EMBO EMBL

10th EMBO | EMBL SCIENCE & SOCIETY CONFERENCE

Food sustainability and plant science

A global challenge

6–7 NOVEMBER 2009
HEIDELBERG | GERMANY

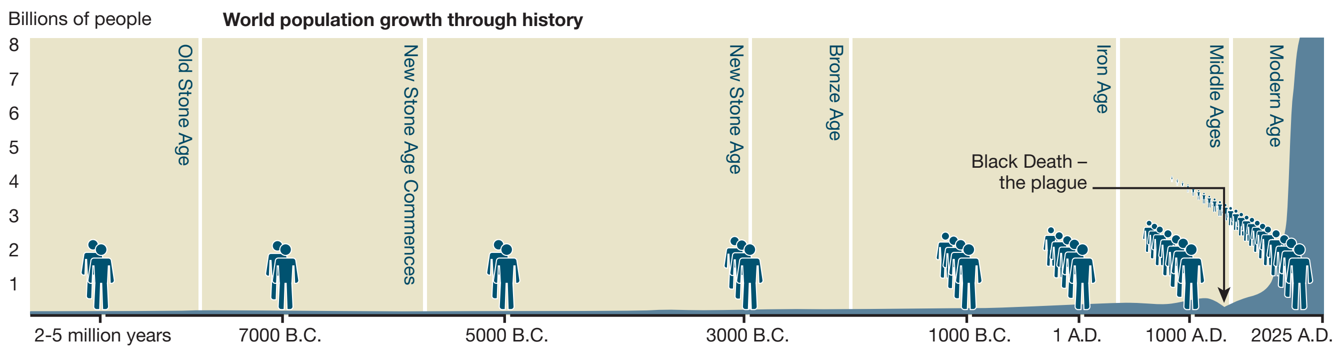
A summary of the talks and discussions presented at the 10th EMBO | EMBL Science & Society conference *Food, sustainability and plant science – A global challenge*, Heidelberg, 6 – 7 November 2009. The aims of the conference were to analyse the current global challenges of human population growth, agricultural production and environmental degradation and to discuss solutions for the future.

Almost seven billion humans live on Earth and about one billion do not have enough food to eat. On average, one adult dies each second and one child dies every five seconds from malnourishment. Yet, the world population continues to grow by around 74 million people per year. The United Nations predicts that, if the current growth rate remains unabated, 9.2 billion humans will live on this planet by 2050. Most of this population growth is taking place in some of the poorest countries of the world and the majority of these people will live in the explosively growing megacities in Asia, Africa and South America.

The role of agriculture in human civilization

About 12,000 years ago, human hunter-gatherers in the Fertile Crescent began to plant seeds in the spring and harvest the crop in the fall. This simple practice marked the dawn of human civilization and the gradual improvement of farming practices enabled humans to become the dominant species on Earth. During the Green Revolution in the 19th and 20th centuries, mechanization, artificial fertilizers and the invention of pesticides drastically increased agricultural production. Even more important was the development of high-yield hybrid crops – for which the American agronomist Norman Borlaug was awarded the Nobel Peace Prize in 1970 – that enabled farmers to grow more food. As a result of these developments, global food production tripled and human population has since been growing exponentially.

