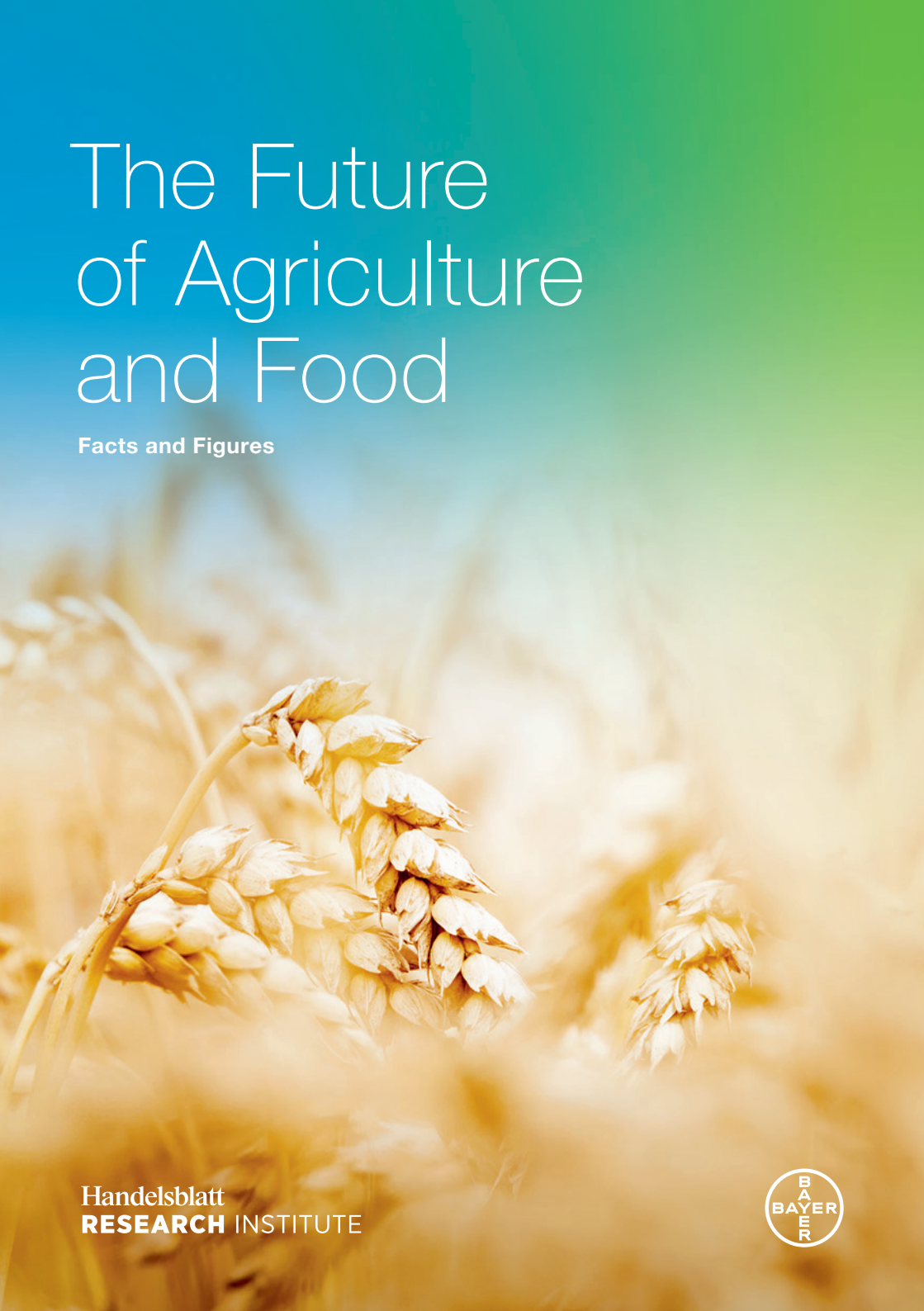
The Future of Agriculture and Food

Facts and Figures



Handelsblatt
RESEARCH INSTITUTE

BAYER

Dear reader,

The United Nations estimate that there will be approximately 10 billion people inhabiting our planet by the year 2050. How can all these people be fed, given that the amount of farmland available per capita is decreasing and approximately 800 million people are already affected by hunger today? This is one of the most pressing issues of our time. Yet many people living in industrialized countries today know very little about agriculture. They have lost interest in where their food comes from and how it is produced, because it has long been taken for granted that food is available in abundance.

This is not the case – at least not everywhere in the world. Over the past decades, farmers have indeed constantly increased the size of their yields. However, the measures that they have used to achieve this growth have reached their limits. For tomorrow's agriculture, we need new approaches aimed at increasing both productivity and environmental protection. The debate surrounding these issues is in full flow, but far too often becomes bogged down in generalizations and basic principles. What we need is a new style of debate. For this, we first need to objectively analyze the challenges facing agriculture in the future. What is often lacking is a shared factual basis.

Bayer has therefore commissioned the Handelsblatt Research Institute to produce this brochure. It contains a wealth of information about nutrition and agriculture that was derived from acknowledged sources and may serve as the foundation for a constructive dialog.

We wish you pleasant reading. As you will see, sober facts can be incredibly interesting!

Best regards,

Liam Condon
Member of the Board of Management of Bayer AG and
President of the Crop Science Division

The challenges facing agriculture

The agricultural and food industry is facing huge challenges. It has to feed a rapidly growing world population while at the same time ensuring the best-possible conservation of our scarce natural resources. Increasingly extreme weather conditions such as droughts and flooding, limited arable land and changing dietary habits make this task even more demanding.

On the path to a food crisis?

The majority of people affected by hunger live in rural areas of developing countries, for example in Asia or Africa. However, the factors that have a negative impact on food security are global rather than regional. This two-page spread presents some of these challenges.

Food loss

Every year, more than one billion tons of food are lost worldwide. In industrialized nations, consumers are responsible for most of these losses: 13 percent of the food purchased in Europe ends up in the garbage, while in the United States this figure is almost 16 percent. (FAO 2011)

Extreme weather and climate change

Record high temperatures, floods, droughts – extreme weather events are becoming increasingly common. In 2016, the damage caused by weather-related events amounted to US$ 44 billion in the United States alone (Munich Re 2017). 3.5 million people in El Salvador, Guatemala, Honduras and Nicaragua were affected by food supply disruptions as a result of El Niño. (WMO 2017)

Agricultural productivity

The over 500 million smallholders around the world are responsible for half of the world's food supply, in developing countries they are responsible for as much as 80 percent. However, they are less productive than agricultural operations in industrialized countries. (FAO 2014)

Infertile soils, species diversity threatened

Fertile soil is being lost all over the world, due to factors such as deforestation, overgrazing and mismanagement. More than 200 million hectares of soil in Latin America are severely damaged (WRI 2016). Many species of mammals, birds, fish and plants are at risk of extinction.

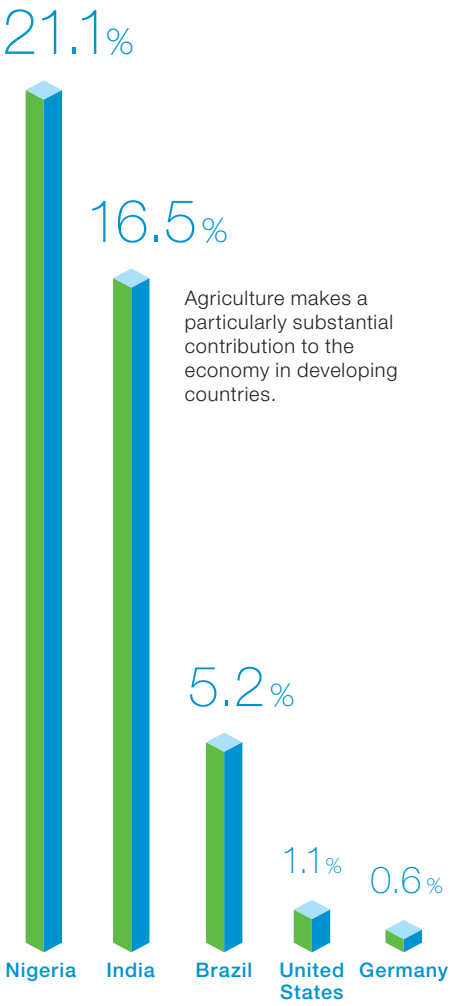
Growing world population and urbanization

By 2050, the world's population will have grown to nearly 10 billion. Two-thirds of these people will live in cities. 90 percent of this growth will be in Asia and Africa. (UN 2017)

What farmers contribute

While agriculture plays a less important role economically in industrialized countries, it is one of the most important segments of the economy in developing countries. Smallholders play a key role in food production.

