

Megatrends in the agri-food sector: global overview and possible policy response from an EU perspective



Research for AGRI Committee - Megatrends in the agri-food sector: global overview and possible policy response from an EU perspective

Abstract

This study provides an analysis of the megatrends that influence the way the world produces, distributes and consumes food. It provides an outlook of the global production needed to sustain human populations until 2050, gives a state of play of the global forces affecting the future of the food chain, suggests possible scenarios and presents policy and recommendation options.

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CONTENTS

LIST OF ABBREVIATIONS	5
LIST OF FIGURES	7
LIST OF TABLES	7
EXECUTIVE SUMMARY	9
1. INTRODUCTION AND METHODOLOGICAL APPROACH	15
2. OUTLOOK FOR GLOBAL FOOD PRODUCTION NEEDED TO SUSTAIN HUMAN POPULATION UNTIL 2050	19
2.1. Megatrends affecting the food demand and production	19
2.1.1. Demographic and income trends	19
2.1.2. Consumption patterns and emerging trends	21
2.1.3. Technological change	23
2.1.4. Climate change	25
2.1.5. Food waste	28
2.1.6. Competition for natural resources	28
2.2. Policy context	29
2.2.1. International agreements, policies and conventions	29
2.2.2. Environmental protection and sustainability	30
2.3. Food production and demand	30
3. GLOBAL FORCES AFFECTING THE FUTURE OF THE FOOD CHAIN	33
3.1. Trade agreements	33
3.1.1. Agri-Food Trade	33
3.1.2. Trade agreements	35
3.2. Economics of the value chain	36
3.3. Innovating food production systems and other elements	37
3.4. Transformation of the marketplace	38
4. MAJOR CHALLENGES	39
4.1. Agricultural productivity	39
4.2. Conservation of resources and environment	40
4.3. Improvement of nutrition and public health	41
5. SCENARIOS ELABORATION AND POLICY OPTIONS	45
5.1. Scenarios and policy options	45

5.1.1. Scenario 1 “Small steps but no goal”	48
5.1.2. Scenario 2 “Mass production at all cost”	49
5.1.3. Scenario 3 “Local Survivors”	50
5.1.4. Scenario 4 “Sustainability for all”	51
CONCLUSION	53
ANNEX 1: DEFINITIONS	55
ANNEX 2: METHODOLOGICAL APPROACH FOR THE SELECTION OF THE COMMODITIES TO BE QUANTITATIVELY ANALYSED IN THE STUDY	57
ANNEX 3: DETAILED QUANTITATIVE DATA	63
Cereals	63
Livestock	64
Others	65
ANNEX 4: SURVEY	67
ANNEX 5: DETAILED POLICY OPTIONS	71

LIST OF ABBREVIATIONS

AGRI	Agriculture and Rural Development Committee
AI	Artificial Intelligence
ALDE	Alliance of Liberals and Democrats for Europe
AoA	Agreement on Agriculture
B2B	Business to Business
B2C	Business to Consumer
BAS	Brake-assist systems
BMI	Body Mass Index
CAP	Common Agricultural Policy
CETA	Comprehensive Economic and Trade Agreement
CFP	Common Fisheries Policy
CMO	Common market organisation
CoR	Committee of the Regions
CULT	Culture and Education Committee
D2C	Direct to Consumer
EAP	East Asia-Pacific
ECOSOC	Economic and Social Committee
ECR	European Conservatives and Reformists
ECTS	European Credit Transfer System
EFDD	Europe of Freedom and Direct Democracy Group
ENF	Europe of Nations and Freedom
EO	Earth Observation
EPP	Group of the European People's Party (Christian Democrats)

FAO	Food and Agriculture Organisation of the United Nations
FPS	Frontal protection systems
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GM	Genetically-modified
GNSS	Global Navigation Satellite System
Greens/EFA	The Greens/European Free Alliance
GUE/NGL	European United Left - Nordic Green Left
ICT	Information and Communication Technology
IFI	International Fund for Ireland
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IUU	Illegal, Unreported and Unregulated
NCD	Non-Communicable Disease
OECD	The Organisation for Economic Co-operation and Development
S&D	Group of the Progressive Alliance of Socialists and Democrats in the European Parliament
TFP	Total Factor Productivity
TSE	Total Support Estimate
VR	Virtual Reality
WHO	World Health Organization
WOCAT	World Overview of Conservation Approaches and Technologies
WTO	World Trade Organisation

LIST OF FIGURES

Figure 1-1: Study Logic	16
Figure 2-1: Population growth in the world	20
Figure 2-2: Projected GDP per capita	21
Figure 2-3: Vegetarians around the world (2018)	23
Figure 2-4: Food waste and losses at the different stages	28
Figure 2-5: Evolution of global production (in mio tonnes)	31
Figure 2-6: Evolution of global livestock herd size (in mio units)	32
Figure 2-7: Evolution of global production of sugar cane, soybeans and cassava (in mio tonnes)	32
Figure 4-1: Impact of agriculture value chain on the environment	40
Figure Annex 3-1: Cereals growth percentage in 2050 in relation to the levels of 2012 in the sustainability for all scenario	63
Figure Annex 3-2: Livestock growth percentage in 2050 in relation to the levels of 2012 in the sustainability for all scenario	64
Figure Annex 3-3: Soybean, cassava and sugar cane growth percentage in 2050 in relation to the levels of 2012 in the sustainability for all scenario	65
Figure Annex 4-4: At which level should solutions be sought for?	69
Figure Annex 4-5: EU policy approach to tackle agri-food sector challenges	69

LIST OF TABLES

Table 2-1: Relevance of different factors affecting consumption behaviour in different parts of the world	22
Table 2-2: Technologies impacting the agri-food sector	24
Table 2-4: Climate change effects on crop and livestock	26
Table 3-1: Top 5 world agri-food - Table 3-2: Top 5 world agri-food	34
Table 3-3: Top 10 destinations of EU agri-food exports in 2018	35
Table 3-4: Top 10 origins of EU agri-food imports in 2018	35
Table 5-1: Overview of the drivers' characteristics per scenario	46
Table 5-2: Overview of the challenges impacting the scenarios	47

EXECUTIVE SUMMARY

KEY FINDINGS

- J The world faces a huge challenge to feed itself over the coming decades, as the world population is expected to reach 10 billion by 2050.
- J A 50 % increase in food production (as compared to present levels) will be needed by this date to feed an additional 2.3 billion people. According to current dietary trends and the expected rise in income per capita over the period, this might entail significant increases in crop yields and livestock units. The latter will prove challenging, as land used for livestock production already represents 80 % of all agricultural land.
- J While hunger has been reduced globally since the 1990s, more than 820 million people still have insufficient food. At the same time, global shifts to unhealthy diets in middle and high-income countries increase the burden of obesity and diet-related diseases.
- J The agri-food sector also faces environmental challenges, as food production is the largest cause of global environmental change: agriculture occupies 40 % of global land and food production is responsible for 21 % of global greenhouse-gas emissions and 70 % of freshwater use.
- J In the context of several key drivers of change (demographic and economic growth, evolving consumption patterns, technological progress, integration of global trade or climate change) which will all impact the agricultural value chain, the agri-food sector will thus have to adapt to this increasing food demand while at the same time addressing sustainability and health challenges.
- J Against this background the study outlines four alternative and contrasting scenarios that could shape the future of the food sector in the coming decades:
 - **Scenario 1 “Small steps but no goals achieved”**
 - **Scenario 2 “Mass production at all cost”**
 - **Scenario 3 “Local survivors”**
 - **Scenario 4 “Food and sustainability for all”**

This study explores the global trends that influence the way the world will produce, distribute, sell and consume food in a changing environment influenced by several key drivers of change (demographic and economic growth, evolving consumption patterns, technological progress, integration of global trade and climate change). Based on the challenges that agriculture and food systems are facing to feed a growing population in a sustainable way, it provides policy options along contrasting and alternative scenario lines.

Drivers and forces affecting food production consumption and agri-food value chain

By 2050 the agri-food sector must generate 50% more food and feed due to increased demand, which is generated by several key drivers:

Production and consumption of agricultural products is affected by a growing population, which will rise to nearly 10 billion people by 2050, especially in South Asia and Sub-Saharan Africa. **Population growth** is expected to take place in urban areas, resulting in 70% of the population living in cities by 2050.

A global rise in GDP per capita from 8,147 EUR in 2012 to 13,503 EUR in 2050 will result in an increase of consumption and **change in current consumption patterns**. Nevertheless, there will be still significant disparities between regions: in high-income developed countries, overproduction and overconsumption will lead to food losses and waste, as well as obesity and other health issues. At the same time, malnutrition will remain a high cause of death in Central Africa and some Asian countries.

Climate change does not only **shape the future conditions of agricultural production**, determining food availability and the stability of food supplies, but it also raises awareness of the effects of agriculture on global warming (**the sector is one of the major sources (21%) of emission of greenhouse gasses** (GHGs)) and the environment at large, leading people to adopt more sustainable food consumption patterns.