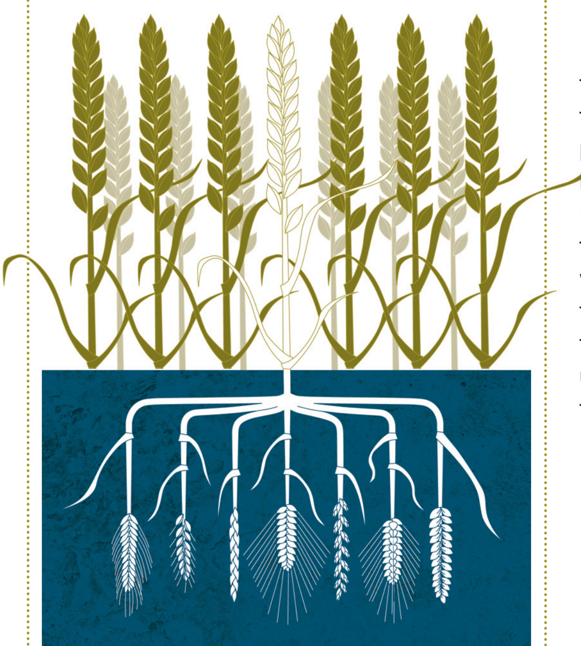
World population growth through history



Breeding and molecular plant biology

Breeding is the art and science of manipulating the genetics of plants and animals to create new varieties. The first farmers in the Fertile Crescent started the process by domesticating certain plants with desirable features. Eventually farmers began to cross closely related plant species to create new varieties with higher yields or greater resistance to pests or pathogens. The discovery of the rules of inheritance by Gregor Mendel and subsequent work that explained how genetic information is stored and transmitted significantly improved the ability of breeders to create new varieties by crossing, selection and backcrossing.

During the past two decades, breeding has also profited from sequencing the genomes of most important crops and vegetables. These projects, together with an increasing understanding of how plants are able to fend off pests or disease or withstand drought or flooding, have generated so-called molecular markers. These are short DNA sequences that mark genetic regions linked to, for example, increased resistance to fungi or other pathogens. So-called marker-assisted breeding based on this information allows breeders to work more effectively.



Prem Bindraban, Wageningen University, The Netherlands
We see an overall deterioration of all resource bases. The speed of deterioration is faster than the speed at which we can reclaim it.

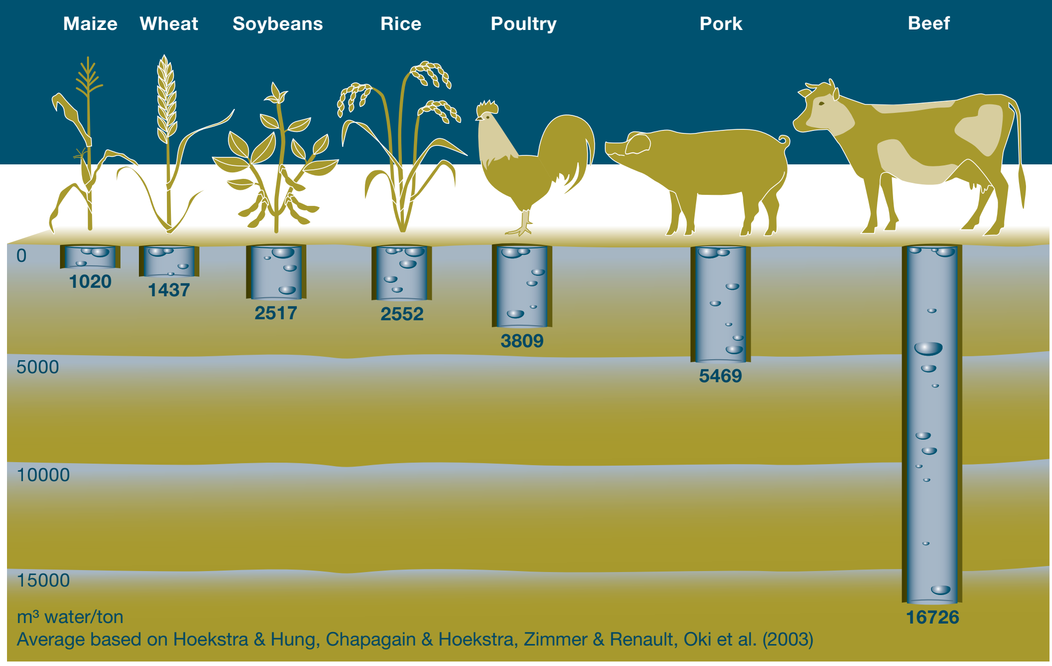
Agriculture is struggling to keep pace with the growing human population; most countries are no longer able to feed their own people. More than 100 countries need to import wheat and 40 countries must import rice, while only six countries – the USA, Australia, Canada, France, Argentina and Thailand – supply 90% of the global grain exports.