Agriculture as an economic factor

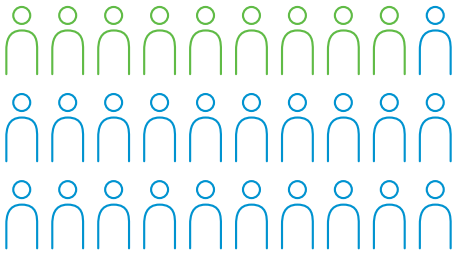


Agriculture makes a particularly substantial contribution to the economy in developing countries.

Share of agriculture in the gross domestic product (GDP), estimate for 2016

Source: CIA 2017

The world's largest employer

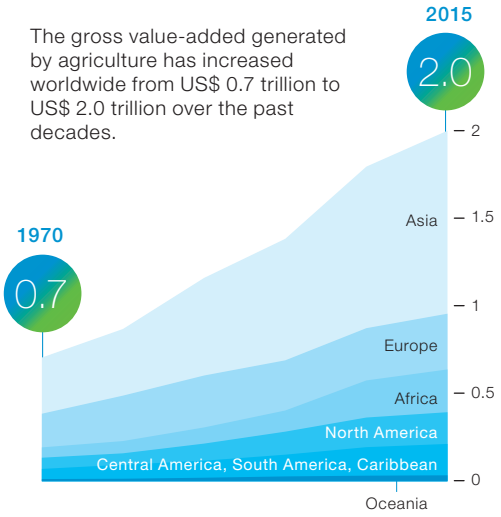


Roughly 30 percent of the global workforce is employed in agriculture. That is approximately 1 billion people.

Source: ILOSTAT 2016

Growing contribution to value creation

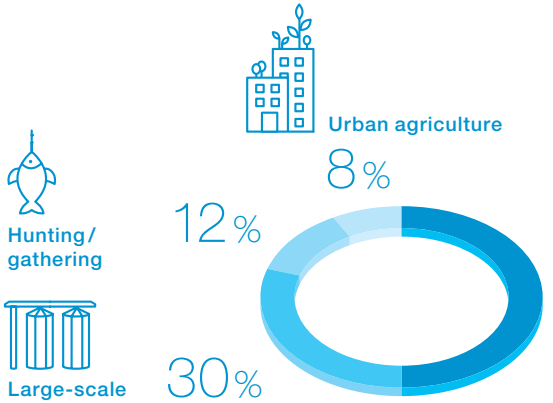
The gross value-added generated by agriculture has increased worldwide from US$ 0.7 trillion to US$ 2.0 trillion over the past decades.



In trillion US$, constant prices from 2005

Source: FAOSTAT 2017

Smallholders produce half of the world's food



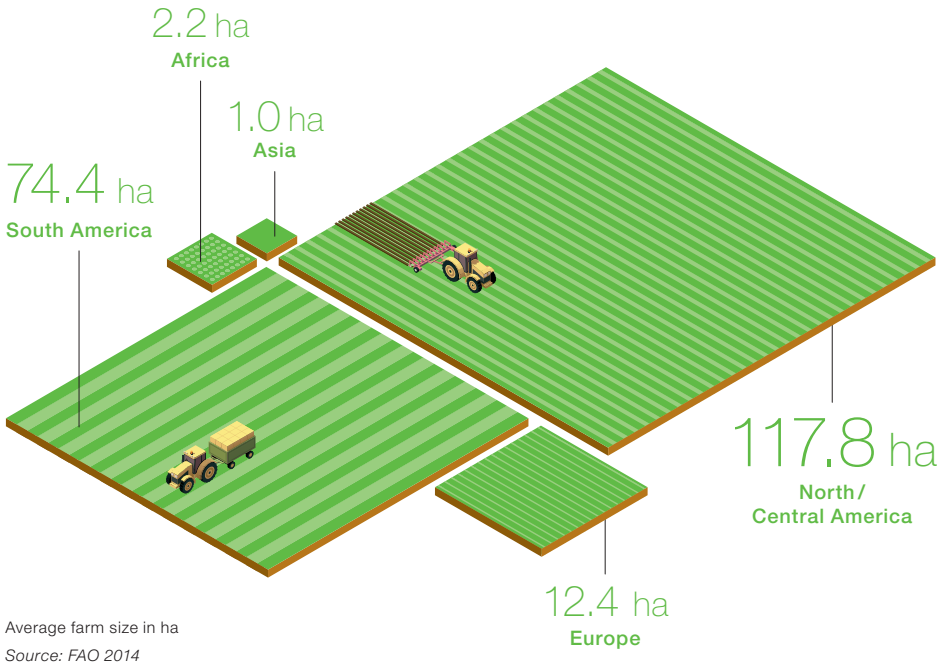
Worldwide, smallholders meet approximately 50 percent of the demand for food; while in Asia and Sub-Saharan Africa this figure is approximately 80 percent.

Source: FAO 2014

*Farms of less than 2 ha

Source: ETC Group 2009

On average, U.S. farms are more than 100 times larger than the farms of Asian smallholders



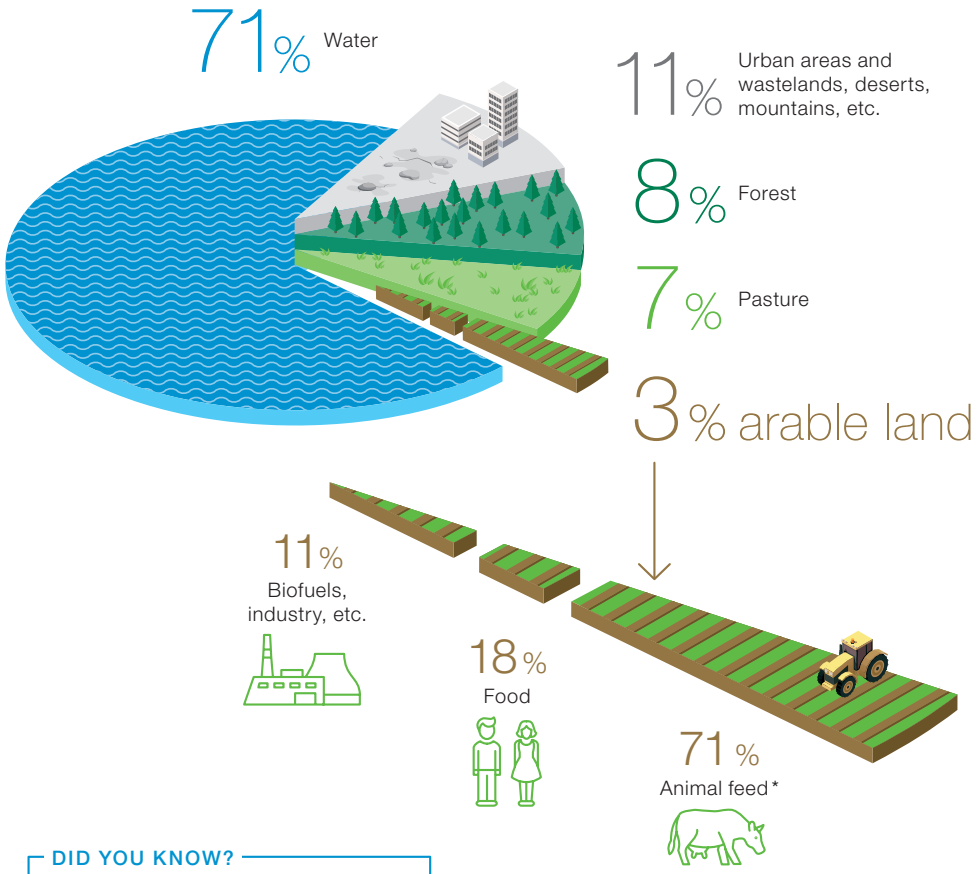
Average farm size in ha

Source: FAO 2014

Arable land is precious

The amount of arable land available for food production per person is limited and constantly decreasing. This is due to population growth, but also factors such as urbanization, erosion and desertification.

