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 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.

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)

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.

Infertile soils, species diversity threatened

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)

Food loss

Agricultural productivity

The over 500 million small-holders 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)

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

<table>
<thead>
<tr>
<th>Country</th>
<th>Share of agriculture in GDP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigeria</td>
<td>21.1</td>
</tr>
<tr>
<td>India</td>
<td>16.5</td>
</tr>
<tr>
<td>Brazil</td>
<td>5.2</td>
</tr>
<tr>
<td>United States</td>
<td>1.1</td>
</tr>
<tr>
<td>Germany</td>
<td>0.6</td>
</tr>
</tbody>
</table>

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

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.

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

Source: FAO 2014

Average farm size in ha

- North / Central America: 117.8 ha
- Europe: 12.4 ha
- Asia: 74.4 ha
- South America: 11.5 ha

In trillion US$, constant prices from 2005

Source: FAOSTAT 2017

What farmers contribute

In trillion US$, constant prices from 2005

Source: FAOSTAT 2017
The population is growing, the amount of arable land per person is 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

Amount of arable land per person in m² in comparison to a 7,140 m² football pitch (rounded figures)
Source: FAO 2012

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

DID YOU KNOW?

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.

Amount of arable land per person in m²

Population in billions

* Rounded figures, including permanent crops
Source: UN 2017, FAOSTAT 2017, FAO 2012, own calculations

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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

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.

1961 – 2007 2005/7 – 2050

Wheat

2.1% 0.7% Required growth rate of approx. 1%

Rice

1.8% 0.6%

Corn

2.0% 0.6%

Average annual yield growth rate in %

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

DID YOU KNOW?

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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

Food

43%

Animal feed

36%

Other uses (e.g. bioplastics, industrial production)*

14%

Biofuels *

7%

Share in percent, 2015, estimates

Source: FAO 2017, *own calculations

Using cereals for the production of bioethanol

2006

2015 (estimate)

69 million tons

165 million tons

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

Each farmer feeds increasing numbers of people

Germany

United States

17

1960

46

1990

69

129

156

2015

168

Source: American Farm Bureau Federation 2016, BZL 2017

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
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.

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

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Developing countries spend a lot of money on food

Percentage of total household expenses spent on food*

* (incl. non-alcoholic beverages)

Source: USDA 2016

Source: FAO 2012
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.

**Amount of land required for typical meals in m²**

- 2.23 m² Bratwurst with bread roll (100 g pork, 25 g beef)
- 0.45 m² Spaghetti with tomato sauce

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

Source: WWF 2015

**Food and emissions**

Annual food-related greenhouse gas emissions in Germany:

- Bratwurst with bread roll (100 g pork, 25 g beef): 2.23 m²
- Spaghetti with tomato sauce: 0.45 m²

That is 1,991 kg of CO₂ equivalents per person.

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

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:**

- Africa (Sub-Sahara): 100%
- Latin America: 90%
- South/Southeast Asia: 80%
- North Africa, Western/Central Asia: 70%
- Asia (industrialized countries): 60%
- Europe: 50%
- North America/Oceania: 40%

Source: WRI 2013

* 68 percent of which are animal-derived products.
* CO₂ equivalents describe the contribution to global warming so that the harmfulness to the climate of different greenhouse gases can be compared.
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

If the temperature increases by 2°C

- The availability of fresh water in the Mediterranean region will drop by 17%.
- Agricultural yields in tropical regions will change:
  - Wheat: -16%
  - Corn: -6%
  - Rice: +6%
- The length of hot spells will increase by up to 1.5 months.
- The intensity of heavy rain will increase by: +7%.
- Sea levels will rise by: +50 cm.
- 99% of coral reefs will be threatened with extinction from 2050 onwards.

Water – a scarce resource

- 40% of the world’s population will suffer from water shortages in 2050.
- 3/4 of all jobs worldwide – including in agriculture, fishing, the energy sector and other industrial segments – are dependent on an adequate supply of water.

Soil loss

- Intensive irrigation with salt water and/or insufficient drainage of arable land leads to increased salinization of the soil.
- 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.
- Worldwide, approximately 62 million ha of irrigated land are affected by this. This is equivalent to an area the size of France.

Species diversity is decreasing

- Animal and plant species are lost globally every year.
- One in five plant species is at risk of extinction.

*Average values relative to 1986–2005

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

Source: Grantham Centre 2015, UNU 2014

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 in 1980, 38.1 in 2011, 100 through 2050
- Private: 9.6 in 1980, 31.1 in 2011

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

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 *

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


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.


Plants need protection

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

DID YOU KNOW?

- 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
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

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.

Genetic engineering

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.

Marker-supported breeding

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.

Tissue culture

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

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Source: ISAAA 2017

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Precision breeding

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

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Source: ISAAA 2017

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

Economic contribution

CHF14 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 CO₂ 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.

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.*

Baseline scenario: Population at risk of starvation (without use of state-of-the-art agricultural technology)

-12.0% (in South Asia -15.4%)
-8.8% Crop protection
-8.8% Soil protection
-7.8% (in Sub-Saharan-Africa -9.4%)
-7.5% Heat-resistant plants
-4.4% Improved soil fertility

* 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.

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

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


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.

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.

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

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.

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.

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

25%
Higher yields due to digital farming

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


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.

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.
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:

- Value food, avoid wastage
- Initiate sustainable agricultural and food policies
- Preserve natural resources
- Invest in research and development
- Enable access to new technologies for farmers worldwide
- Promote partnerships
- Enable access to new technologies for farmers worldwide

Masthead

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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 – Bundesinformatikzentrum 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
ILSTAT – Statistical database of the International Labour Organization
InSTePP – International Science & Technology Practice & Policy
ISAAA – International Service for the Acquisition of Agri-biotech Applications
IVA – Industrieverbund 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

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