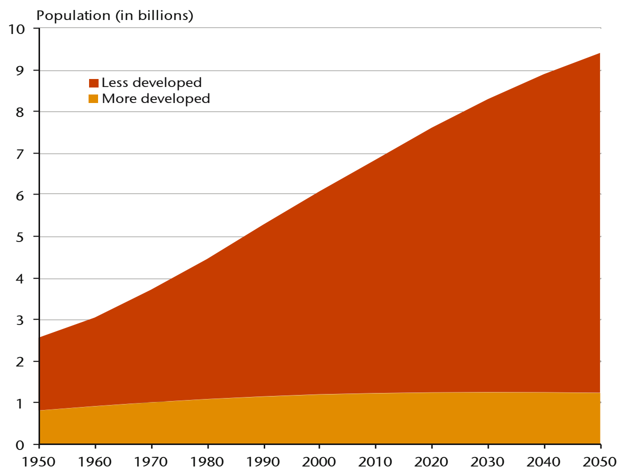


Figure 1: World population 1950 – 2050[1]

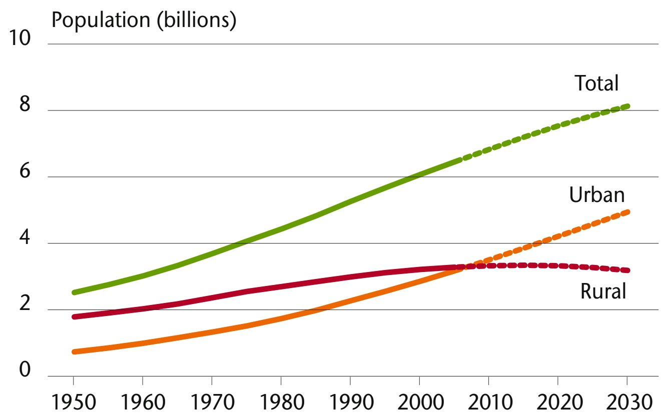


Figure 2: World's population shifting to the cities[2]

<Agriculture is the cultivation of land for the advantage of selected species including agricultural crops, livestock, tree crops and grazing lands.>

- As of 2006, an estimated 36% of the world's workers were employed in agriculture,[3] down from 42% in 1996. But it still remains the most common occupation.
- Agriculture's contributions to development differ around the world. The World Bank describes three types of countries:[4]

Type	% GDP growth contributed by agriculture	% of poor in rural areas
Agriculture-based countries e.g., sub-Saharan Africa	32%	70%
Transforming countries e.g., China, India, Indonesia	7%	82%
Urbanized countries e.g., Latin America, Europe	<5%	45%

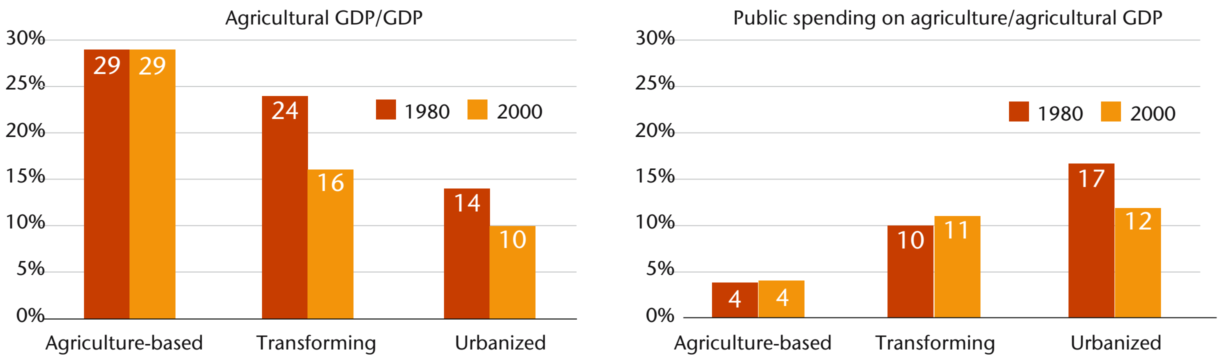


Figure 3: Public spending on agriculture is lowest in agriculture-based countries[5]

Shifting consumer patterns

As wealth increases so does per capita calorie intake. The demand for a more diverse diet that includes animal protein such as meat and milk products requires more land to produce. What role do consumers play when choosing their diet? Do consumers need to be encouraged to have a vegetarian diet?

- Meat consumption in China has more than doubled in the last 20 years and it is projected to double again by 2030.[6]
- Consumer concerns about food safety, the origin of produce and environmental impacts are also driving improvements in food quality throughout the global agri-food value chain.
- Diet changes in richer countries towards increasing consumption of fruit and vegetables contribute to generating less calories per hectare. For instance China is gradually abandoning field crops – such as cereals – to produce vegetables and fruit; it has now become the world's largest producer of vegetables and apples.
- Producing meat, milk, sugar, oils and vegetables typically requires more water than producing cereals.[8]
  - Average water use also differs greatly between feed-based meat production and grazing systems.
  - Food production to satisfy a person's daily dietary needs takes about 3,000 liters of water – a little more than one liter per calorie.[9]

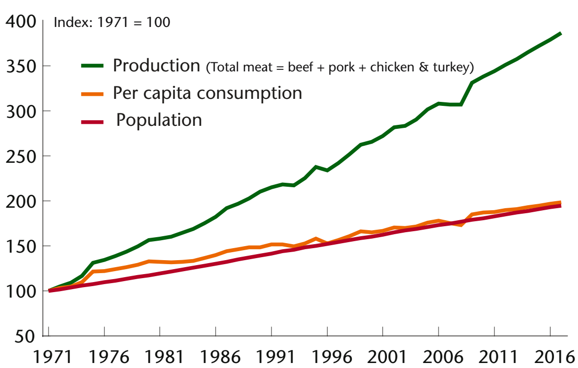


Figure 4: Global meat – production, per capita consumption and population[7]