While the number of humans is increasing, the global surplus of food production is rapidly shrinking. In 2008, a severe drought in Australia and reduced harvests in other food-exporting countries drove up the prices for many staple foods – including wheat and rice – which sparked food riots in Haiti, Bangladesh and other impoverished nations.

Expanding agriculture to produce more food is not an option due to the limited amount of arable land and freshwater available. In addition, global climate change will have as yet unknown, but likely serious, effects on agricultural productivity. Moreover, an increasing number of people in developed and emerging economies, such as China, India and Brazil, are able to afford a protein-rich, meat-based diet. This drives up food prices because farmers have to produce more feed for the livestock industry at the expense of basic staple foods for the poor. The increasing demand for meat also puts more pressure on arable land and freshwater resources (Figure 1).

Current agricultural practices exacerbate the problem. According to the United Nations, the Earth has already lost 25% of its capacity to produce food and is still losing 100,000 square kilometres of arable land – more than the size of Portugal – each year to erosion and desertification, particularly in Africa and Asia. In addition, wasteful irrigation practices are rapidly depleting freshwater resources – worldwide about 70% of freshwater is used for agriculture – and contribute to the salinization of soils, which leads to further losses of 1 to 2% of arable land per year.

Figure 1 Amount of virtual water needed to produce 1 ton of food



Slash-and-burn agriculture in South America, Africa and Southeast Asia is rapidly destroying native rain forests and their enormous biodiversity. Once the farmers move on, they leave in their wake exhausted soils that are barely able to support plant life.

Industrialized agriculture, with its heavy use of chemical pesticides, herbicides and artificial fertilizers, coupled with intense mechanization, has drastically increased food production, but is simultaneously creating major environmental problems. For example, excess fertilizer washed from fields and carried by the Mississippi river causes a huge 'death zone' of up to 18,000 square kilometres in the Gulf of Mexico every year: an explosive growth of algae and bacteria depletes the ocean of oxygen until no fish or other animals are able to survive. Moreover, industrial agriculture heavily depends on fossil fuels for mechanization, food processing and transportation, and the production of fertilizers and pesticides.

Modern agriculture also relies on a few elite crop varieties. India, for instance, used to grow about 30,000 rice varieties; today, most acreage is used for a few high-yield varieties. Two-thirds of the cropland in the USA is devoted to growing only four crops: maize, wheat, soybean and cotton. These monocultures are more susceptible to pathogens and pests and even enable their spread. In the meantime, many local crop and vegetable varieties are rapidly disappearing and with it the treasure trove of genetic diversity to breed new pathogen or drought-resistant plants.

At the beginning of the 21st century, the greatest challenge for humanity is to find new ways to feed the growing human population without further destroying the environment and depleting Earth's biodiversity. This will necessitate a shift away from using harmful chemicals and artificial fertilizers towards environmentally friendly ways of growing food. It would require new crop management strategies based both on traditional and organic practices, such as crop rotation or integrated pest management, and high-tech solutions, such as satellite-based methods for efficiently using irrigation and fertilizers, and biotechnology. Cooperation between breeders and farmers could help to develop new crop varieties and farming methods that are adapted to local situations instead of relying on a few high-yield, one-size-fits-all crops. This calls for the preservation of wild and locally used crops and vegetables that can be used in breeding programmes.

Research into the genetic basis of how plants naturally deal with abiotic challenges such as drought or salinization, or how they fend off pests and pathogens will help scientists and breeders to develop new crop varieties that are better suited to deal with those challenges. Genetic engineering is another important technology that allows the transfer of desirable traits to high-yield varieties.

In addition to new technologies and practices, it is also vital to develop social sustainability and participation. The task of feeding the human population rests on the shoulders of farmers:

Pamela Ronald, University of California Davis, USA
Without the best science and without the best farming we are not going to get to where we need to go.