Only a small part of the Earth's surface is arable land



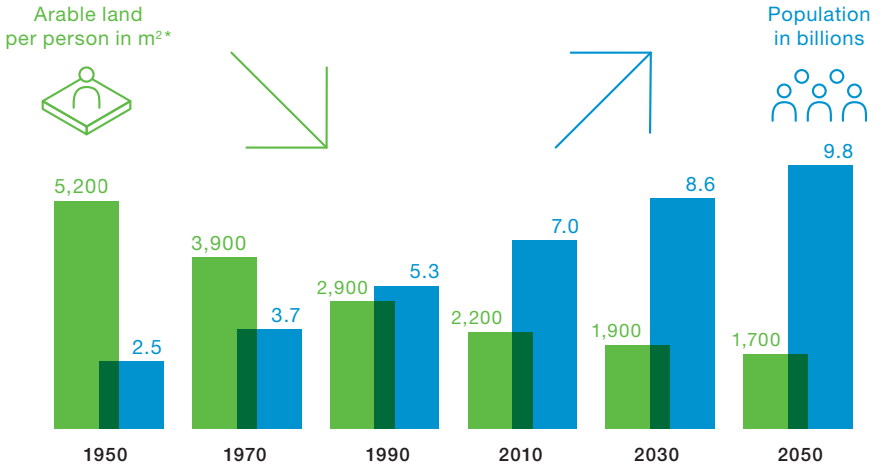
DID YOU KNOW?

Merely 3 percent of the Earth's surface is used as arable land. Only 18 percent of that **– or 0.5 percent of the Earth's surface –** can be used for growing food crops.

*incl. by-products

Source: Raschka et al. 2012, nova-Institut

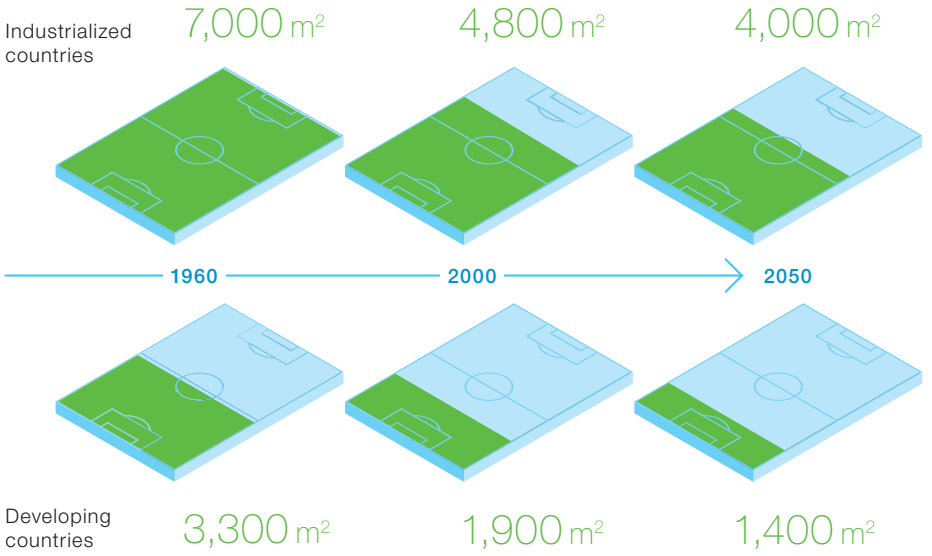
The population is growing, the amount of arable land per person is decreasing



*Rounded figures, including permanent crops

Source: UN 2017, FAOSTAT 2017, FAO 2012, own calculations

In developing countries, the amount of arable land per person will be falling by more than 60 percent (1960 – 2050)



Amount of arable land per person in m² in comparison to a 7,140 m² football pitch (rounded figures)

Source: FAO 2012

Enough food for everyone?

Strong population growth has led to an increased demand for food. By the middle of the century, the demand for agricultural products will be 50 percent higher on average than in 2013. An increase of 112 percent is forecast for the Sub-Saharan Africa and South Asia regions.

Source: FAO 2017

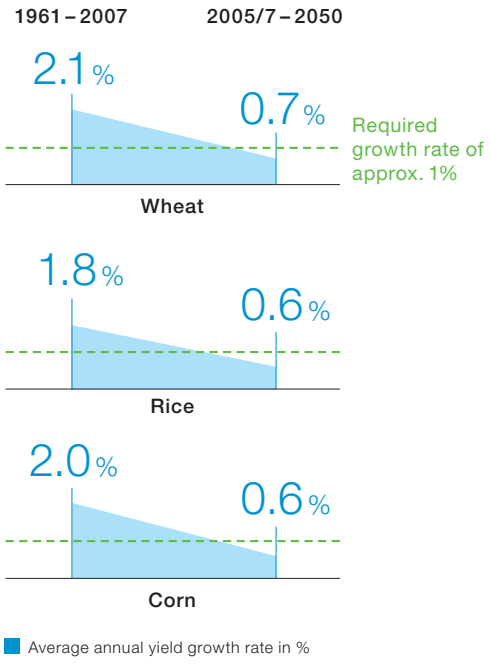
Each farmer feeds increasing numbers of people

Germany		United States
17	1960	46
69	1990	129
156	2015	168

Source: American Farm Bureau Federation 2016, BZL 2017

Land productivity is growing too slowly

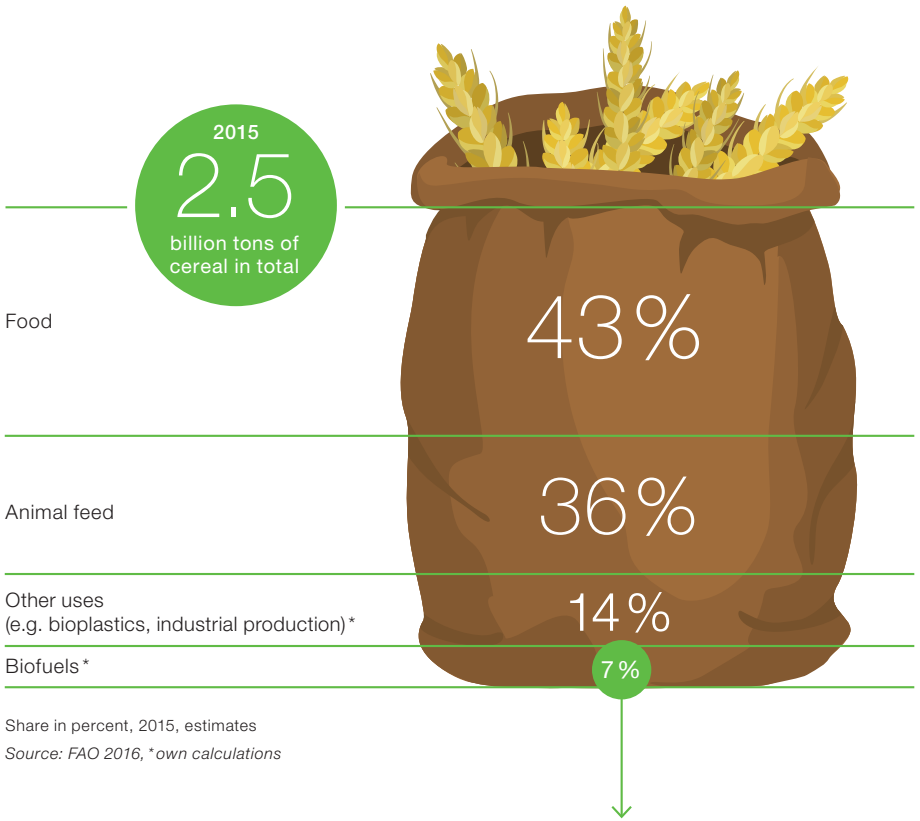
While farmland productivity for most crops increased by 1.7 percent on average every year from 1961 to 2007, according to the FAO the growth rate will fall to less than 1 percent by 2050.



To meet the rising demand through 2050, cereal yields must increase each year by approximately 1 percent. The total amount of cereals required in 2050 will be approximately 3 billion tons.