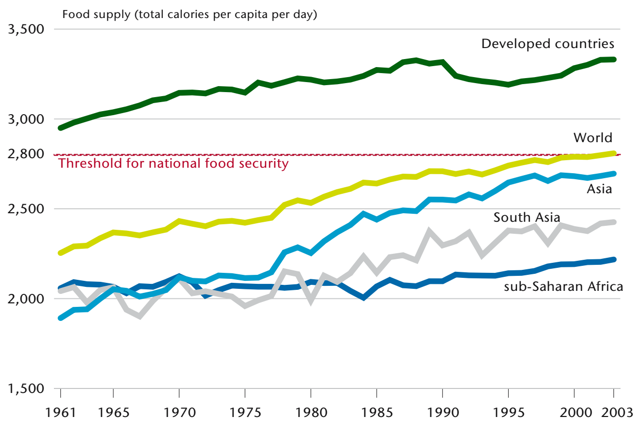


Figure 5: Increase in nutritional status since the 1960s; developing countries still lag behind[10]

2. Biodiversity and ecosystem services

Agricultural biodiversity (the biodiversity associated with agricultural ecosystems) is indispensable for plant stability, and therefore sustaining crop production, food security and livelihoods for everyone.

- The productivity of agricultural ecosystems depends on numerous species, such as soil micro-organisms, pollinators, predators of agricultural pests and the genetic diversity of the crops and livestock.
- Agricultural ecosystems serve as important habitats for many wild plant and animal species.
  - Wild species found in agricultural lands and nearby forests, wetlands and other natural habitats play a critical role in food security for many low-income farmers and rural people, as animal feed, fuel, raw materials for processing, and to provide supplemental food during "lean" periods before the harvest or in crop failures.
  - Wild species are sometimes used to provide valuable genetic resources, for instance for certain plant breeding. When preserved, these can help meet future food and livestock production challenges, including adapting to climate change.
  - The first gene banks to preserve plant biodiversity were created by breeders in the 1930s. Today, more than 6 million samples of different crops are currently maintained in collections in some 1,500 gene banks around the world.[11] For example, the Millennium Seed Bank in the UK contains over one billion seeds.
- Ecosystem services provided by ecosystems other than agriculture, such as clean water, carbon regulation, nutrient cycling or soil maintenance, are equally important to sustaining agricultural ecosystems.

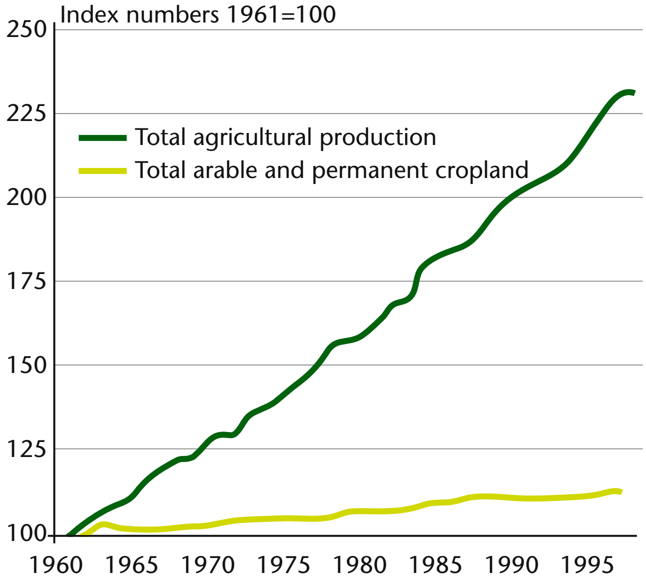


Figure 6: Trends in agricultural production and cropland area, 1961-1998[12]

<An ecosystem is a dynamic complex of plant, animal and micro-organism communities and the non-living environment interacting as a functional unit.[13] >

<Biological diversity – or biodiversity – means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.[14] >

<Ecosystems Services are the benefits people obtain from ecosystems, including the "goods and services of nature".[15] >

As such, biodiversity supports ecosystem services

✔ Good practice

Sustaining agricultural ecosystems

- Increased demand for food and non-food crops such as biofuels requires careful management of biodiversity and agricultural ecosystems to ensure environmental health.
- Agricultural producers can conserve and manage biodiversity and ecosystem services[16] by:
  - Producing more output with less land. Goklany[17] estimates that if the same amount of the same food were to be produced today, with the yield levels of 1961, this would require an additional 970 million hectares, or more than the total land area of the United States. It is estimated that some 30-60% of yield increases are due to improved crop varieties made possible by plant breeding.[18]
  - Establishing or maintaining wildlife habitats and diverse land cover on farms. These can provide: year-round vegetative cover to protect soils and rainfall infiltration, natural management of agricultural inputs and wastes to minimize pollution, protection of plant communities along river margins and wetlands, networks of connected wildlife corridors, non-crop habitats such as hedges, beetle banks, cover and refuge for pollinators.
  - Using farm management systems and stewardship approaches that improve ecosystem health.
- Experience has demonstrated that agricultural management systems and environmental stewardship are investments by farmers. Incentives and rewards – such as market driven certification systems – encourage the development and use of sustainable production systems. A broad range of successful sustainable agricultural production initiatives already exist, but they need to be scaled-up, promoted and actively encouraged.

Two examples of management systems that focus on sustainability

Integrated crop management (ICM) balances the economic, social and environmental dimensions of sustainable farming and sets a framework of good agricultural practices. These practices comprise a wide portfolio of measures such as soil and nutrient management, crop choice and protection, biodiversity enhancement, and water, energy and landscape management.