The abovementioned drivers affect not only farmers, but the entire agri-food value chain. **Agri-food value chains are becoming increasingly global**, offering employment opportunities for low- and middle-income countries, while potentially creating barriers for small-scale producers due to the consolidation of distribution channels. As one of the global forces affecting the value chain, **international trade is key to** the availability of food worldwide to meet increasing food demand, even if in most countries the majority of food consumed continues to be produced domestically. At global level, the introduction of **new technologies** could potentially **increase production more than land expansion (technology solutions are expected to increase yields by 30%)**.

Challenges

Against this background **coping with the rising demand for food** will become an even bigger challenge in the decades to come. **Combatting hunger and undernutrition** while **achieving satisfactory levels of food security** is already a major challenge in most low-income countries (e.g. Central Africa). On the other end, there is a global epidemic of obesity that is **increasingly starting in childhood** and has led to **1.9 billion overweight people**.

In parallel, all actors of the agriculture value chain (from production and storage to transport, food processing and retail) will have to adapt to rapidly evolving consumption and distribution patterns.

Land and water scarcity will also prove challenging since agriculture covers around 40% of the land surface (a proportion that is expected to increase by 5% by 2050). It also uses around 70% of freshwater, with significant differences in water availability across the globe, which will exacerbate water scarcity in some regions and might result in conflicts between countries. Faced with competing needs by other activities, farmers will have to secure land and water use, while at the same time coping with increased

price volatility and labour shortages. **The agri-food chain will thus have to step up its innovation efforts to live up to these challenges, while making sure that new technologies and production techniques are accepted by society. The fight against food waste will be part of the equation, given that around 50% of food produced is currently wasted between the farmer and the consumer.**

Scenarios

Based on the development of these specific drivers, four contrasting scenarios could shape the future of the agri-food system:

- J **SCENARIO 1 “Small steps but no goals achieved”** represents the business as usual situation, whereby despite some efforts, the main challenges of environmental sustainability and food security are not fully addressed. Under this scenario, by 2050 the environment will have degraded significantly, and food demand will not be met.
- J **SCENARIO 2 “Mass production at all cost”**, is a scenario where the boundaries of natural resources are pushed to an extreme and actions are undertaken only in the direction of producing more agricultural output to cope with food demand without taking into consideration sustainability. Under this scenario food security is achieved at the cost of climate change and environmental degradation.
- J **SCENARIO 3 “Local survivors”** represents a situation where, worldwide, many countries and regions move towards securing their food supply based on domestic or regional production, abandoning global free trade and weakening international institutions.
- J **SCENARIO 4 “Food and sustainability for all”** is a very optimistic and proactive scenario, where a lot of actions towards sustainable food and agricultural systems are put in place to reduce environmental impacts and increase food production, in order to ensure both food security and sustainability by 2050. To achieve a “great food transformation”, sustainable food production for about 10 billion people should use no additional land, safeguard existing biodiversity, reduce consumptive water use and manage water responsibly, substantially reduce nitrogen and phosphorus pollution, produce zero carbon dioxide emissions, and cause no further increase in methane and nitrous oxide emissions.

Policy options

The likelihood of the scenarios depends on the policy options that could be adopted in order to respond to the agri-food trends and challenges.

Focus	Policy options
Scenario 1 “Small steps but no goal”	
Food security	Improve production potential by using current CAP instruments and ensure well-functioning food chain.
Climate change	<p>Increase incentives under the CAP proposal for resource-efficient and climate-friendly agriculture technologies.</p> <p>Continue to support global initiatives to reduce GHG emissions (e.g. Paris Agreement) and biodiversity losses as well as to ensure that all bilateral trade agreements negotiated by the EU duly consider environmental protection.</p>
Farmers	<p>Ensure fair revenue for farmers through CAP direct aid system, decoupled and current coupled aid. Prioritise innovation and technology in Rural Development investment support.</p> <p>Support farmers with infrastructure, credit facilities, facilitate and further digitalise the CAP. Public support to young farmers.</p>
Food safety	Continue to monitor and ensure that European food safety and quality standards are applied by all local and national food producers as well as in the countries from where EU imports originate.
Consumers	<p>Continue to support and invest in education regarding obesity and undernutrition to adopt healthier lifestyles and diet habits among future generations (e.g. EU school fruit, vegetables and milk scheme).</p> <p>Continue to contribute towards the development of a fully-fledged EU nutrition policy (e.g. consumer information, content of nutrients relevant from a public health perspective) through regulation and self-regulation as appropriate.</p>
Scenario 2 “Mass production at all price”	
Food security	<p>Ensure that food production and supply in the EU reaches the appropriate level to feed all population in the long term.</p> <p>Develop crisis management plans for situations in which EU production or supply are disrupted because of market or natural occurrences (e.g. weather conditions, animal and plant diseases etc.).</p>
Climate change	Deprioritising climate change across relevant EU policy areas.

Farmers	<p>Increase CAP support to farmers revenue with shift from decoupled aid system towards coupled aid and price support mechanisms linked to food security objectives.</p> <p>Establish compulsory priority mechanisms of investment in technology uptake. Allow EU farmers to have access to existing and new biotechnology techniques.</p>
Food safety	<p>Monitor and ensure that European food safety and quality standards are applied by all local and national food producers as well as in the countries from where EU imports originate.</p>
Consumers	<p>Support and invest in education regarding obesity and undernutrition to achieve healthier dietary habits among future generations.</p>
Scenario 3“Local survivors”	
Food security	<p>Address food security in a non-structured and inhomogeneous way.</p> <p>Invest in technology innovation to grow products under specific conditions and guarantee enough production in terms of quantity.</p>
Climate change	<p>Stop addressing climate change in international fora and via international cooperation</p> <p>Invest in the protection of agriculture at domestic level.</p>
Farmers	<p>Improve farmers revenue in areas where agriculture policies exist already (e.g. CAP, U.S. Farm bill).</p>
Food safety	<p>Continue to monitor and ensure that European food safety and quality measures are applied by all local and national food producers.</p>
Consumers	<p>Design and implement protectionist policies that encourage consumers to buy domestic and local food products and as a result compartmentalise the international agri-food market.</p>
Scenario 4“ Food and sustainability for all”	
Food Security	<p>Foresee incentives under CAP proposal for increasing and/or maximising agricultural production in the EU.</p> <p>Foster uptake and knowledge-sharing of technology and digitalisation in agricultural production as driver for food security.</p>
Climate change	<p>Continue to support global initiatives to reduce GHG emissions (e.g. Paris Agreement) and biodiversity losses as well as to ensure that all bilateral trade agreements negotiated by the EU duly consider environmental protection.</p>

	<p>Ensure effective and timely implementation of EU requirements at reducing GHG emissions, including in agricultural production.</p> <p>Prepare for the “Great Food transformation” at all levels (producers, consumers, technology providers, retailers...).</p>
Farmers	<p>Increase and improve CAP spending to support EU farmers through decoupled aid system as well as coupled aids to specific product with health and food security objectives.</p> <p>Establish minimum thresholds for Member States to support investments with high degree of innovation and technology uptake.</p>
Food safety	<p>Making sure that EU food safety standards are necessary, proportionate and consistent with other policy objectives so that ultimately food safety is not detrimental to food security.</p> <p>Continue to monitor and ensure that European food safety and quality standards are applied by all local and national food producers as well as in the countries from where EU imports originate.</p>
Consumers	<p>Increase support and investment in education regarding environmental protection, obesity and undernutrition to achieve adoption of healthier lifestyle and diet habits of future generations (e.g. EU school fruit, vegetables and milk scheme)</p> <p>Develop of a fully-fledged EU nutrition policy (e.g. consumer information, content of nutrients relevant from a public health perspective) through regulation and self-regulation as appropriate</p>

1. INTRODUCTION AND METHODOLOGICAL APPROACH

The worldwide agri-food sector has in recent years undergone some major changes, namely in terms of demographics, food demand and supply, consumption patterns and agricultural production techniques. Over the coming years till 2050 these changes are expected to accentuate: there will be more people to feed; older farmers producing food under changing environmental conditions; new technologies entering in the agricultural processes and new consumption requirements to satisfy. In order to successfully cope with these changing conditions, it is important to understand the forces behind these changes to the agri-food landscape and the challenges that they will potentially bring to the sector and to adapt policy in a timely manner.