Source: FAO 2012, FAO 2017

Less than half of these cereals are used directly as food



Share in percent, 2015, estimates

*Source: FAO 2016, *own calculations*

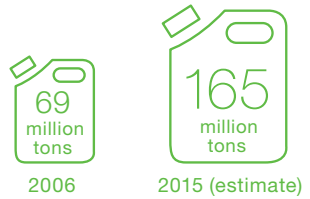
DID YOU KNOW?

Consumers in Europe are reliant on imports of food and agricultural raw materials from developing and emerging countries. In 2013, the EU imported agricultural produce with a value of approximately EUR 80 billion from these countries.

Exports from the EU to developing and emerging countries by contrast were significantly lower at approximately EUR 58.3 billion (2013).

Source: BMEL 2015

Using cereals for the production of bioethanol



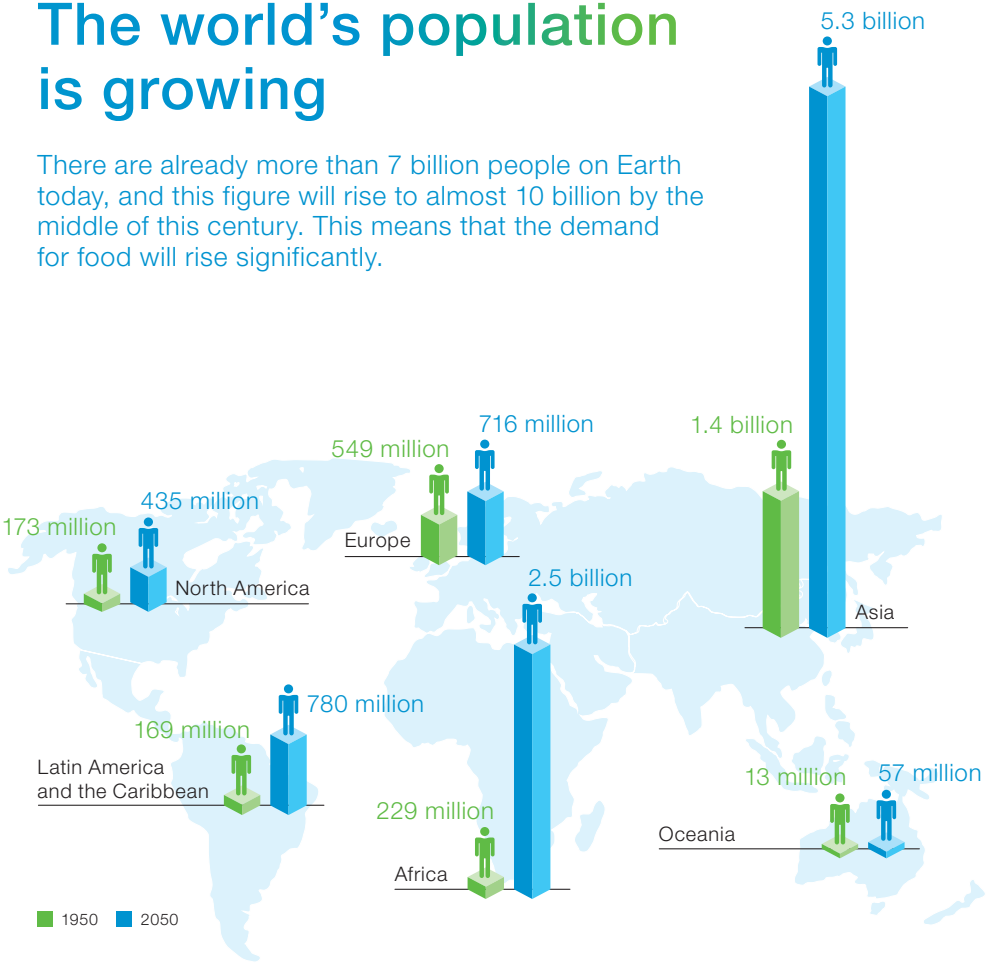
Source: OECD Stat 2017

The amount of arable land used for the production of biofuels will more than triple from 30 million hectares in 2010 to approximately 100 million hectares by the middle of this century.

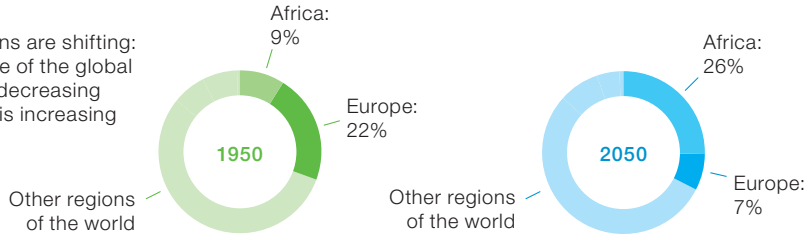
Source: IEA 2011

The world's population is growing

There are already more than 7 billion people on Earth today, and this figure will rise to almost 10 billion by the middle of this century. This means that the demand for food will rise significantly.



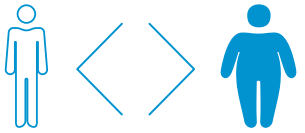
The proportions are shifting: Europe's share of the global population is decreasing while Africa's is increasing dramatically.



Source: UN 2017

Hunger and abundance

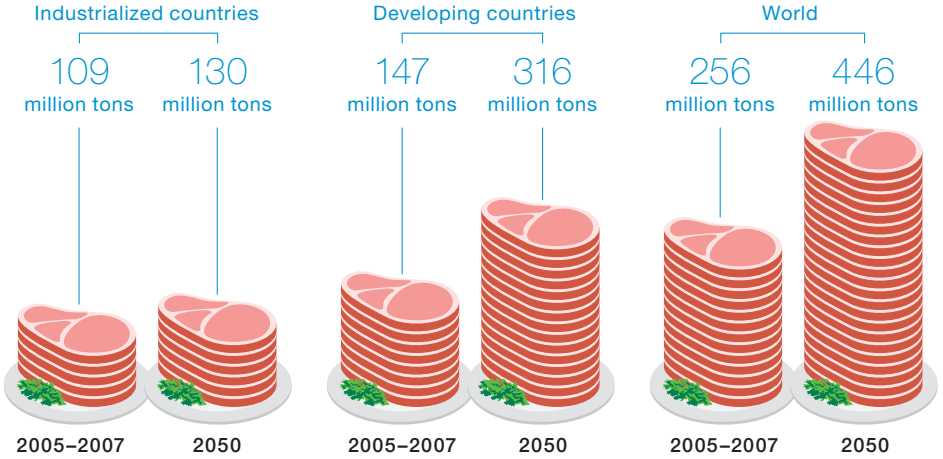
Worldwide, 795 million people suffer from malnutrition. Hunger is a major problem, particularly in developing countries. The populations in industrialized nations, by contrast, are increasingly affected by obesity: in the period from 1980 to 2014, the number of obese adults* in these countries more than doubled to over 600 million.



Source: WHO 2016, Welthungerhilfe 2016

*Obesity: BMI of 30 or higher

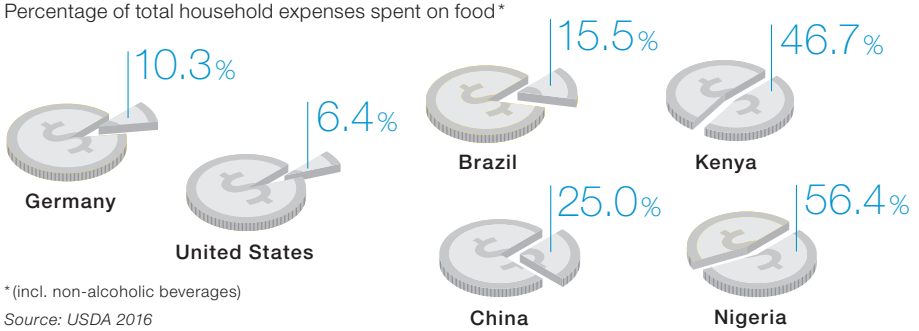
Meat consumption set to increase – above all in developing countries



Source: FAO 2012

Developing countries spend a lot of money on food

Percentage of total household expenses spent on food*



*(incl. non-alcoholic beverages)

Source: USDA 2016

Consumption needs resources

The dietary habits of consumers in industrialized countries necessitate large amounts of resources and cause climate-damaging greenhouse gases.