Conservation agriculture uses minimum tillage to improve soil structure. This reduces soil erosion and improves water and nutrient retention. The increase in organic matter under this management system has been seen to increase the number of soil organisms and small mammals.

<Tillage is the practice of plowing or cultivating the soil to create arable land. Today, crops can be grown for several years without any tillage, often facilitated through the use of herbicides or herbicide tolerant crops. This practice, called minimum or no-till farming, reduces costs and fossil fuel use through avoidance of plowing while reducing soil erosion and improving water and nutrient retention. The possibility of adopting reduced tillage practices is determined by the different soil types.>

3. Climate

Climate determines to a great extent which crops can grow in an agricultural ecosystem (e.g., precipitation, temperature, winds). Climate change can have both positive and negative effects on agriculture. The challenge for agriculture is to adapt fast enough to a changing climate, and to shift production practices to reduce and preferably mitigate the "carbon footprint" of the food production system.

- Climate change can directly affect agricultural systems, for example by influencing the types of crops that can be grown, or indirectly impact agriculture by affecting the biodiversity and ecosystem services on which agriculture depends, e.g., increased spread of invasive species.
- Agriculture was responsible for 14% of global greenhouse gas (GHG) emissions in 2000.[19] Agriculture emissions result from several sources, including fertilizers (directly through the volatilization of gases from fields and indirectly through other pathways), livestock (methane is a waste product of digestion by ruminants), wetland rice cultivation (anaerobic decomposition in flooded rice fields produces methane), manure management methods and burning of savannah and agricultural residues, each producing methane, CO_2 and/or N_2O.
- Despite large annual exchanges of CO_2 between the atmosphere and agricultural lands, the net flow is estimated to be roughly balanced, if land-use change is excluded.
- The conversion of forest or long-term grassland to agriculture is the major source of CO_2 emissions from the agricultural sector through a 50% loss of soil carbon. Subsequent plowing reduces soil carbon too. Further, the permanent conversion of forests to agriculture, primarily in developing countries, accounts for an estimated 80% of CO_2 emissions through land-use change and forestry.[20]

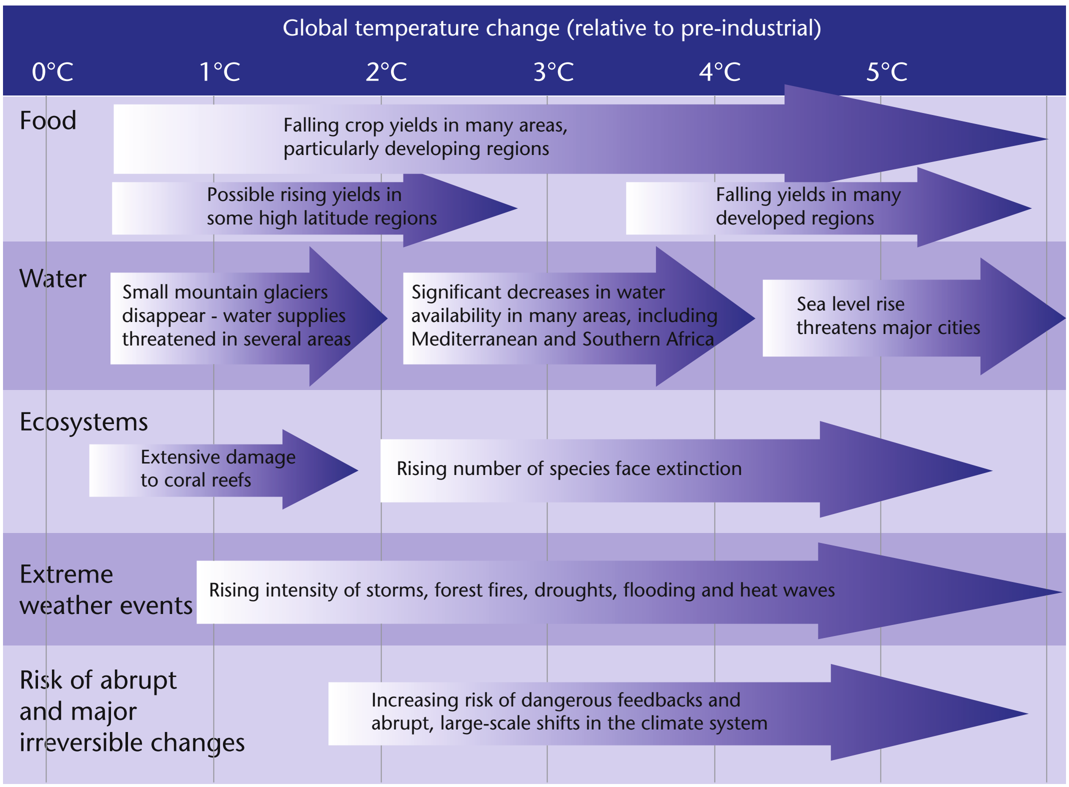


Figure 7: Projected impacts of climate change[21]

✔ Good practice

Mitigation, sequestration and adaptation

- Mitigation of agricultural GHG emissions can be carried out through practices such as integrated crop management and conservation agriculture (or minimum tillage).
  - However other practices that can also mitigate emissions include improved water management in rice production, set-asides, agro-forestry (that can encourage perennial grasses, palms and trees in farming systems), as well as improved livestock and manure management.[22]
  - Bioenergy and biomaterials *(see also Chapter 6. Future challenges)* can help reduce GHG emissions, but there are a number of issues that must be considered and managed on a case-by-case basis. Care must be taken regarding land resources, net carbon emissions, and the food vs. fuel debate, biodiversity conservation and waste management. Choosing the right policy and technologies over the next decade will significantly enhance the GHG and energy savings of these renewable resources.
- Soil also plays an important role as a carbon "sink" through its capacity to sequester and store carbon.[23]
  - The soils of the world contain more carbon than the combined total amounts occurring in vegetation and the atmosphere.[24]
  - Depending on climatic conditions and suitability, minimum or no-tillage conservation agriculture can increase the soil carbon sequestration of existing farmland by 0.1 to 1 ton per hectare per year.
  - Additionally, carbon dioxide emissions are reduced by over 50% through the reduced use of fossil fuels in plowing.[25]