A number of **megatrends** are influencing the food availability, security and the overall functioning of the agri-food systems. These trends have different impacts on different industries, and their analysis may help to trace **potential scenarios and establish policy options** linked to them. This study will present the main megatrends affecting the agri-food sector in the recent past and the decades to come, namely in terms of:

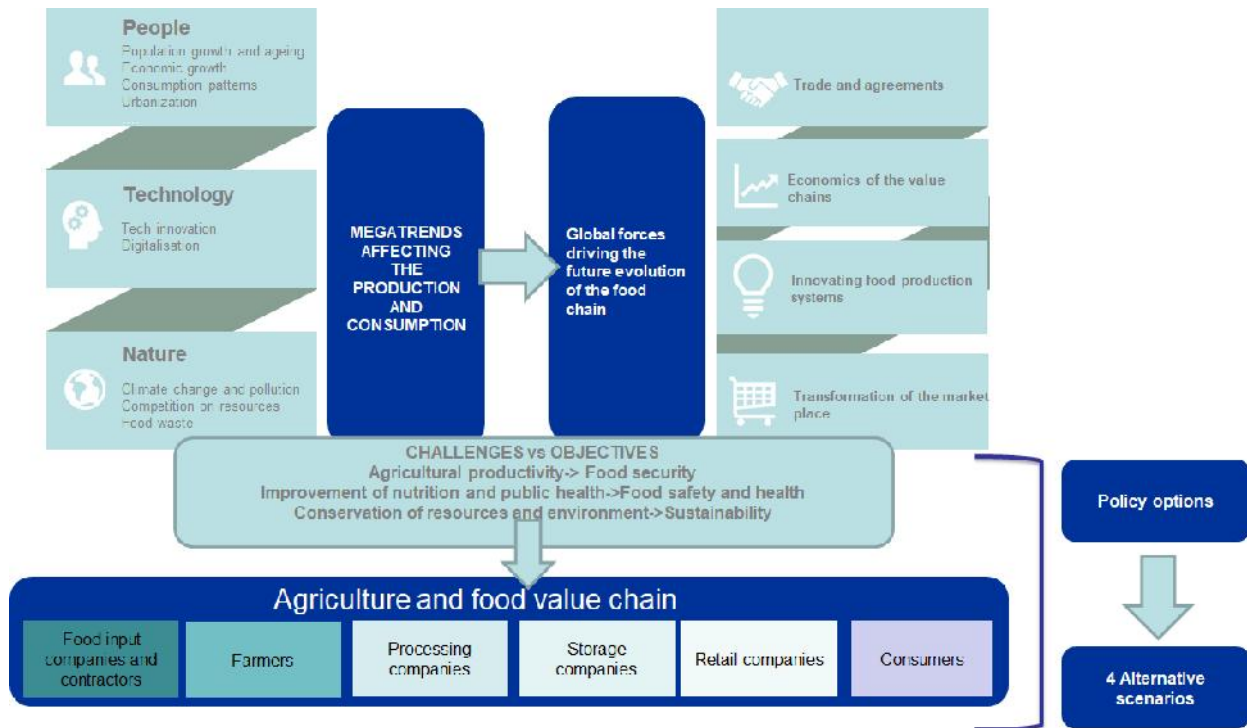
-) Demographic and income trends
-) Consumption patterns
-) Technological change and innovation in the agri-food sector
-) Environmental trends linked to climate change, food waste and scarcity of natural resources.

Global forces such as growing demand for food, change in production techniques and global trade **are affecting the agri-food value chain**, which on top of the trends, influence the food security and availability. Food availability is one of the main issues in the framework of the forecasted agri-food situation in 2050. In fact, these trends and global forces generates a series of challenges such as:

-) Uncertain agricultural productivity;
-) Difficulty to estimate the real consequences of climate change and to protect resources and environment;
-) Necessity to improve nutrition and public health.

A combination of those drivers, forces and challenges lead the report to four possible scenarios, which generate different policy options.

Figure 1-1: Study Logic



Source: VVA

Beyond desk research and analysis, to illustrate the above topics the study also provides:

-)] **Quantitative data regarding the necessary growth in production by 2050 for main agriculture products** such as cereals and meat, in order to meet rising food demand. The analysis presented in this section is based on FAO’s database of food and agriculture projections to 2050 in the towards sustainability scenario, which corresponds with the “sustainability for all” scenario as it is described in Chapter 5. This part of the study provides quantitative evidence to illustrate for a specific selection of agricultural products (the multi-criteria analysis for the selection of the crops can be found in Annex 2), the required increase in production in order to cope with the food demand under environmental sustainability. Quantitative data is provided for the group of cereals (maize, rice and wheat); for the group of meat (buffaloes, cattle, pigs, poultry) as well as cassava, soybean and sugar cane. For cereals, cassava, soybeans and sugar cane the quantitative data presents the growth of production (in%) needed by 2050 in order to feed the world in a sustainable way. The total production is the product of the yield and the harvested area, for which the needed percentage of growth is also calculated. The evolutions are illustrated among 8 regions, predefined by FAO. For the meat subgroup, the model illustrates the percentage increase needed in the herd size, in order to meet the food demand and minimise the environmental impact (Annex 3).
-)] **Scenario development.** Starting from the identification of the most pertinent scenarios-based studies, the study developed four scenarios, which consider previously investigated drivers, forces, challenges. The aim of this approach is to compare alternative future scenarios in which challenges are tackled in different ways. This comparison will help understand the potential implications of the policy options in each of the scenarios.
-)] **Survey on the main drivers and challenges of the Agri-food sector.** In order to gather international views on the main drivers and challenges across the agri-food value chain, a

survey was launched. The survey gathered the opinion of 21 agri-experts, who contributed to the validation of the study findings. The results of the survey can be found in Annex 3.

) **High level stakeholder consultation with main agri-experts.** With the purpose of gathering information and validating findings several stakeholders from across the whole food-chain were interviewed. During the interview, the stakeholders were asked to contribute to the qualitative analysis of the current megatrends and of their impact. The companies, associations and universities that contributed are listed below.



2. OUTLOOK FOR GLOBAL FOOD PRODUCTION NEEDED TO SUSTAIN HUMAN POPULATION UNTIL 2050

KEY FINDINGS

-) The population is growing at a significant rate and is predicted to reach nearly 10 billion people in 2050. According to FAO, by 2050 the agri-food sector will have to generate 50% more food and feed to be able to meet the increased demand for food.
-) Growing income per capita and increasing urbanisation generate higher food consumption per capita. Current food systems will only be able to feed a total population of almost 10 billion people in 2050 if healthy diets from sustainable food sources are adopted (this implies notably that the consumption level of red meat and dairy products remains at current levels).
-) New technologies are a critical driver affecting food production. Technological innovation could potentially increase production more than land expansion (technology solutions are expected to increase yields by 30%). Technology can enhance ecological efficiency and create new business models while fostering innovation.
-) Climate change has significant consequences for the agriculture sector. Moreover, agriculture itself is responsible for high GHG emissions. Climate change will cause higher rates of undernutrition due to availability of fewer calories per capita. Food insecurity will rise as climate change increases the frequency of damaging climate events that will affect production.
-) From producer to consumer, one third of the world's food is being lost or wasted, whereas natural resources for agriculture are projected to become even more scarce by 2050 (About 70% of all water is used for agriculture).
-) Biofuels are being increasingly used by countries (60 billion litres in 2007 to 130 billion litres in 2015) looking for alternatives to fossil fuels. Bio energy consumes three quarters of all energy coming from renewable sources (cereals and oilseeds are being used more and more to make biofuels).

2.1. Megatrends affecting the food demand and production

2.1.1. Demographic and income trends

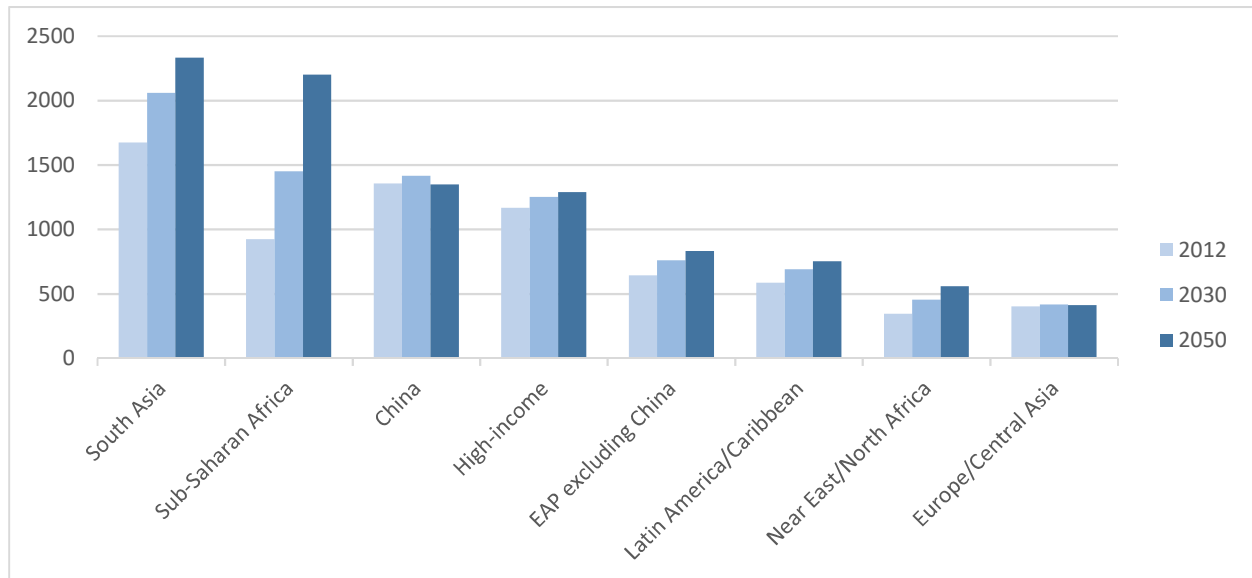
a. Population growth

The main factor affecting the demand for food is the current growth in global population. The Food and Agricultural Organization (FAO)¹ estimates that overall the current agriculture will have to produce 50% more by 2050 to keep up with demand.