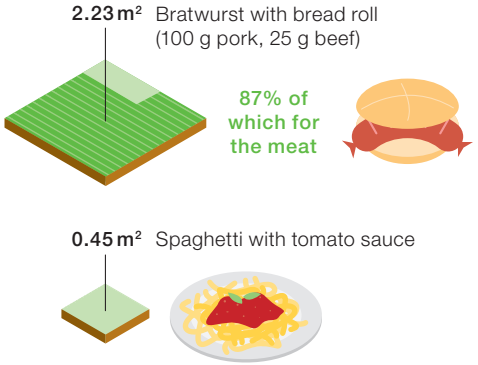
How much land do we need to make our food?

The current food supply for Germany requires an area of **19.4 million ha** *. This includes the land in Germany as well as an additional area for growing crops or rearing livestock abroad to meet the demand for food in Germany.

* at an annual food consumption of approximately 679 kilograms per person – 87 kilograms of which is meat.

Source: WWF 2015

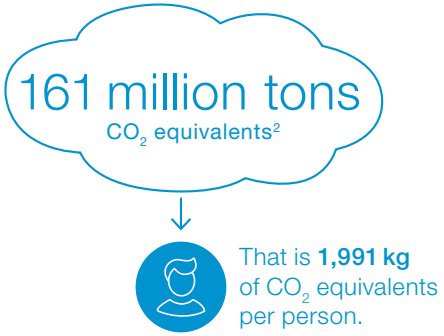
Amount of land required for typical meals in m²



Source: WWF 2015

Food and emissions

Annual food-related greenhouse gas emissions in Germany[1]:



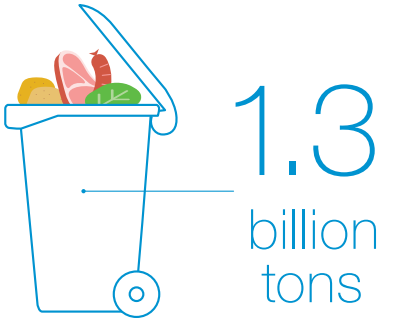
[1] 68 percent of which are animal-derived products.
[2] CO_2 equivalents describe the contribution to global warming so that the harmfulness to the climate of different greenhouse gases can be compared.

Source: WWF 2015

Excessive losses

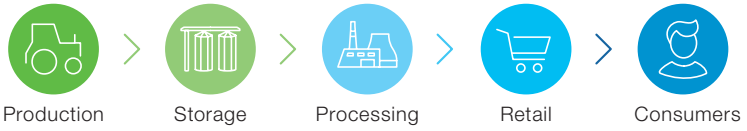
One-third of food worldwide – approximately 1.3 billion tons annually, enough to feed 3 billion people for a year – is either lost during the production process or ends up in the garbage.

Source: FAO 2011, 2013

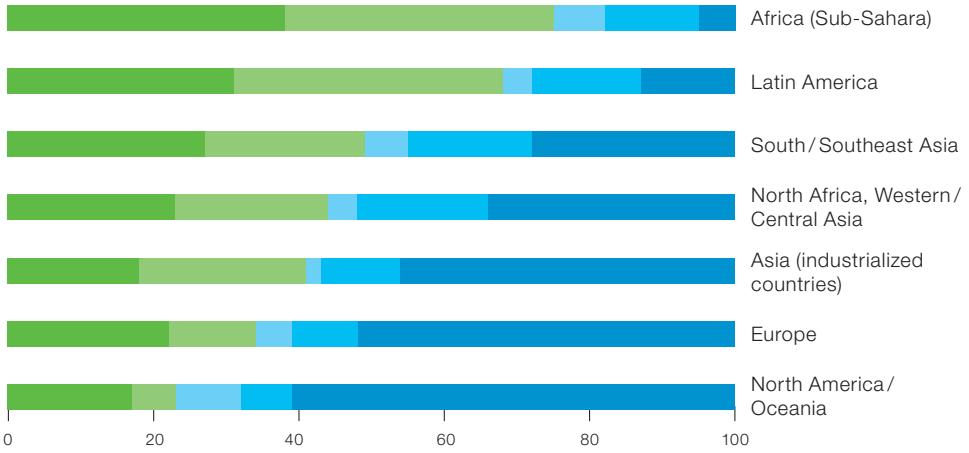


In industrialized countries, private households waste the most food

Losses are sustained along the entire way from the field to the plate. While in poorer regions food is mainly lost during production and storage, in rich countries losses arise because consumers throw a lot away.



Percentage of kcal lost or wasted worldwide:



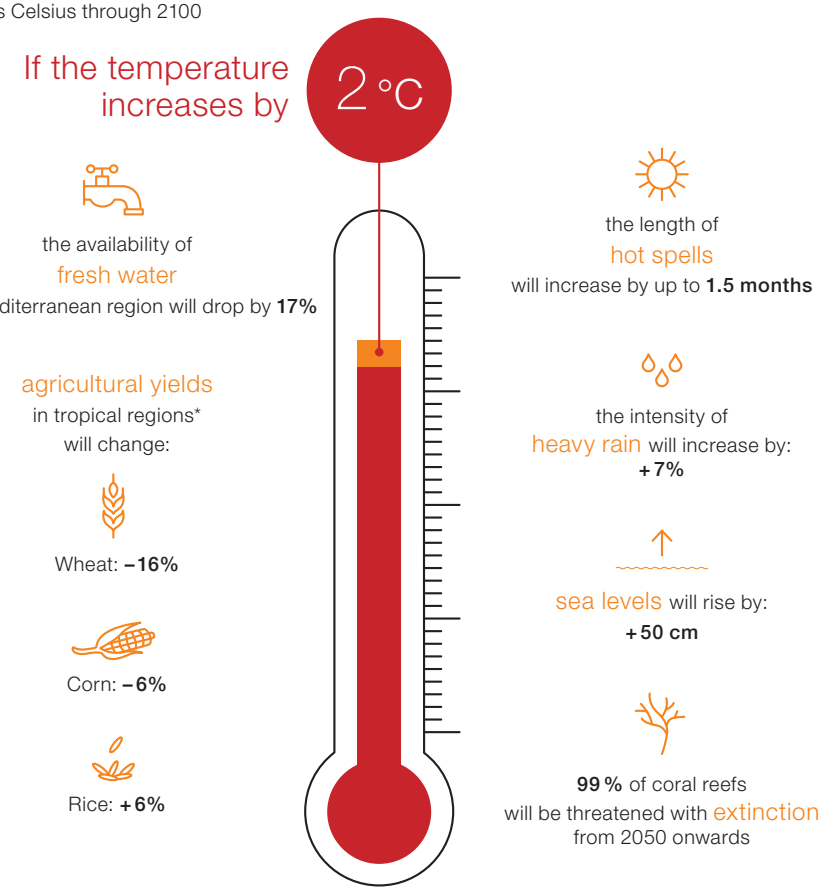
Source: WRI 2013

Consequences of climate change

Agriculture plays a part in climate change and at the same time is affected in turn by global warming. Rising average temperatures are leading to droughts, flooding and storms all over the world. This has far-reaching consequences for natural resources and ecosystems.

Climate change has consequences for both humans and the environment

Effects of a temperature increase of 2 degrees Celsius through 2100



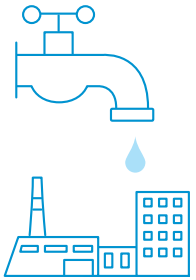
*Average values relative to 1986–2005

Source: Schleussner et al. 2016 in Earth System Dynamics 7: 327–351

Water – a scarce resource

40 %

of the world's population will suffer from water shortages in 2050.



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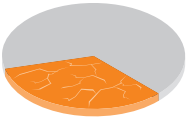
of all jobs worldwide – including in agriculture, fishing, the energy sector and other industrial segments – are dependent on an adequate supply of water.

Source: OECD 2012, UNESCO 2016

Soil loss

1 / 3



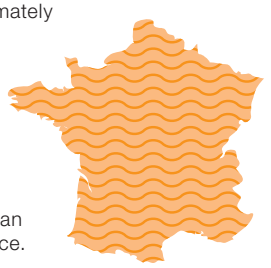
of the world's fertile soil is at risk. Erosion, salinization and excessive fertilization are making increasing areas of arable land unusable for agriculture.