- Adaptation strategies are critical in agriculture in order to adjust to new environmental conditions such as higher temperatures, increased risk of droughts and other extreme weather events.
  - In general, the more diverse the agricultural ecosystem is (e.g., increased biodiversity), the higher its ability to adapt. Plant breeding is seen as an effective way to adapt to climate change.

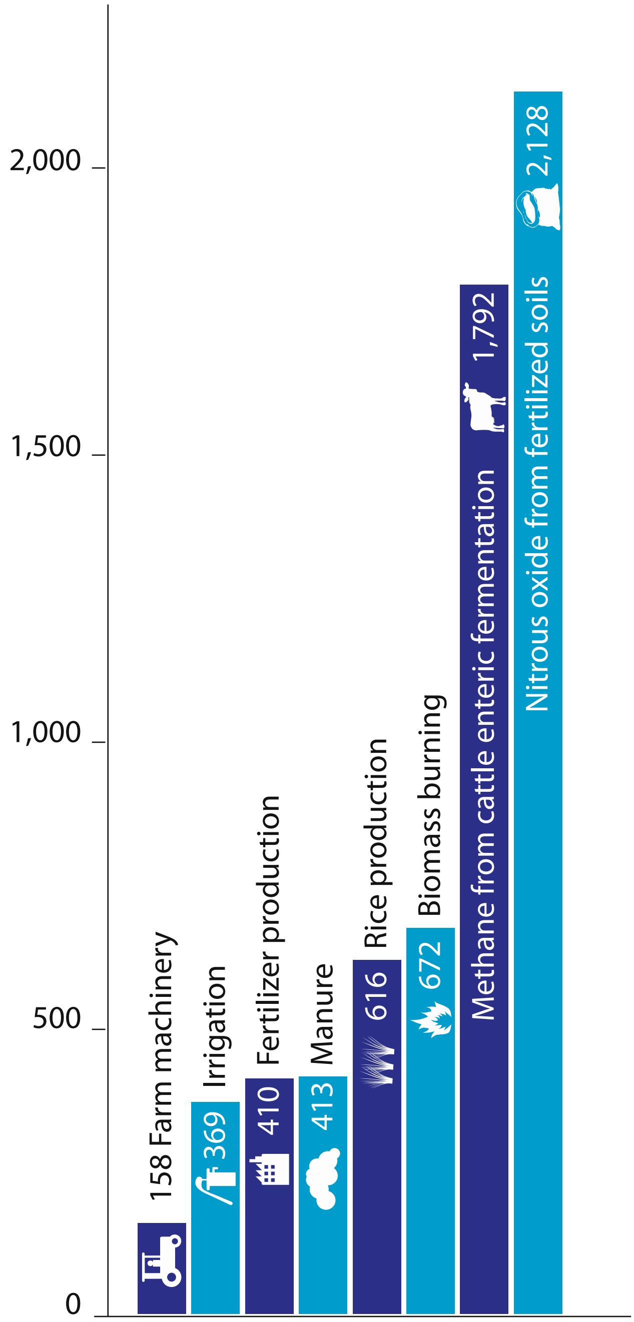


Figure 8: Sources of agricultural greenhouse gases, excluding land-use change[26]

4. Water

Agriculture uses 70% of total global "blue water" withdrawals, most of which is for irrigation.

In developing countries, as much as 80-90% of freshwater is used for agriculture. However, industrial and domestic use is competing and growing relative to that for agriculture.

- Only 17% of all cropland is irrigated, but this land provides 30-40% of the world's food production.[27]
- Over 60 % of the world's irrigated area is in Asia, most of which is devoted to the production of rice.[28]
- Some 60% of all rainfall is "green water" – water that never reaches a river or aquifer but replenishes soil moisture; thereafter it evaporates from the soil or is transpired by plants.[29]

Climate change is affecting water availability through droughts and water scarcity in regions such as the Mediterranean basin and southern Europe, South and Central America, western Asia, and the subtropical regions of Africa and Australia.[30]

- In addition, higher temperatures increase evapotranspiration and lower soil moisture levels.