The world population has been growing constantly and will continue to grow from 7.1 billion people in 2012 to an estimated 9.8 billion in 2050 and up to 11.2 billion in 2100.² The figure below represents the FAO's projections for population. As the graph shows, Sub-Saharan Africa will experience the largest increase with a projected growth of more than 100% between 2012 and 2050, accounting for almost 1.3 billion people. South Asia ranks second with a growth of almost 700 million people followed by Near East/North Africa which will both experience a growth of around 200 million people. The populations of high-income countries will increase by around 10%, i.e. 111 million people.

South Asia and Sub-Saharan Africa are expected to increase their population up to 4.5 billion people, which will represent more than 46% of the global population. FAO estimates that these two regions will have to more than double their agricultural output by 2050 to meet their food demand in the current state of play.

Figure 2-1: Population growth in the world



Source: VVA elaboration based on FAOSTAT database. Numbers are in '000 people.

The population growth is expected to take place in urban areas, resulting in **70% of the population living in cities by 2050**. By definition, urbanisation has led people to live further away from rural areas where food is produced and to reduce their food markets options.³

b. Ageing workforce

High-income countries already experience an ageing population and low-income countries are following suit. Together with urbanisation, this process will have considerable consequences for the agricultural labour force and the socio-economic situation of rural communities. Additionally, older farmers often experience discrimination when trying to access credit, training or other income-generating resources. Older farmers thus often miss out on new technology or agricultural innovations because they lack the resources, skills or energy to invest. To support older people in farming, it will be therefore be necessary to adapt farming technologies and policies to their needs.⁴

c. Rising GDP per capita

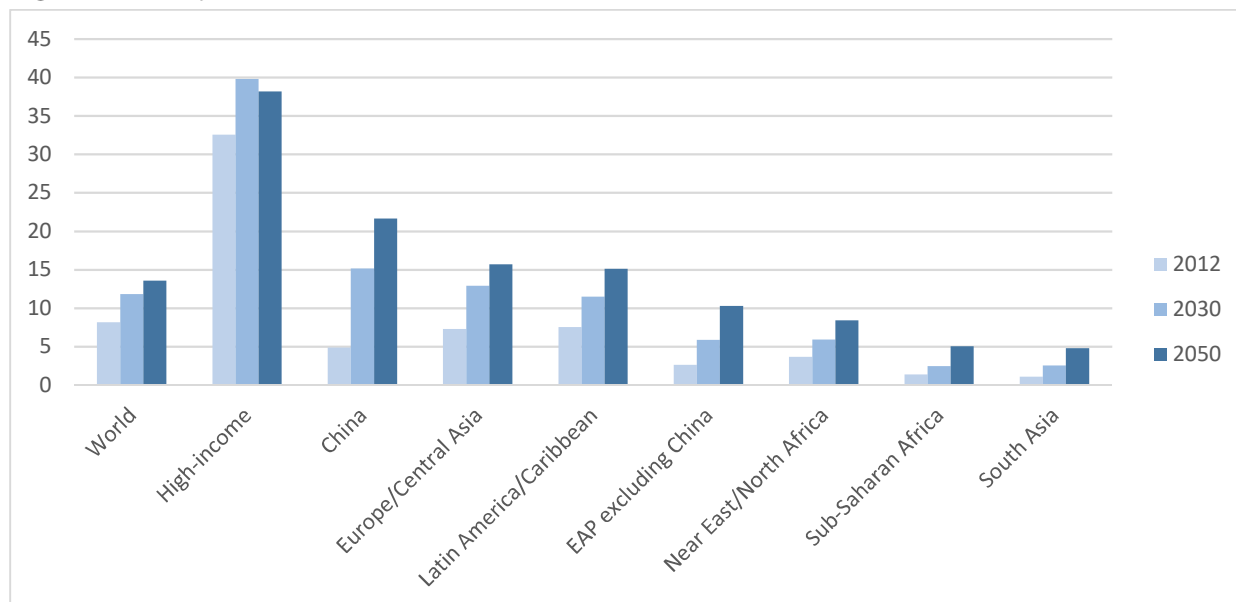
In addition to population growth, income affects food consumption and demand. People from low-income countries spend a high proportion of their income on food. Furthermore, the absolute demand for food increases with rising incomes in low-income countries (FAO). The level of income is also positively related to the consumption of animal-based proteins. People tend to eat more meat, milk and eggs as their income rises.⁵

All regions of the world are projected to experience a **positive change in income**, As shown in the graph below. Globally, GDP per capita is forecast to increase from 8,178 EUR in 2012 to 13,554 EUR in 2050. In **China, East-Asia Pacific, South Asia and Sub-Saharan Africa**, it is projected to **more than quadruple by 2050** compared to 2012. Other growing regions are Europe/Central Asia (excluding high-income countries) and Near East/North Africa, which are expected to double their GDP per capita

by 2050. In all regions high-income countries will stabilise around 2030 and even experience a slight decrease from 2035 until 2050.

An increasing GDP per capita represents a higher purchasing power, thus implying an increase in consumption. Combined with an increase in population, the effect of rising incomes will also increase demand and production will need to increase accordingly.

Figure 2-2: Projected GDP per capita



Source: VA elaboration based on FAOSTAT database

Note: The projections are estimated based on the 2012 prices and average USD/EUR exchange rate of 2012. Numbers are in 000' EUR.

2.1.2. Consumption patterns and emerging trends

Growing income per capita and increasing urbanisation generate higher food consumption per capita⁶. Urbanisation could affect consumption patterns as people take less time to buy and/or prepare their own meals. The consequence is that there could be a rise in demand for convenience products such as ready-made meals and packaged meals.⁷ Food processing is therefore expected to play an increasingly important role in the agri-food value chain. This choice for convenience and higher food prices will lead people to buy more of their food in the form of pills, shakes and powders, which will lead to more demand for processed foods.

The consumption itself differs across countries and depends on education level, tradition, consumers' purchasing power, religious and non-religious beliefs, social awareness, age and other factors. The table below shows how these patterns differ across regions according to how relevant they are. Convenience and healthiness are among the most important factors that affect consumption behaviour.

Table 2-1: Relevance of different factors affecting consumption behaviour in different parts of the world

Consumption patterns	Africa	Developed Asia-Pacific	Emerging Asia	Developed Europe	Emerging Europe	Latin America	Middle East	North America
Consumption behaviours								
Convenience	Medium	Medium	Medium	High	Low	Medium	Low	High
New experiences	Low	Insignificant	Low	Medium	Medium	Medium	Medium	High
Healthier food	Insignificant	High	Low	High	Medium	High	Low	High
Food as a treat	Insignificant	Low	Medium	High	Insignificant	High	High	Low
Food preferences and choices								
Health & belief driven	Low	Medium	High	Medium	Low	Low	Low	High
Desire driven	Low	Low	Low	Medium	High	Medium	Medium	High
Influencing factors								
Education	Low	Low	Insignificant	Low	Medium	Insignificant	Low	Low
Social media	Low	Medium	Medium	High	Low	High	High	High
Friends & Family		Low	High	High	High	High	Medium	Medium
Regulation	Insignificant	Low	Low	Medium	Medium	Medium	Medium	Low
Health awareness	Insignificant	High	Low	High	Medium	High	Low	High

Source: VVA elaboration based on <https://www.wbcsd.org/Programs/Food-Land-Water/Food-Land-Use/FReSH/Resources/Understanding-the-shift-required-towards-healthy-sustainable-and-enjoyable-diets>