Intensive irrigation with salt water and/or insufficient drainage of arable land leads to increased salinization of the soil.

Worldwide, approximately

62 million ha

of irrigated land are affected by this. This is equivalent to an area the size of France.



Source: Grantham Centre 2015, UNU 2014

Species diversity is decreasing

27,000

animal and plant species are lost globally every year.

One in five plant species is at risk of **extinction**.

Source: UNCCD 2016, Kew Foundation 2016

Creating a sustainable future

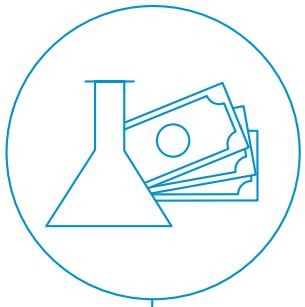
Agriculture needs innovation: the challenges of tomorrow cannot be resolved with yesterday's methods. Investment in research and development is more important than ever before, in order to make agriculture more efficient and also more sustainable at the same time. Digital solutions, crop protection and modern breeding methods will all play an important role in this process, as will targeted support for smallholders.

More research required

Innovation can make an environmentally friendly positive contribution to agricultural productivity. However, it requires major investment in research and development.

Spending on agricultural research is increasing

Annual expenditure for research and development in billion US$*:



Public 17.8 → 38.1 (1980 → 2011)

Private 9.6 → 31.1 (1980 → 2011)

The demand for agricultural research is likely to grow to US$ 100 billion per year by 2050.

through 2050

100

*in 2009 prices taking into consideration the purchasing power of the different national currencies

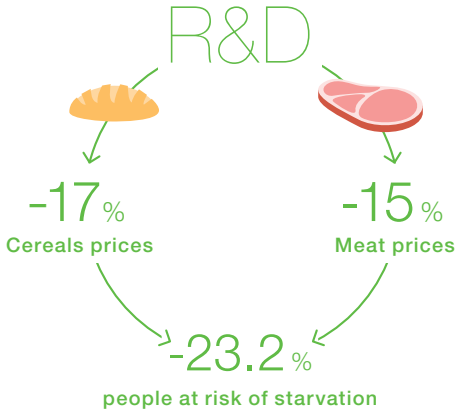
Source: InSTePP (Pardey et al. 2016); Cai et al. 2016 at AAEA Annual Meeting

New products cost time and money

The time it takes for a new crop protection product to reach the market, from laboratory testing to registration, is about 11 years. The development costs amount to US$ 286 million on average.

Source: Phillips Mc Dougall 2016

Innovation benefits consumers*

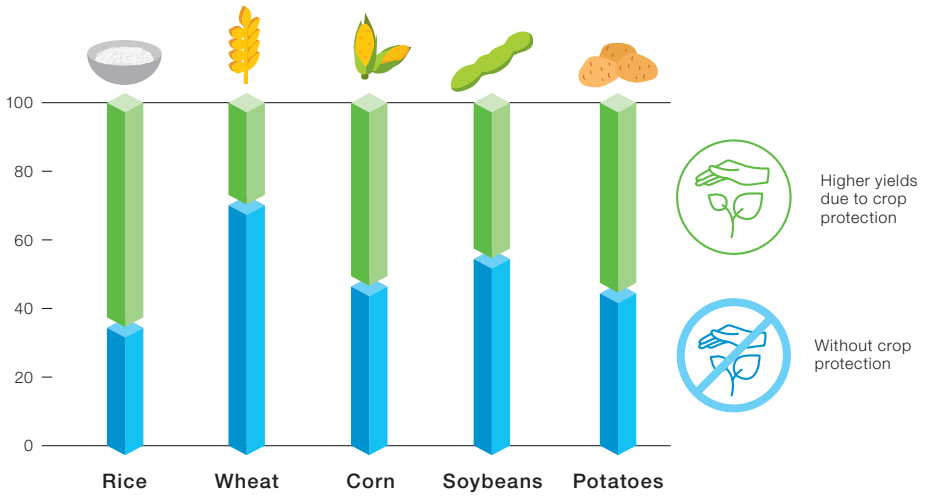


*These figures are based on the assumption of an increase in research and development spending that would lead to a 2 percent annual increase in agricultural productivity through 2030.

Source: Perez, Rosegrant 2015, IFPRI Discussion Paper 1447.

Plants need protection

Pathogens, pests and weeds are increasingly threatening farmers' yields worldwide. Without crop protection, the harvests of major arable crops would be approximately one-third lower today.



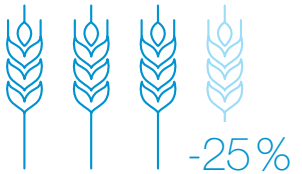
Relative percentage of yield

Source: Oerke 2006 in Journal of Agricultural Science 144: 31–43.

Lower yields in organic farming

On average globally, organic farming produces yields that are one-quarter lower than those achieved by conventional farming. Producing the same amount of food using solely organic farming would require substantially more arable land.

Source: Seufert et al. 2012 in Nature, Volume 485: 229–232



DID YOU KNOW?

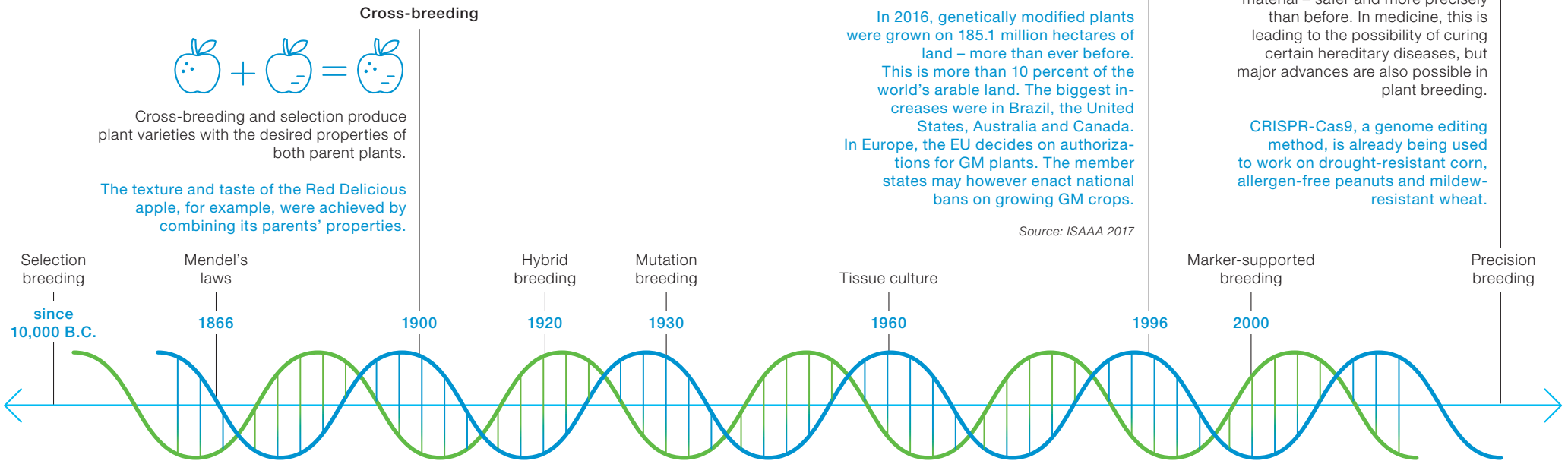
Food in Europe is safe and free from harmful residues. This is checked at regular intervals by European authorities. The legally prescribed limit for crop protection residues is 100 times lower than the dose that can be ingested without health risks. If this margin was applied in road traffic, it would mean **maintaining a safety distance of 6 kilometers** to the vehicle ahead when travelling at 120 km/h.

Source: IVA 2013

Plant breeding: methods and benefits

Higher yields, more resilient plants, better taste – these are the main objectives of plant breeders. Their methods range from conventional cross-breeding and selection to the targeted insertion of a desired trait into the DNA of a plant.

New tools are making plant breeding increasingly precise and efficient



Cross-breeding and selection produce plant varieties with the desired properties of both parent plants.