Sir Peter Crane, Yale University, USA
Global agriculture demands a diversity of approaches, specific to crops, localities, cultures and other circumstances.

Luis Herrera Estrella, National Polytechnic Institute, Mexico
Nobody claims that GM technology is going to replace plant breeding. I think they are complementary and in some cases it is necessary to use GM technology (…).

Luis Herrera Estrella, National Polytechnic Institute, Mexico
Most of the definitions I see on sustainable agriculture are environmentally sustainable and they overlook people. If agriculture is not economically sustainable for the small farmer, it's not sustainable.

Catherine Feuillet, INRA, France
If you are familiar with the European Framework Programmes and if you see how much is dedicated to agricultural research compared to Information Technology, in my opinion this is not good enough.

Pamela Ronald, University of California Davis, USA
In China, insecticide use fell by 156 million pounds after introduction of Bt-cotton, and that's equal to the entire amount that we spray in California every year.

Joyce Tait, University of Edinburgh, UK
A major outcome of this regulatory system [for GMOs] that we have in Europe is that the industry sector itself is dominated by multi-national companies (…) because they are the only ones who can afford to take a product through to a market place (…), given the onerous nature of the regulatory system.

Genetically engineered plants: promise or threat for sustainable agriculture?

Genetic engineering allows scientists directly to insert the desired genes – which could come from the same plant species, but also from unrelated ones such as other plants or bacteria – into the plant genome. Genetically Modified (GM) plants cultivated today are more resistant to insects, herbicides, or are able to synthesize pharmaceuticals or raw materials for the chemical industry. Eventually, scientists hope to create GM plants that produce higher yield, make more efficient use of sunlight, need less fertilizer, or grow under harsh conditions like cold, high salinity and drought where current crops would not be able to survive.

Opponents of GM crops argue that these plants could harbour unknown risks that might pose a threat to human health and the environment and endanger global biodiversity. On the other hand, more than 20 years of experience growing GM crops in North America has shown that such fears are so far unfounded. Even pest-resistant plants, genetically modified to produce a bacterial toxin to fend off insect predators, have not had any serious impact on local insect fauna – much less than the blanket spraying with the same toxin as is the case, for example, in organic agriculture.

However, the EU's strict regulatory regimen for growing and importing GM crops makes their approval in Europe forbiddingly expensive such that small companies cannot afford to invest in the technology and the market is controlled by large multinationals.

any sustainable solution must therefore contribute to empowering farmers both in developed and developing countries. New crop varieties and new technologies, including genetically modified crops, should be made affordable for all farmers so that they can use these in the most efficient way. Governments can contribute by investing more into agricultural research instead of leaving this vital area to a few profit-oriented companies. Western societies will also have to reconsider agricultural subsidies to take into account their global effects on, for example, small farms or farmers in impoverished nations.

The first decade of the 21st century has highlighted the enormous challenges posed by a growing human population, global climate change, environmental degradation, biodiversity loss and the concomitant struggle to produce enough food. As Klaus Hahlbrock stated in concluding the conference, "we now have for the first time, instead of growth, expansion and exploitation, a time when we have to deal with foresight and solidarity, and that is something entirely new."

Further reading

Baulcombe D et al (2009) Reaping the benefits. Science and the sustainable intensification of global agriculture. London, UK: The Royal Society

Ronald PC, Adamchak RW (2008) Tomorrow's table. Organic farming, genetics and the future of food. Oxford, UK: Oxford University Press.

Klaus Hahlbrock (2010) Feeding the Planet: Environmental Protection through Sustainable Agriculture (The Sustainability Project). London, UK: Haus Publishing

2009 World Summit on Food Security
www.fao.org/wsfs/world-summit/en/

The Golden Rice Project
www.goldenrice.org/

For more information on the conference
www.embo.org/policy-and-society/science-society/conferences/2009.html

A DVD with a selection of the conference talks is available upon request
Please send an email to: scisoc@embo.org