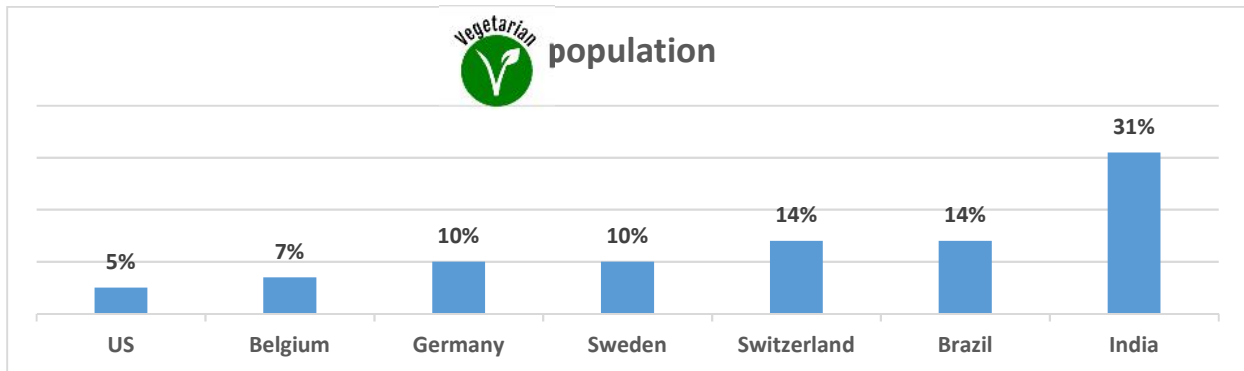
In low-income countries, consumers currently look for affordable food options, which often correspond to highly processed and energy-dense foods. Low-income countries are expected to witness a considerable shift towards higher consumption of not only ready-to-eat and highly processed products but also of products of animal origin, sugars and vegetable oils. It is noticeable that in low-income countries the trend for consumption of animal products is higher than in high-income countries, where the food choice is more centred on plant-based products and cereals.⁸ In this sense, it is also important to highlight that there is an overall trend among low-income countries towards a high-calorie and high-protein diet.⁹ When it comes to fruits and vegetables, low- and middle-income countries increased their consumption by 3% between 1961 and 2011. FAO expects these trends to continue.

In high-income countries food choice is potentially healthier and increasingly centred on products of non-animal origin. They are expected to experience an increase in the consumption of cereals, fruits and a decrease of products of animal origin, namely red meat. However, in the past 50 years, daily intake of protein has increased in high-income countries, particularly from meat, eggs, milk and dairy products. Looking ahead, these trends are likely to further consolidate. In high-income countries, still, people with lower income consume cheaper foods and more processed and packed food.

Over the last decades mainly middle- and **high-income countries have witnessed a growing consumer's appetite for healthier, more environmentally conscious and ethical diets and lifestyles**. Indeed, consumers living in these countries are increasingly mindful of the impact and the

implications of their daily purchasing decisions in terms of environmental protection, animal welfare and respect of labour standards. There is a rise of **veganism**ⁱ, **vegetarianism**ⁱⁱ and, more recently, **flexitarianism**ⁱⁱⁱ. These dietary choices and lifestyles that a growing number of individuals have been embracing were mainly prompted by strong concerns over animal welfare practices in the current food production system and health consequences resulting from animal-based diets. Currently, it is estimated that 21.9% of the world population is vegetarian.¹⁰ National surveys provide a good indication of the uptake of this diet across the world.¹¹

Figure 2-3: Vegetarians around the world (2018)



Source: Arcadia adaptation based on national sources¹²

Likewise, consumers, especially in high-income countries, are increasingly willing to purchase high-value **organic food** as opposed to more affordable conventional food.

Another consumption trend is the **alternative protein sources** such as laboratory created meat or insects, which are already getting to the plates. These alternative proteins and new methods of food design are being developed to provide more efficient and environmentally friendly food sources. Among others, edible insects are also becoming more and more popular in certain specific markets such as sports nutrition, dietetic food, food supplements. Whilst consumption of edible insects is culturally accepted in several countries, it remains to be seen whether and to what extent consumers in the western world, who are not yet familiar with them, will be ready to accept and integrate them into their diets.¹³

The EAT-Lancet commission reports that **current food systems will only be able to feed a total population of almost 10 billion people in 2050 should healthy diets from sustainable food sources be required. This would only be possible if the consumption level of red meat and dairy products remains as it is without further increase.**¹⁴

2.1.3. Technological change

The usage of new technologies in the agri-food sector can generate numerous benefits:

-) **Technological innovation could potentially increase production more than land expansion.** Innovation can boost the Total Factor Productivity (TFP) of the agricultural industry, i.e. it can increase crop and livestock output without an increase of input (e.g. use of

ⁱ Veganism is a diet centred on the consumption of food derived from plants, which excludes the consumption of fish and meat and all animal products.

ⁱⁱ Vegetarianism is a diet centred on the consumption of food derived from plants, which excludes the consumption of fish and meat but admits consumption of certain animal products (e.g. dairy products, eggs).

ⁱⁱⁱ Flexitarianism (otherwise known as semi-vegetarianism) is a diet mainly centred on the consumption of food derived from plants and which admits consumption of meat and fish occasionally.

land, labour and capital). Technologies have the potential to enable the development of precision agriculture solutions, which overall **are expected to increase yields by 30%**.¹⁵

J The introduction of new technologies in the agri-food processes can enhance **ecological efficiency**, considering that **agriculture is one of the main causes of the emission of greenhouse gasses (GHGs)** and is thus a major factor of climate change. FAO estimates that agriculture is **responsible for 21% of total GHG emissions**. Technology improvements can for example be the used for new **land and water conservation techniques, improved biodiversity preservation technologies, enhanced production technologies** (such as agroforestry, organic agriculture, agroecology) and **integrated pest management**.

J **Technological solutions** will not only modernise agriculture, increasing the efficiency of its processes, but also **create new business models** while fostering innovation (e.g. Mobile applications to rent tractors).

These technologies are depicted in the below table:

Table 2-2: Technologies impacting the agri-food sector

Technology	Impact on agriculture
Biotechnology	Genetic modelling to increase the production while decreasing the volatility of the yield and the usage of pesticides.; laboratory-grown meat
Synthetic biology	Crops with higher nutritious values with less resources, and resistant to more variable climates. ¹⁶
Internet of Things (IoT)	IoT to collect and publish information on the production processes and the farm.
Automation and Robotization	Increased productivity by reducing the need for human workforce. ¹⁷
Artificial Intelligence (AI)	Contribute in agricultural robotics (e.g. automatization of farm equipment), soil and crop monitoring (e.g. identify plant diseases), and predictive analytics (e.g. detect pest infestation). ^{18 19}
Big Data	Contribute in the decision-making process to increase efficiency in crop planning, intelligent irrigation systems development, pest control, weather alerts implementation. ²⁰
Global Navigation Satellite System (GNSS)	Improve crop yield and reduce environmental impact through the application of for example farm machinery guidance, automatic steering, variable rate applications, yield and soil condition monitoring. ²¹
Drones	Soil, field and crop analysis and monitoring, variable rate applications, e.g. crop spraying and irrigation. ²²
Blockchain	Enhance transparency, accountability and efficiency in agricultural insurance, land registration, and agricultural supply chains. ²³
Augmented Reality	Optimization of the farming process. ²⁴

Source: VVA

The following box summarizes the impact of the new technologies in the agri-food sector, based on a study commissioned by the European Parliament's Committee on Agriculture and Rural Development in 2019^{iv}:

Impacts of the digital economy on the Food-chain and the CAP

(Research for the AGRI Committee, February 2019)

The study researched the impact of **new emerging technologies on agriculture**. Demand for technology in agriculture is rising and can assist farmers to face current and future challenges.

The main outcomes of the study were threefold:

- 1. Expected high impact on the agri-food value chain** by technological advancements that include the integration of technologies in systems to enhance traceability. These advancements are mostly seen in a combination of **IoT, big data** and **AI** or **AI** and **robotization**.
- 2. Expected medium impact on the agri-food value chain** by technologies like **Blockchain, global navigation satellite system (GNSS)** and **Virtual Reality (VR)**.
- 3. Expected low impact on the agri-food value chain** by broadband networks, **Information and Communication Technology (ICT)** and **platforms for e-business**.

Lower prices of technologies will increase the demand for new technologies. New developments in technology can provide new and effective production possibilities.

Technological applications sometimes target **reduction of risks in production** like the detection of crop diseases in early stages. Drones are used to create detailed soil maps for **damage control** that benefits the whole value chain. Other applications aim at reducing **the risks from emissions and climate change** that have an effect on society in general. More than often, **efficiency in production** is the main driver of technological development which leads to a reduction of the use of energy and water resources impacting the environment and climate positively. Finally, technological advancement drive not only vertical integration but also **horizontal integration** in the food-chain which tends to favour large food suppliers.

Cooperative farming is on the rise for small sized farmers that can't afford to purchase equipment. They establish consolidated land and share the benefits and costs related to the purchase of new technology. **Digital services and platforms** exist now that make it possible to **hire machinery** through **smartphone apps** and allow a 'pay per use' mechanism.