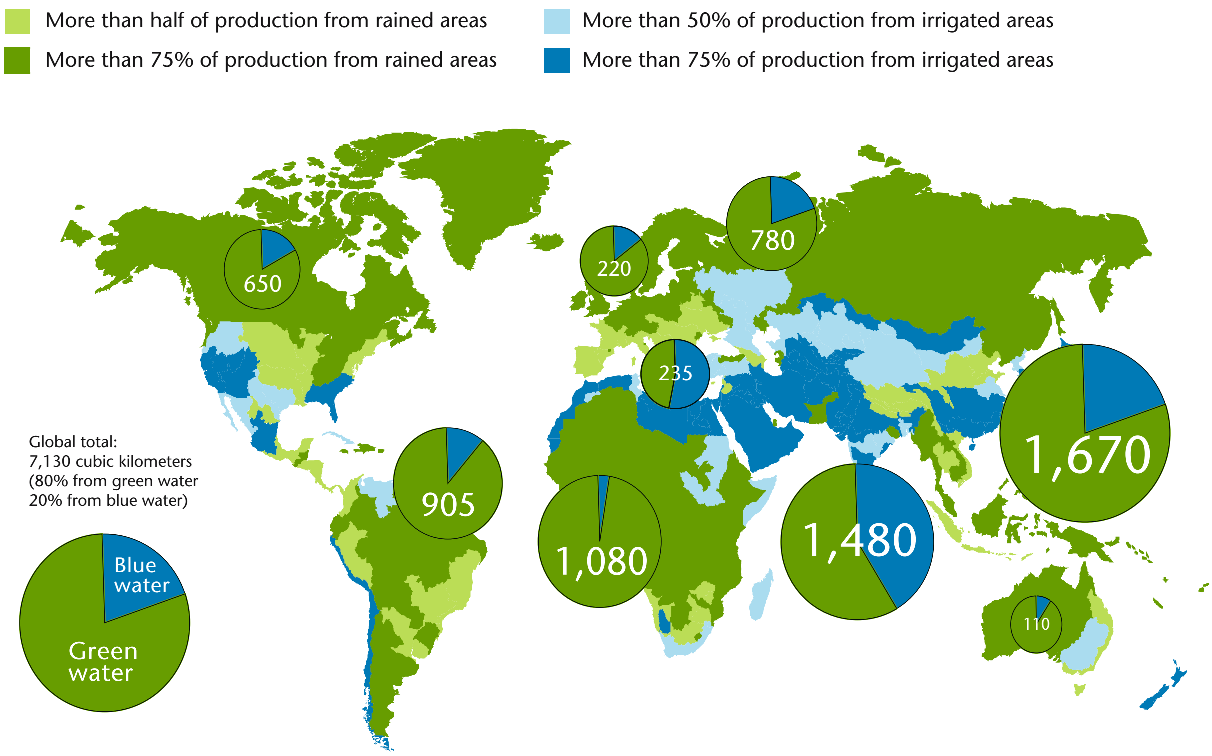


Figure 9: Food crop evapotranspiration from rain and irrigation[31]

<Blue water is the liquid water flowing in rivers, lakes and groundwater aquifers.>
<Green water is water in soils and vegetation in the form of soil moisture and evaporation.[32]>

✔ Good practice

Improving water use and watershed management

- Agricultural practices that can contribute to improved water availability include:
  - Using more efficient irrigation systems (e.g., drip irrigation)
  - Moving towards more precision agriculture
  - Boosting rainfed agriculture, upgrading rainfed systems, as well as waste- and rainwater management
  - Using conservation agriculture
  - Using more water-efficient crops and assessing soil type
  - Maintaining year-round vegetative cover of soils
  - Using intercropping to maximize uptake of water and crop productivity in the agroecosystem.
- Well-managed watersheds can have a positive impact on the challenges faced by agriculture.
- One of the most important impacts of nitrogen and phosphorus on the environment is on water quality *(see also Chapter 5. Land, soil and nutrients).*
  - Inappropriate or excessive use of nitrogen and phosphorus are factors in eutrophication, an over-enrichment in chemical nutrients of waterways that can trigger excessive growth of algae and related impacts.[33]
  - Physical movements of lost soil can have major impacts on water quality through sedimentation and the release of nitrogen and phosphorus.[34]

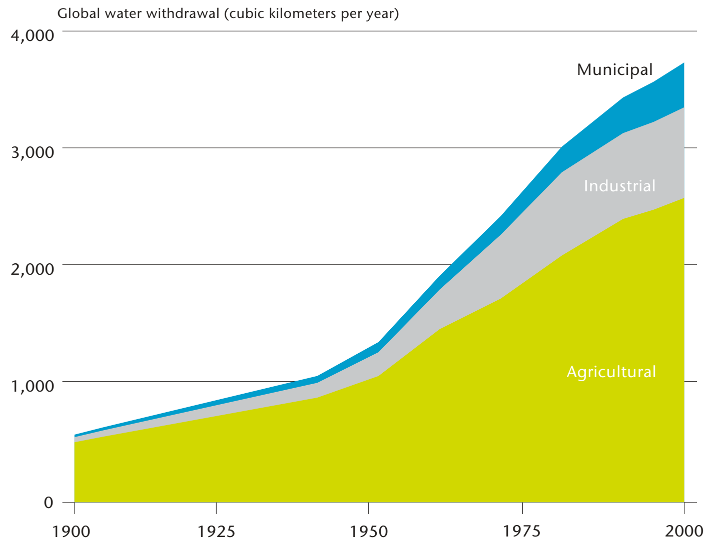


Figure 10: Sectoral competition is increasing for blue water withdrawals for human uses[35]

- Rainfed agriculture has the potential to meet present and future food demand through increased productivity, given appropriate water management.
  - Integrated water management for multiple uses such as domestic, crop production, aquaculture, agro-forestry and livestock can improve the productivity of water and reduce environmental impacts.

5. Land, soil and nutrients

Land, soil and nutrients are key factors that are often linked in agricultural management practices. For example, the health of an agricultural ecosystem depends on the way the land is used, the quality of the soil and the input and output of nutrients.

- In the last 40 years, the area of global agricultural land has grown by 10%, but in per capita terms agricultural land area has been in decline. This trend is expected to continue as land is increasingly limited and the population grows.[36]
  - South Asia's total agricultural area has remained constant for more than 20 years at approximately 223 million hectares.[37]
- Human-induced soil degradation has been rising since the 1950s. About 85% of agricultural land contains areas judged to have been degraded by erosion, salinization, compaction or soil compression, nutrient depletion, biological degradation or pollution.
  - Soil degradation has already reduced global agricultural productivity by 13% in the last 50 years,[38] especially of agricultural land in Africa and Central America and pastures in Africa.[39]
- Each year, 12 million hectares – or enough land to grow 20 million tons of grain – are lost to desertification (extreme land degradation, usually in arid or semi-arid areas).[40] This is about the size of Greece or Nepal that is lost each year, and represents enough grain to feed over 6 million people per year.
- Although some types of degradation are irreversible, many can be prevented or reversed by, for example, adding nutrients to nutrient-depleted soil, rebuilding topsoil through soil amendments, reestablishing vegetation, or buffering soil acidity.
  - The practicality of rehabilitating degraded landscapes depends on the costs relative to the value of the output or environmental benefits expected.