The texture and taste of the Red Delicious apple, for example, were achieved by combining its parents' properties.

Introduction of one or more genes from the same or different species into the DNA of a plant to create the desired trait.

In 2016, genetically modified plants were grown on 185.1 million hectares of land – more than ever before. This is more than 10 percent of the world's arable land. The biggest increases were in Brazil, the United States, Australia and Canada. In Europe, the EU decides on authorizations for GM plants. The member states may however enact national bans on growing GM crops.

Source: ISAAA 2017

New molecular biology methods make it possible to rewrite or change individual DNA blocks in genetic material – safer and more precisely than before. In medicine, this is leading to the possibility of curing certain hereditary diseases, but major advances are also possible in plant breeding.

CRISPR-Cas9, a genome editing method, is already being used to work on drought-resistant corn, allergen-free peanuts and mildew-resistant wheat.

Source: BDP 2014

Value contribution made by plant breeding – e.g. in the EU since 2000

Economic contribution

€14 billion

The yield increases resulting from plant breeding over the past 15 years currently contribute more than EUR 14 billion annually to the gross domestic product of the EU.

Higher yields

Due to plant breeding, harvest yields have increased annually by:

22 million tons of wheat

10 million tons of potatoes

Climate protection and sustainability

Annual CO_2 reduction due to plant breeding of approximately

-170 million tons

Affordable food

Without plant breeding, the prices of many foods would have increased over the past 15 years.

+7 % Wheat, potatoes

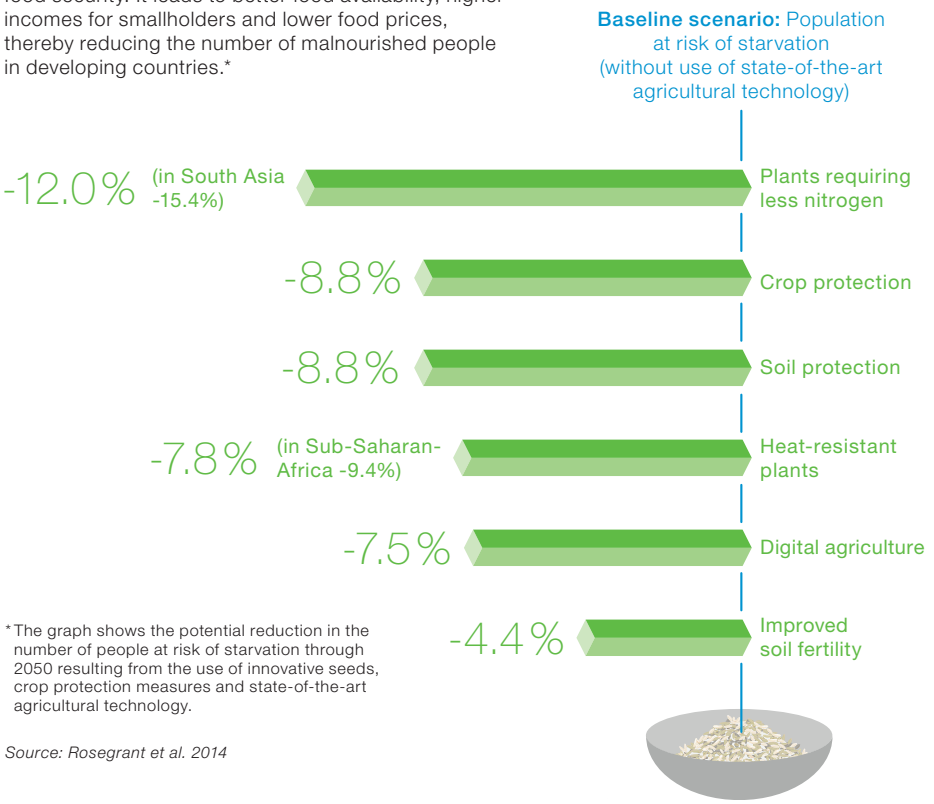
Source: Hffa Research GmbH 2016

Progress through innovation

Agriculture needs progress: new, weather-resistant varieties and technological improvements – for example in the area of irrigation – could help us win the battle against hunger and preserve natural resources.

State-of-the-art techniques can help us prevent starvation

Using modern technologies significantly increases food security. It leads to better food availability, higher incomes for smallholders and lower food prices, thereby reducing the number of malnourished people in developing countries.*



*The graph shows the potential reduction in the number of people at risk of starvation through 2050 resulting from the use of innovative seeds, crop protection measures and state-of-the-art agricultural technology.

Source: Rosegrant et al. 2014

DID YOU KNOW?

A **10 percent** rise in yields could reduce the number of people subsisting on less than US$ 1 per day by **7 percent** in Africa and more than **5 percent** in Asia.

Source: IFAD and UNEP 2013

Urban farming is becoming increasingly popular

Urban agriculture has become a major trend. In vertical farming, fruit or vegetables are grown in buildings on multiple levels, all year round. This reduces the demand for new farmland and can preserve natural resources.

+25%

On average the market volume for vertical farming is forecast to grow by 25 percent annually to more than US$ 6 billion by 2022.

+2.5 billion

Urbanization is picking up speed
By 2050, two-thirds of the world's population will live in cities. In 1950, this figure was roughly one-third.

+37%

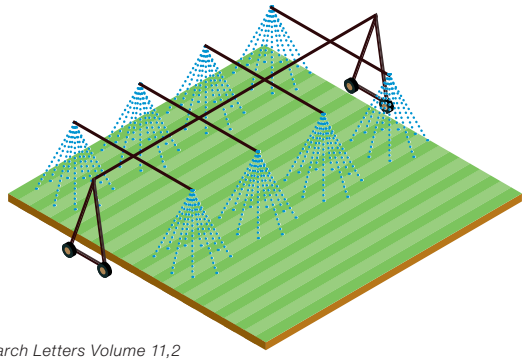
The number of megacities with more than 5 million inhabitants is forecast to grow by almost 37 percent to 104 by 2030.

Source: Market Research Engine 2017; UN 2014, 2016

Smart irrigation increases yields

Cutting-edge irrigation management can increase global kilocalorie production by

41%.