New players like **start-ups** are entering the traditional farming value-chain. They introduce the **technologies and expertise** in the network of stakeholders around the farms. **Precision farming** is revolutionising the agricultural industry with **centimetre accuracy** in fields and the ability to manage seeds, fertilizers, water, crops and reduce and target spraying of diseased plants, providing **continuous control and supporting decision making**.

The future of agriculture will also be greatly impacted by **biotechnology**. Disease-resistant plants will **decrease the volatility of the yield, increase the production and reduce the usage of chemical pesticides**.

2.1.4. Climate change

The impact of climate change on agricultural production is widely researched, and it is certain that countries with a low latitude are expected to be affected the most. **Globally, the increase in droughts and floods will decrease yields in general**. Increased temperatures can have a positive effect on yields, but when they exceed a certain threshold, crop yields could decrease considerably. **Rising**

^{iv} [https://www.europarl.europa.eu/thinktank/fr/document.html?reference=IPOL_STU\(2019\)629192](https://www.europarl.europa.eu/thinktank/fr/document.html?reference=IPOL_STU(2019)629192)

temperatures and increasing water scarcity will negatively impact small-scale livestock farmers especially in arid, semi-arid and rangeland environments located close to the equator. It will have adverse effects on the health of the cattle and the quality and supply of feed and fodder (FAO, 2009). Countries in low-latitude areas, i.e. closer to the equator, will experience higher temperatures and longer droughts which will result in lower crop yields – e.g. rainfed agriculture in semi-arid zones. At the same time, some countries located in mid latitudes will experience higher crop yields. **On the one hand, 19-23 ha are being lost per minute due to soil erosion and desertification, with tropical regions the most affected**, in addition to the decrease of available lands for agriculture due to urbanisation (estimated to be around 1.5 million km² up to 2030). On the other hand, climate change is expected to increase the cropland suitable for agriculture by 5.6 million km², primarily in Canada, China and Russia.

The table below summarises the different effects of climate change on crops and livestock in different areas of the world.

Table 2-3: Climate change effects on crop and livestock

North America	Crop yields decline until 2050.
Latin America and the Caribbean	Productivity decreases and increases in different parts of the region.
Europe	Countries with temperate and polar climates will see a yield increase but mid-latitude countries will eventually see a decrease.
Sub-Saharan Africa	This region will, in general, experience yield decreases.
Near East and North Africa	Rising temperatures and water shortages will decrease production of wheat in North Africa and maize in the whole region.
Asia	Water shortages will lead to a move of agricultural production to the north.
Oceania	New Zealand will benefit in terms of wheat yields, but pasture will decline in contrast with Australia that will face soil degradation and water scarcity.

Source: VVA elaboration based on FAO, The state of food and agriculture (2016)

In low- and middle-income countries, climate change will cause higher rates of undernutrition such as a lower calorie per capita availability, undernutrition of children and related infant mortality. **Food insecurity will rise because climate change will bring harsh climate events such as droughts and floods, tropical storms, heat waves and wildfires, which will affect production.** Not only will the supply be affected, but the quality, access and utilisation of food will be negatively impacted too. The nutritional value of some crops may decrease due to higher levels of carbon dioxide²⁵.

THE IPCC' SPECIAL REPORT ON CLIMATE CHANGE AND LAND (August 2019)

The IPCC Special Report on Climate Change and Land, authored by 107 experts from 52 countries, explores the relationship between climate change and landscapes across the globe and what it means for our collective future. It arrives less than a year after the IPCC's alarm-raising 1.5°C report, which found that the world needs to take urgent, transformative action to avert the worst impacts of climate change beyond 1.5°C degrees warming.

Its conclusions are threefold:

1) Climate Change is already impacting people and ecosystems on land : dangerous events caused by changing weather patterns, including flooding, drought, wildfires, and extreme heat (like the heat wave that hit Europe this summer) are becoming more common across the globe. Climate change impacts are also undermining food and water security. Overall, it is expected that every degree of warming will likely reduce crop yields, productivity, and livestock production globally, while food demand continues to rise.

2) Changes to land are driving climate change: human-driven changes to land cause roughly a quarter (**23%**) of man-made emissions. Activities like agriculture and food production, deforestation, and desertification (when fertile land turns to desert) are some of the biggest sources of climate change on land. Land serves as a sink for carbon, because healthy ecosystems and soils can absorb carbon from the atmosphere. However, degraded land *does not have the capacity to absorb carbon and can actually release carbon*. And it's possible that climate change and human activities could damage land to the point where it becomes **a net source of carbon emissions**.

3) We can harness solutions from the ground up, right now. Listed below are some possible solutions from the land we need to step up to meet the climate challenge:

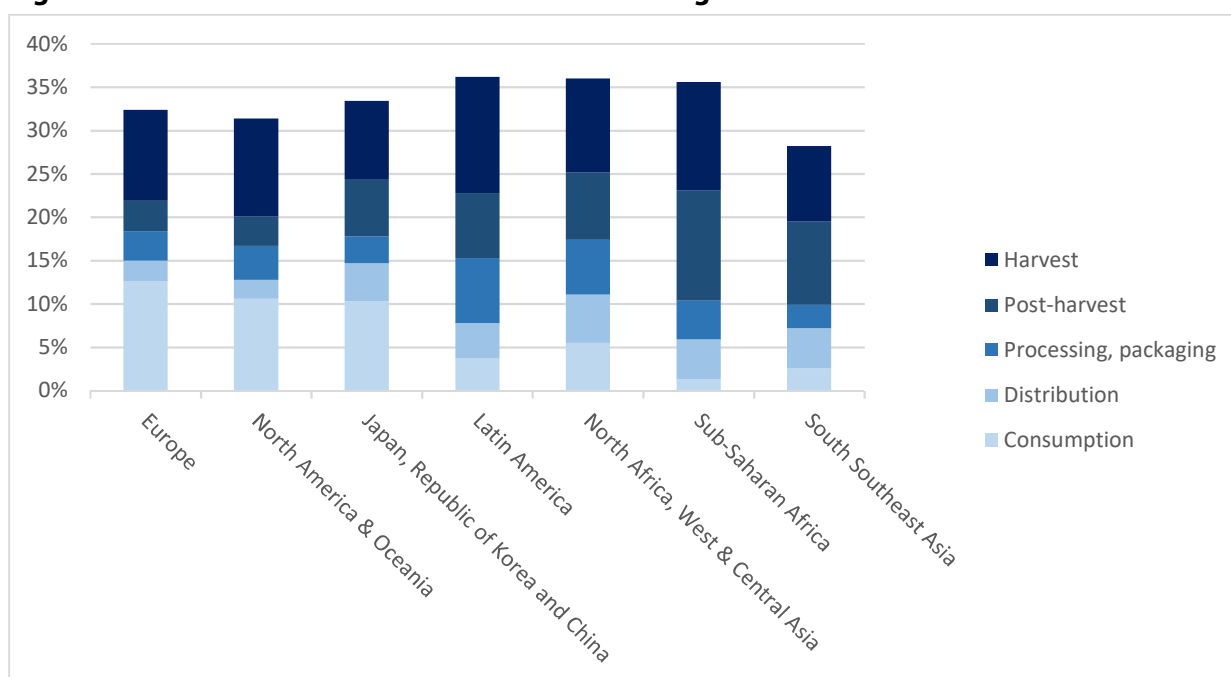
- Protecting Ecosystems: Roughly 72% of ice-free land is affected by human activity. Keeping wild areas wild and free from human pressures is crucial for saving biodiversity and drawing down emissions.
- Reforestation and Afforestation: Planting trees on recently deforested land or agricultural lands that were previously forested can restore ecosystems and absorb major amounts of carbon.
- Eating Healthier Diets and Reducing Waste: Being smarter about what's on our plates can be game-changing for the planet and better for our diets. An additional 1 billion people could be fed if food waste was halved globally. And reducing meat consumption can cut down on the most polluting forms of agriculture.
- Soil Management: Over 2.7 billion people are affected globally by desertification, meaning nearly a third of the world's population has lost productive lands for farming and for absorbing carbon. Soil management can be applied to decertified soils to an area slightly bigger than Europe, improving peoples' livelihoods and economic opportunities.

2.1.5. Food waste

From producer to consumer, one third of the world’s food is being lost or wasted.²⁶ In particular, it causes loss of land, water, energy and agricultural inputs and an unnecessary emission of tonnes of GHG.

The difference between food waste and loss is important to indicate since they have different causes and require different solutions. Food waste occurs when food fit for consumption is wasted accidentally or intentionally at the retail level. Food losses, conversely, occur along the food chain (for instance, during transport and storage) and are not always under direct control of the actors involved. Food losses are often due to inadequate technology, lack of knowledge and skills, bad logistics and inefficient markets.