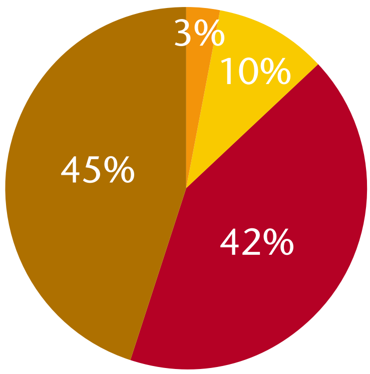


Figure 11: Land affected by human-induced soil degradation[41]

✔ Good practice

Land, soil and nutrient management

- Soil provides the physical support and mediates the availability of water for plants. It provides a habitat for many species of bacteria, fungi, protozoa and animals that contribute to a variety of important environmental functions such as decomposition, recycling of nutrients, breakdown of pollutants and storage of essential elements.
- Soil erosion is a major threat to the long-term sustainability of agricultural production. There are many means to control erosion through physical and vegetation barriers, various types of passive and active terracing on slopes, and good cultivation and soil management practices.
- Agricultural productivity depends on the availability of nutrients. The three required in greatest quantities are nitrogen, phosphorus and potassium.
- Any nutrient – from organic or mineral sources – not absorbed by crops can be lost to the environment.
- Good management practices include:
  - Maximizing on-farm recycling of nutrients
  - Matching nutrient applications precisely to crop needs, and at the right moment (weather changes)
  - Planting varieties that absorb nutrients efficiently
  - Physical or vegetative barriers to movement of nutrients out of the field.

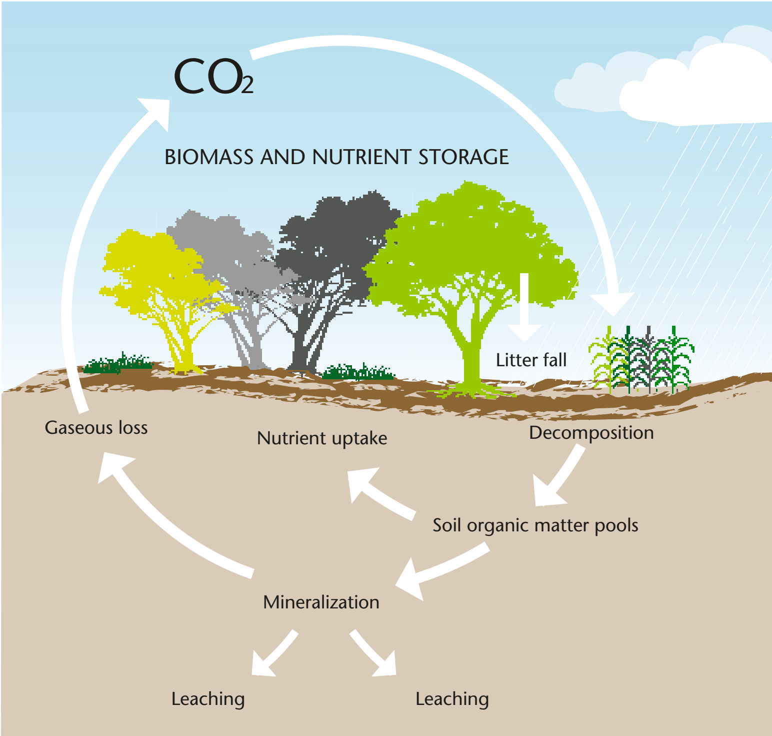
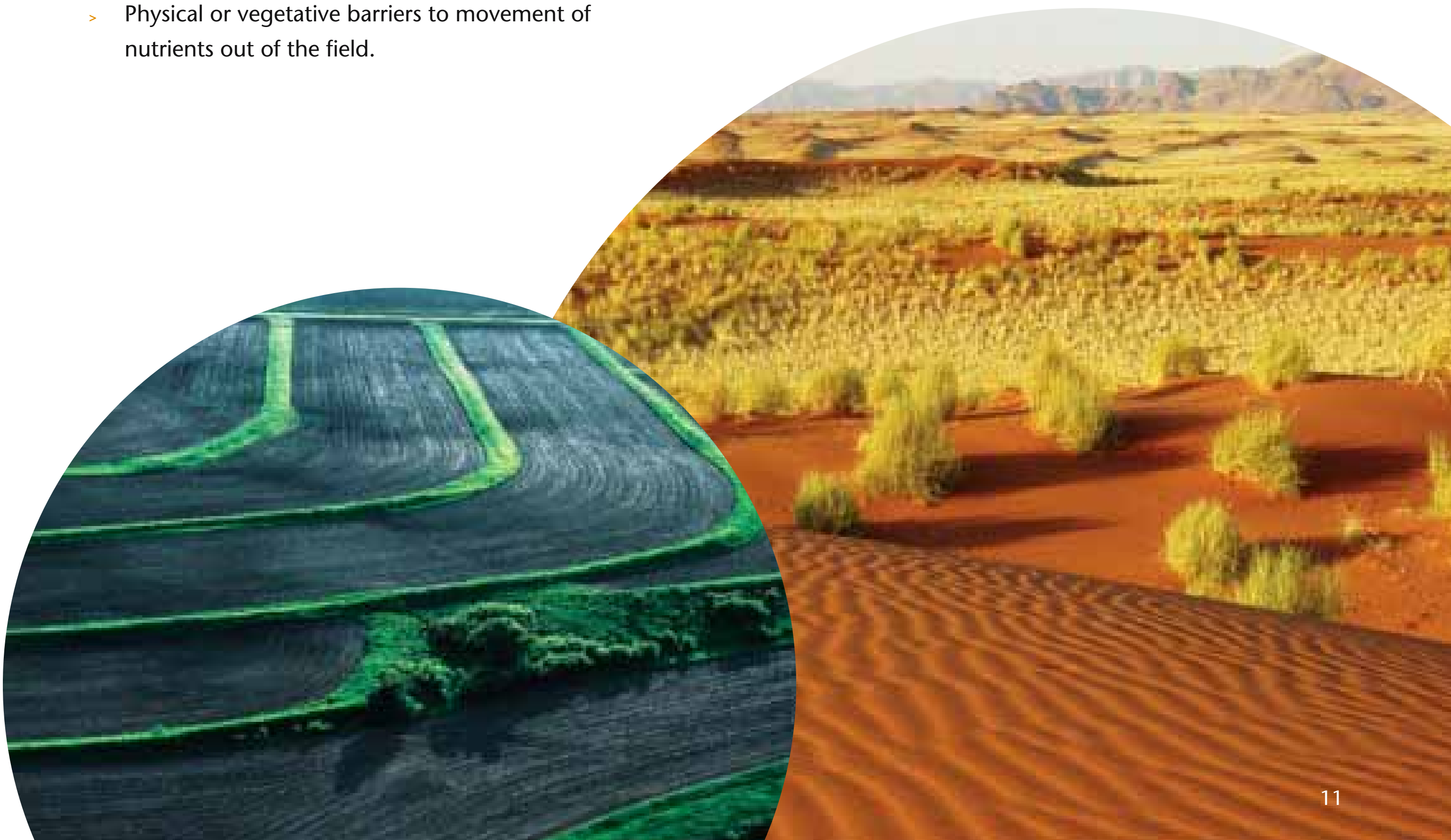