Source: J. Jägermayr et al. 2016 in Environmental Research Letters Volume 11,2

Digital fields

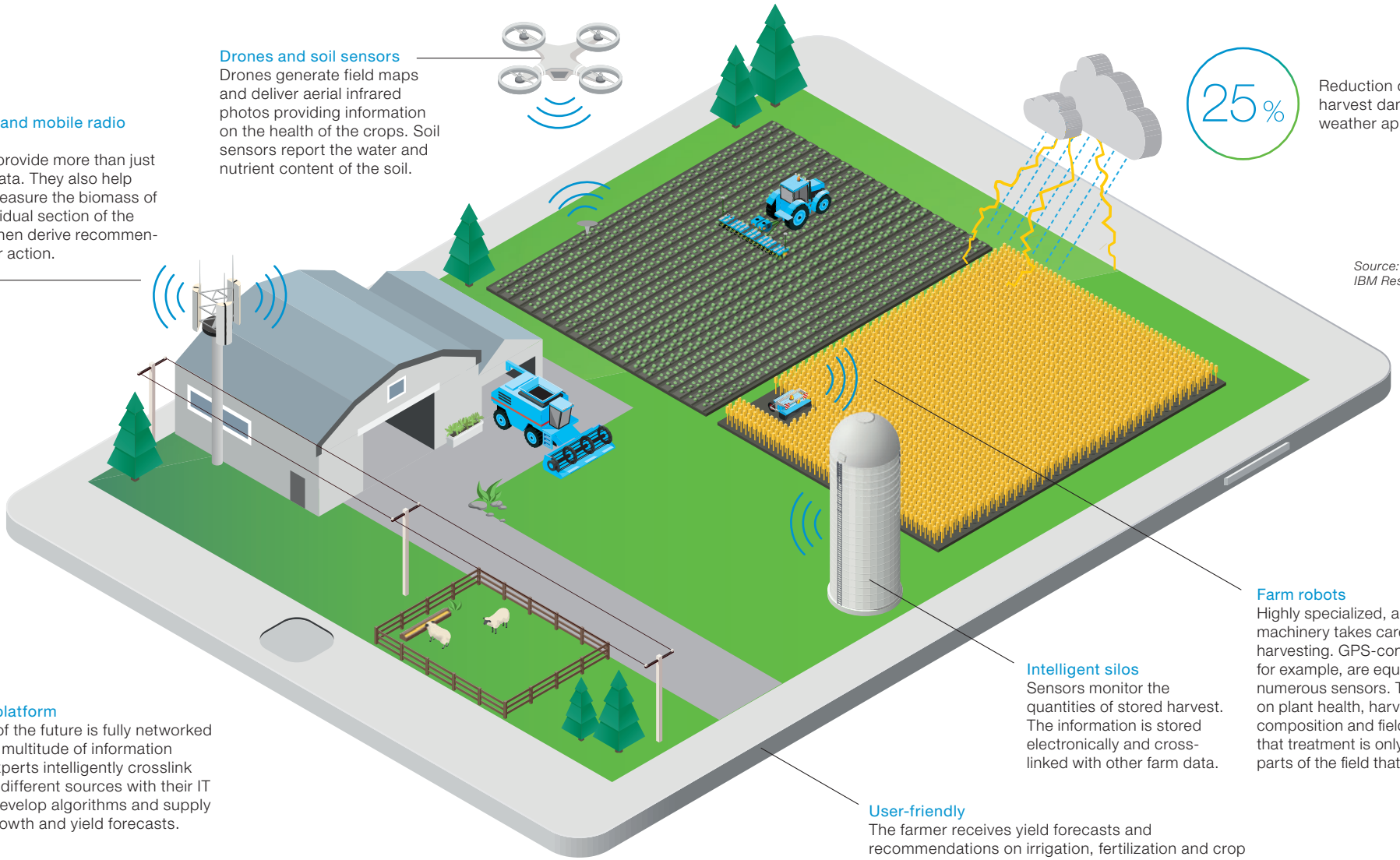
The digital revolution is changing agriculture as well. State-of-the-art tractors drive almost autonomously across the fields. Drones and soil sensors can detect diseases in the fields at an early stage. This enables farmers to apply fertilizer and crop protection agents more precisely.

25 %
Higher yields due to digital farming

Huge economic benefits
McKinsey estimates the economic benefits of digitalization in agriculture at up to US$ 330 billion through 2025.

Drones and soil sensors
Drones generate field maps and deliver aerial infrared photos providing information on the health of the crops. Soil sensors report the water and nutrient content of the soil.

Satellites and mobile radio antennas
Satellites provide more than just weather data. They also help farmers measure the biomass of each individual section of the field and then derive recommendations for action.



25 %
Reduction of weather-related harvest damage thanks to weather apps

Source: McKinsey 2015, IBM Research 2012

Farm robots
Highly specialized, automated machinery takes care of planting and harvesting. GPS-controlled tractors, for example, are equipped with numerous sensors. They collect data on plant health, harvest yields, soil composition and field topography so that treatment is only applied to those parts of the field that need it.

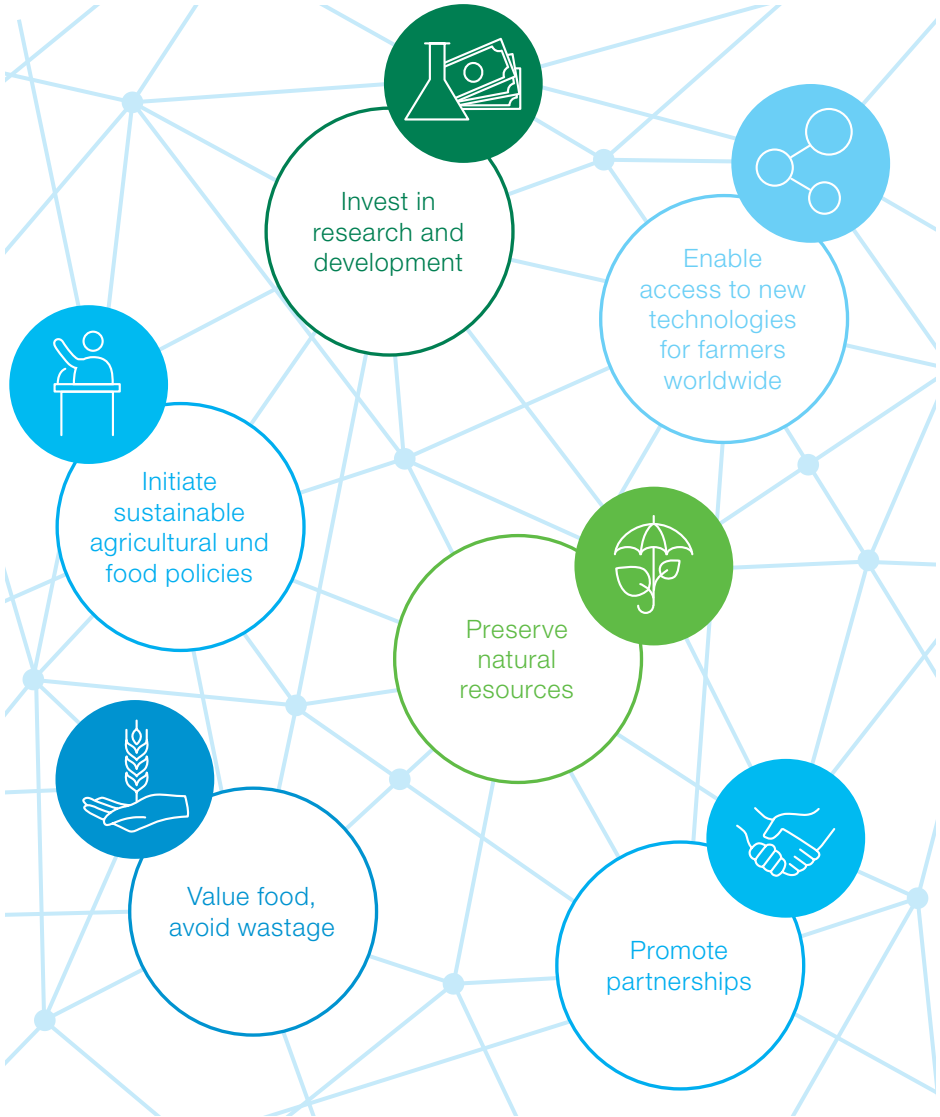
Intelligent silos
Sensors monitor the quantities of stored harvest. The information is stored electronically and cross-linked with other farm data.

Analysis platform
The farm of the future is fully networked and has a multitude of information assets. Experts intelligently crosslink data from different sources with their IT centers, develop algorithms and supply precise growth and yield forecasts.

User-friendly
The farmer receives yield forecasts and recommendations on irrigation, fertilization and crop protection on his smartphone, tablet or laptop.

For a world without hunger

To sustainably safeguard the food supply for a growing world population, it will not be sufficient to increase agricultural yields alone. Several factors have to intermesh to achieve a long-term improvement:



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AFBF – American Farm Bureau Federation

BDP – Bundesverband Deutscher Pflanzenzüchter e. V. [German Plant Breeders' Association]

BMEL – German Federal Ministry of Food and Agriculture

BZL – Bundesinformationszentrum Landwirtschaft [German Federal Agriculture Information Center]

CIA – Central Intelligence Agency

FAO – Food and Agriculture Organization of the United Nations

FAOSTAT – The Food and Agriculture Organization Corporate Statistical Database

Hffa Research – Humboldt Forum for Food and Agriculture Research

IEA – International Energy Agency

IFAD – International Fund for Agricultural Development

IFPRI – International Food Policy Research Institute

ILOSTAT – Statistical database of the International Labour Organization

InSTePP – International Science & Technology Practice & Policy

ISAAA – International Service for the Acquisition of Agri-biotech Applications

IVA – Industrieverband Agrar e. V. [German Agricultural Industry Association]

OECD – Organisation for Economic Co-operation and Development

UN – United Nations

UNCCD – United Nations Convention to Combat Desertification

UNEP – United Nations Environment Programme

UNESCO – United Nations Educational, Scientific and Cultural Organization

USDA – United States Department of Agriculture

UNU – United Nations University

WHO – World Health Organization of the United Nations

WMO – World Meteorological Organization

WRI – World Resources Institute

WWF – World Wide Fund For Nature

Masthead

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