Figure 2-4: Food waste and losses at the different stages



Source: VVA adaptation from FAO database

Food losses and waste are estimated to be 1.3 billion tonnes every year, almost equally distributed among high-income countries and low- and middle-income countries.²⁷

Consumers will have to decrease their own waste and be more mindful about food waste along the agri-food value chain by prioritising suppliers committed to supporting the circular economy. Policy and economic decisions could have a negative impact on food waste, for example when **some subsidies cause excess production in order to lower prices.**²⁸ These excesses lead to less concern about food waste by both producers and consumers because of the lower prices. Policies will have to raise awareness on the need for food prices to **cover the environmental and social costs of food production and waste.**

2.1.6. Competition for natural resources

The greater competition between food and non-food uses of biomass will increase the interdependence between food, feed and energy markets. There are risks that this competition may also have harmful impacts on local food security and access to land resources. **Water and land are the two most precious natural resources needed to preserve to keep a sustainable agri-food system.**

Natural resources for agriculture are projected to become even more scarce by 2050. Increased scarcity will intensify competition for these resources, which can lead to their over-use. In turn, such over-use can cause land degradation, leading to even more scarcity and competition. The growing trend of unsustainable competition is causing more land degradation, deforestation and water scarcities. In some cases, where countries have made efforts to decrease GHG emissions, they increased competition for land and water resources, for example with the creation of bioenergy that takes up agricultural production.²⁹

Biofuels are being increasingly used by countries looking for alternatives to fossil fuels. Bio energy comprises three quarters of all energy coming from renewable sources. **Cereals and oilseeds are being used more and more to make biofuels,** just as biomass is gradually being used to substitute petrochemicals. The production of biofuels has seen a significant increase in the past decade, growing from 60 billion litres in 2007 to 130 billion litres in 2015, and it is expected to keep growing in the coming years. This trend is putting extra pressure on agricultural output. In addition, the production of fish through aquaculture is increasing demand since oilseeds are used as fish feed.³⁰

Freshwater availability is becoming increasingly critical because of irrigation and urbanisation. About **70% of all water usage is meant for agriculture,** and in areas with limited rainfall, such as Middle East, North Africa, central Asia, India and China, depletion of natural water sources for irrigation is a serious problem.³¹

2.2. Policy context

2.2.1. International agreements, policies and conventions

Although the characteristics of the agriculture sector may differ substantially from one regional or national context to another, the current challenges are largely the same across all countries.³² These include primarily:

-) ensuring that farmers receive a viable income and develop greater resilience towards agricultural risks;
-) addressing environmental concerns, including climate change and scarcity of natural resources such as land and water; and
-) guaranteeing higher agricultural productivity so as to meet the rising future food demand.

Against this background, countries plan, and design integrated national agricultural policies so as to best respond to their own political, economic, environmental and/or social priorities. It is also unquestioned that over the last decades agriculture has received increased public attention owing to growing awareness about its importance in modern societies in terms of food security, healthy living, economic competitiveness, trade and environmental impact.

The following subsections focus in particular on the evolution of public intervention in support of agriculture and of the progressive integration of the environmental dimension into agricultural policies at international level.

Agricultural policy support

Particularly because of the role that agriculture plays in the economic context of all countries and its dependence on global and local forces and shifts, government policies traditionally provide support to farmers through a mix of instruments that best suit national needs.

According to the Organisation for the Economic Co-operation and Development (OECD), over the last two decades **OECD countries have progressively reduced the overall level of policy support to**

agriculture. In the OECD countries, on an average, total support to agriculture - expressed as Total Support Estimate (TSE) - slightly declined from 1.3 % of OECD aggregate GDP in 1995-1997 to 0.7% in 2015-2017. In addition to that, direct support to farmers - expressed as Producer Support Estimate (PSE) - represented **18% of gross farm receipts** in 2015-2017 across the whole OECD area, registering a decline of almost 30% as opposed to 1995-1997. This trend has been also accompanied by a shift in the type of policy intervention embraced by high-income countries, notably in the **EU** and the **US**, insofar as direct payments have been gradually favoured over other more distortive forms of public intervention such as output payments and market price support.³³

Conversely, **countries with emerging economies have been generally increasing aid to agricultural production** primarily by introducing market price support measures. In 2015-2017, government support in such countries, expressed as PSE, was estimated to be around **14% of gross farm receipts**. Although this is still below the OECD average, the gap has been reduced.³⁴

2.2.2. Environmental protection and sustainability

Drastic or major overhauls of national agricultural policies do not happen very often nowadays. Rather, countries seem to opt for reviewing and adjusting their agricultural policies in light of emerging needs and priorities at national and international level.

From this perspective, the most important changes registered over time to the content of agricultural policies are an immediate consequence of **global environmental concerns**, amongst which land management and climate change stand out in particular. In this context, **innovation** is increasingly regarded as a key driver to meet market demand for agricultural products and, at the same time, to ensure **sustainability of the agricultural sector** as a whole.³⁵

The EU makes no exception to this general trend owing to the place that environmental protection and sustainability have on the EU agenda. By way of example, already in 2003 the EU had strengthened cross-compliance under EU agricultural policy by linking direct payments to farmers to the respect of good agricultural practices and ecological conditions. More recently, in 2013 **EU agricultural policy** was given a **stronger focus on the provision of environmental public goods** and a **'greening' component of direct payments** was introduced.³⁶

2.3. Food production and demand

In the current situation, to meet the future food and feed demand of the projected world population in 2050, the agricultural production levels should increase compared to the current levels by almost 50%. Considering that between 1961 and 2011, the global agricultural output tripled, this increase is estimated by FAO as feasible. However, taking into consideration all the current drivers and trends previously explained, this increase may be more difficult to achieve than before. The increase in production could be achieved via accommodation of new land or increase in production, where the latter is the preferred option, in order to preserve water resources, biodiversity and forests.

According to FAO's towards sustainability projections³⁷ and data, the following production increase is required in the main agricultural products in order to respond to the projected demand^v:

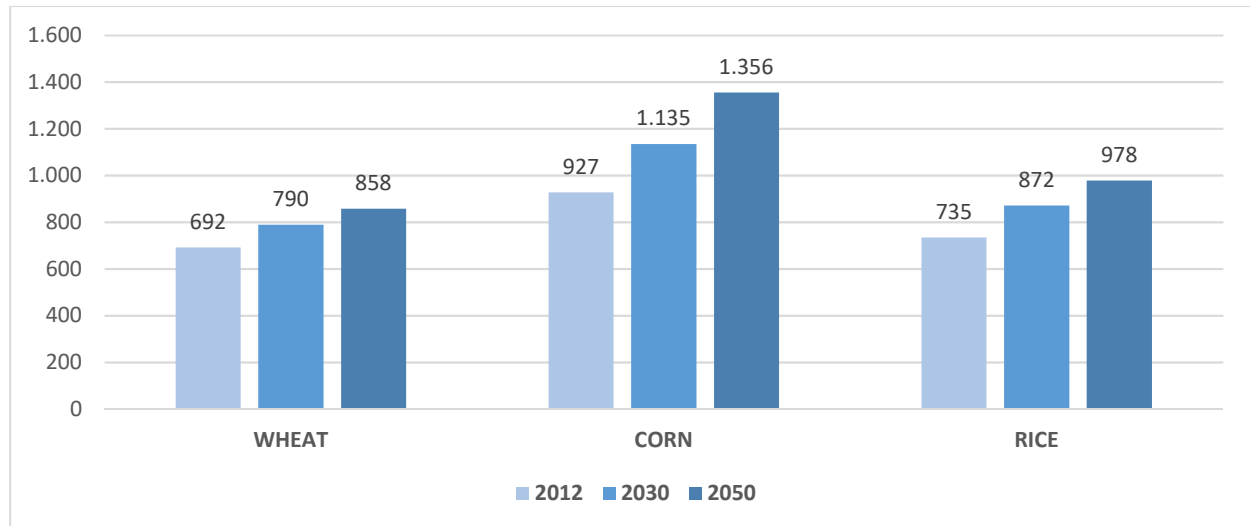
^v The FAO database, food (agriculture) production and demand match by construction. The database is built through the FAO GAPS partial equilibrium model that matches supply and demand.

Cereals

Under the FAO's "Towards sustainability" projections, where the consumption of meat decreases and as a consequence the need for feed production decreases, the model projects an **increase in global cereal production^{vi} of 39% from 2012 to 2050**, which is lower than the levels that could be required if the world continue to follow the current state of play (54%)³⁸.

The figure compares the growth in cereals crop production required to feed the population in 2050

Figure 2-5: Evolution of global production (in mio tonnes)



The production of wheat should increase by 24% compared to the historical values of 2012, the **rice** production should, in its turn, increase by **33%** and the **corn by 34%** compared to the historical values of 2012, the **rice** production should, in its turn, increase by **33%** and the **corn by 34%**.

The average annual increase in wheat, corn and rice yields is slightly more than 1% since 1990.