Figure 12: Above- and below-ground carbon sequestration[42]



6. Future challenges

This section describes some future challenges that can be subject to debate. These include bioenergy & biofuels, regulatory and policy frameworks, certification standards, incentives for farmers and improving agricultural efficiency.

Bioenergy & biofuels

- Bioenergy is energy produced from organic matter (biomass), whereas biofuels are liquid, solid or gas fuels derived from biomass, recently living organisms or metabolic waste.
- The most widely used biofuel, ethanol, is currently made largely from sugar cane in Brazil and from corn in the United States.
- In 2005, global biofuel production represented about 1% of global road-transport fuel energy consumption.[43]
- Biofuel production is an integral part of agricultural management, with which it shares the same concerns, such as biodiversity impacts.
- Issues around biofuels include:
  - Greenhouse gas emissions, including both direct and indirect emissions, associated with different types of biofuels, throughout their life cycle, and ensuring that the net energy balance is positive.
  - The level of water consumption and degree of water contamination associated with different biofuel types, particularly concerning the cultivation, conversion and distribution stages of biofuel production.
  - Competition for land use to provide food, fiber, fodder and forest products that can also affect food prices and impact the poor.

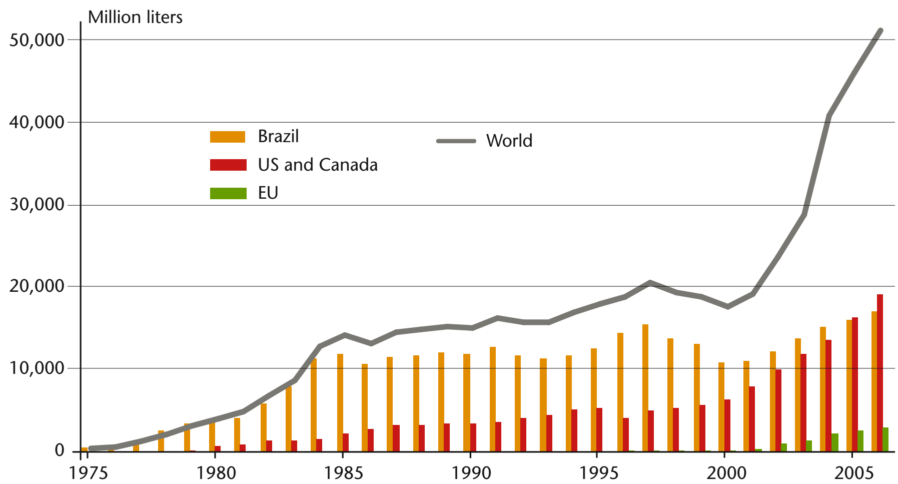


Figure 13: World and regional ethanol fuel production (1990-2006)[44]

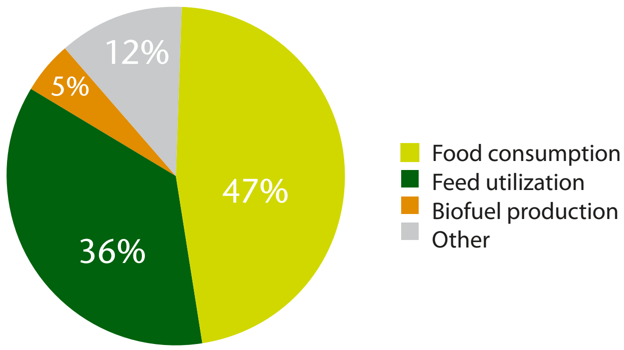


Figure 14: Global cereal utilization 2007-2008[45]


Enabling regulatory and policy frameworks for sustainable practice

- Policies such as international trade agreements, trade barriers, taxes and subsidies, as well as other environmental policies can have profound impacts on agricultural ecosystems.
- Some policies create economic distortions that spill over into the environmental sphere, leading to inappropriate patterns of production and inefficient use of inputs.
  - However, some subsidies, especially through vouchers, can be an essential element to helping smallholders access inputs and thus begin to improve their efficiency and profitability.
- These are not new issues: In 1987, OECD ministers committed themselves to reducing support levels and allowing a greater role for market signals in farmers' decision-making.[46]
- In most world regions, environmental policies have been put in place to address certain negative impacts. This has resulted in an increase in agricultural efficiency, while reducing erosion and enhancing biodiversity.

Certification standards

- One of the more established market-based mechanisms for ecosystem management is the use of eco-labeling and certification schemes to distinguish products and services by their social and environmental performance.
- Various labels and certification standards exist for agricultural practices such as "bird friendly", "shade-grown", "conservation", "sustainable" and "organic". Many of these only focus on one specific aspect of production such as biodiversity conservation or greenhouse gas emissions reductions. A future challenge therefore, is to develop more holistic approaches that address all pillars of sustainability.
- Market mechanisms, such as certification schemes, should be developed by professionals, farmers, government bodies and other stakeholders to suit site-specific needs. Landscape-scale certification systems could be developed to achieve ecological viability and engage larger numbers of farmers.

Incentives for farmers

- Environmental stewardship activities entail a number of costs to farmers, yet all of society benefits. In order to encourage farmers to adopt sustainable practices, they may need to be compensated for any additional costs incurred, so as to maintain or even improve their profitability. Such activities would therefore:
  - Aim to conserve the soil, enhance biodiversity and protect water supplies
  - Develop and apply good practices
  - Be tailored to reflect the local, site-specific situation
  - Add commercial value mostly through better quality, yields, etc.
  - Include secure land tenure rights.

Improving agricultural efficiency

- The four ways to produce more crops are:
  1. cultivate more land and/or
  2. achieve higher yield on the land currently used;
  3. restore the productive capacity of degraded agricultural lands and water supplies; and/or
  4. reduce wastes and losses in production process.
- In practice, it is not feasible to rely on expanding cultivated land since further encroachment into natural ecosystems would put even further pressure on biodiversity. Also additional arable land is finite and largely unavailable without significant investments in infrastructure.

Future challenges

- In addition to the "good practice" sections in the previous chapters, technological solutions are also part of the solution to increasing agricultural productivity while sustaining ecosystems.
- A recent review of scientific studies found more than 80 agricultural technologies that both increase crop productivity and improve habitat conditions for wild species.[47]
  - Many studies have shown how agricultural systems can be managed to protect watersheds.
- The development of improved plant varieties have contributed to significant yield increase since the 1930s, leading to the Green Revolution in rice and wheat in the 1960s. More recently, genetically engineered crops have enabled another significant step forward in terms of yield and quality increase (e.g., higher levels of longer cotton fibers), as well as resistance to disease and pests. New improved seed varieties are already contributing to healthier diets (e.g., less trans-fatty acids) and current breeding programs show promising potential for climate change adaptation (e.g., through the breeding of stress- and drought-tolerant crops).
  - According to the International Service for the Acquisition of Agri-biotech Applications, biotech crops have already decreased CO_2 emissions, e.g., through the reduction of fossil fuel as tillage is avoided – with CO_2 savings of 14.8 million tons, or equivalent to removing 6.5 million cars from the road.[48]
  - Some members of the public have concerns about biotechnology – generally these refer to its perceived negative impact on food safety and the environment.

Joining forces

It is critical to work within the whole agricultural value chain to achieve the goal of providing healthy and affordable food for all while protecting the environment. This means that cooperation and coordination between all stakeholders is essential. To help maintain healthy agricultural ecosystems, expertise in natural resource management, project management, agronomy, biology and other areas needs to be shared.

Mainstreaming sustainable agricultural ecosystem practices is an objective that must be shared by industry, the conservation community and consumers. Current tight agricultural markets are a signal for the urgency to act. Formal knowledge, new technologies and practices need to be combined with appropriate local and traditional knowledge to develop long-term, sustainable solutions.

7. Good news and bad

Agriculture is the most common occupation globally

……..but the majority of people in developing countries have insufficient resources or assistance to improve their livelihoods or yields

Nutritional status has increased around the world since the 1960s

……..but developing countries are not progressing as fast as necessary

We are producing more food with less land

……..demand continues to increase, putting added pressure on ecosystem services

There are techniques to reduce GHG emissions in agricultural practices

……..agriculture is still responsible for about 14% of global GHG emissions

60% of the world's food production comes from rainfed agriculture

……..rainfed agriculture is not used to its full potential

The land used for agriculture per capita has been in decline

……..each year 12 million hectares are lost to desertification

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The World Business Council for Sustainable Development (WBCSD) brings together some 200 international companies in a shared commitment to sustainable development through economic growth, ecological balance and social progress. Our members are drawn from more than 30 countries and 20 major industrial sectors. We also benefit from a global network of about 60 national and regional business councils and partner organizations.

Our mission is to provide business leadership as a catalyst for change toward sustainable development, and to support the business license to operate, innovate and grow in a world increasingly shaped by sustainable development issues.

Our objectives include:

Business Leadership – to be a leading business advocate on sustainable development;

Policy Development – to help develop policies that create framework conditions for the business contribution to sustainable development;

The Business Case – to develop and promote the business case for sustainable development;

Best Practice – to demonstrate the business contribution to sustainable development and share best practices among members;

Global Outreach – to contribute to a sustainable future for developing nations and nations in transition.

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