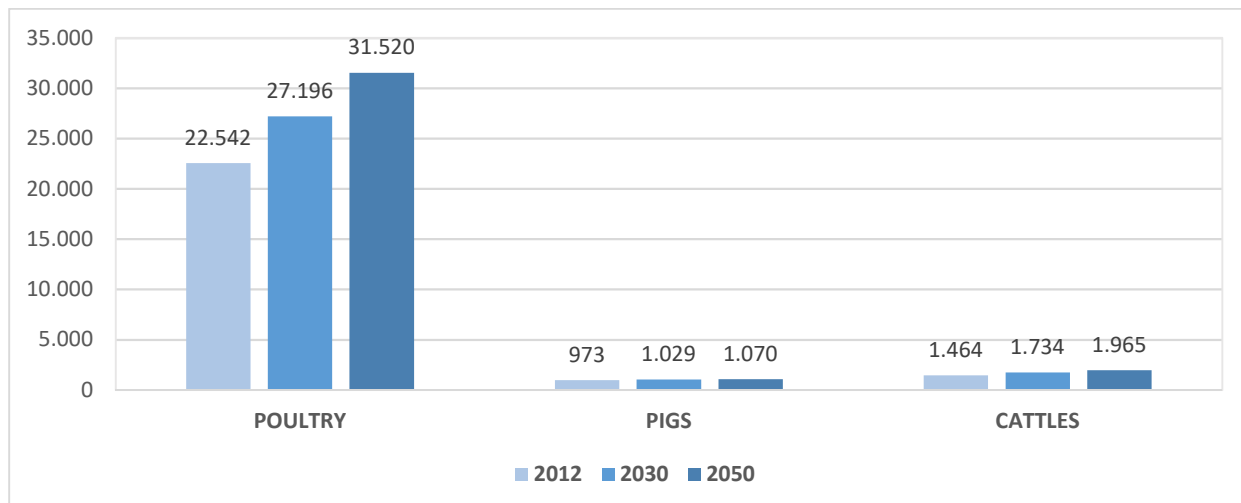
Livestock

Although there is a need to decrease the consumption of meat to achieve sustainable agriculture by 2050, there should be a relatively modest expansion of the current levels of production in order to feed the world. Under FAO's "Towards sustainability scenario" **the global meat production should increase by less than 30% by 2050 compared to 2012**. The increase is relatively low due to change in consumption patterns. In a scenario with current consumption patterns, where there is lack of awareness for healthy diets and preservation of the environment, the increase would be much higher.

Regarding meat production, the following figure analyzes the growth in raising poultry, pigs and cattle required to feed the population in 2050. **The herd size of poultry would need to increase by 40%, the one of cattle by 34% and the pigs only by 10%.**

^{vi} Not limited to wheat, corn and rice.

Figure 2-6: Evolution of global livestock herd size (in mio units)



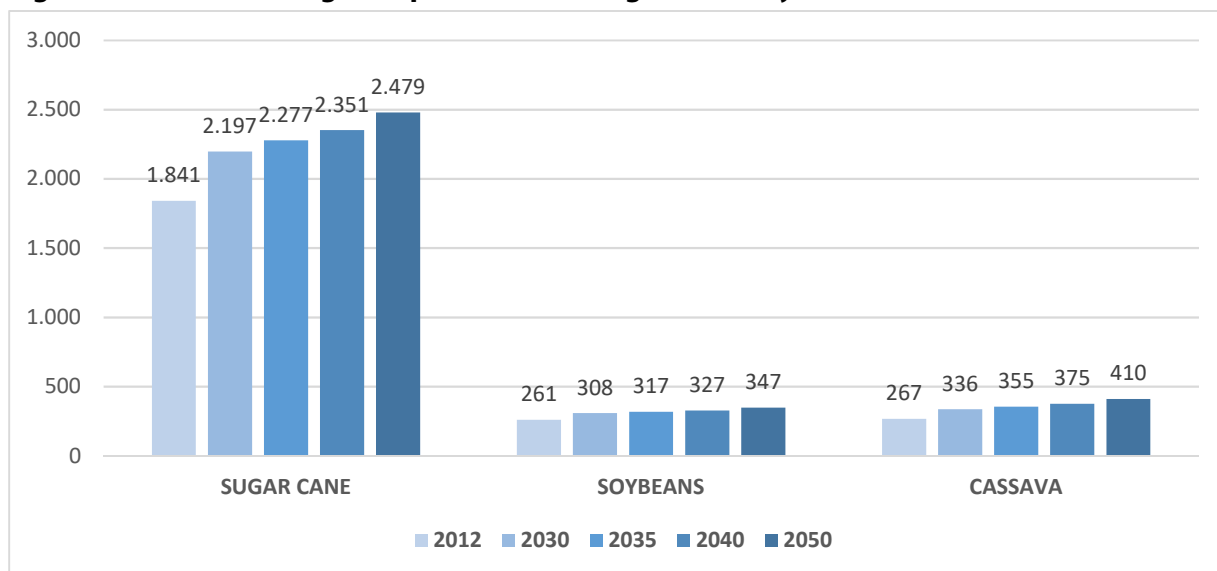
Others

By 2050 the production of sugar cane should increase by 35% compared to the level of production in 2012. The production of soybeans is expected to reach a 33% increase and the cassava 54%.

The global average annual increase in the yields of soybeans and sugar cane is less than 1% since 1990, which could be alarming, considering the fact that the increase in demand should mainly be focused on increasing the yields rather than the land.

The figure provides the growth in sugar cane, soybeans and cassava crop production required to feed the population in 2050 under FAO's "Towards sustainability scenario".

Figure 2-7: Evolution of global production of sugar cane, soybeans and cassava (in mio tonnes)



3. GLOBAL FORCES AFFECTING THE FUTURE OF THE FOOD CHAIN

KEY FINDINGS

- J Given that the distribution of crops production around the world is not uniform, international trade in agricultural goods has the potential to contribute to a better availability of food across the globe, which is essential to address the forecasted high demand.
- J Agri-food value chains are becoming increasingly global, offering employment opportunities for low- and middle-income countries, while potentially creating barriers for small-scale producers due to the consolidation of the distribution channels.
- J A consolidation of the current consumption trend is expected, i.e. in low-income countries, increased consumption of highly processed and energy-dense foods, products of animal origin, sugars and vegetable oils, while in high-income countries, food choice is increasingly focused on products of non-animal origin.
- J Consumers living mainly in middle and high-income countries are increasingly mindful of the impact and the implications of their daily purchasing decisions in terms of environmental protection, animal welfare and respect for labour standards.
- J The agro-food marketplace is undergoing far-reaching changes, including horizontal and vertical collaborative partnerships between actors (producers, retailers) and the development of business-to-consumers and business-to-business digital platforms and on-line food sales.
- J While innovation penetration varies according to the farm size, foreseen benefits and typologies of business, it is always key to cope with climate change and new consumption patterns and will be instrumental in meeting the demand of an increasing population.

3.1. Trade agreements

The significant increase in population and demand for food expected by 2050, especially in low-income countries, is driving a need for a more **integrated international trade**, namely in the agribusiness sector. Generally, **export markets provide an important source of growth for a country's agricultural sector** by offering greater demand and subsequent increased income margins for farmers. Moreover, given that the distribution of **crops production around the world is not uniform**, international trade in agricultural goods has the potential to contribute to better availability of food across the globe, which is essential to address the forecasted high demand.

3.1.1. Agri-Food Trade

World trade grew on average 5% per year between 1990 and 2010³⁹. Despite the growth of agricultural trade, most of the food consumed in many countries is produced domestically. According to FAO forecasts, world food trade will continue to grow until 2030, with both China and India doubling their global market share during this period to gain 25% of the total world trade. The share of all low-income countries is foreseen to amount to 65%.

In terms of trade balance, **Argentina, Australia** and the **US** are net exporters of agri-food products with more than 50% of their domestic production destined to foreign markets. Conversely, the **Near**

East/North Africa region together with **Sub-Saharan Africa, South Asia, China** are net importers of food.^{vii} The two tables below show the top world agri-food exports and importers of agri-food trade in 2018.

Table 3-1: Top 5 world agri-food
Exporters in 2018

	Top world agri-food exporters	Billion €
1	EU 28	138
2	United States	128
3	Brazil	72
4	China	49
5	Canada	40

Table 3-2: Top 5 world agri-food
importers in 2018

	Top world agri-food importers	Billion €
1	United States	118
2	EU 28	116
3	China	105
4	Japan	51
5	Canada	31

Source: https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/news/documents/agri-food-trade-2018_en.pdf

Currently, the **EU** is the first agri-food exporter worldwide, with a positive trade balance of over EUR 21 billion registered in 2018. In the same year, wine, spirits, infant foods and other cereal-, starch- and milk-based preparations ranked as the top three EU exports, while tropical fruits, nuts, spices, oils and coffee and tea represented the most important EU imports value wise.⁴⁰

The two tables below show the EU main destinations and origins of agri-food trade in 2018.

^{vii} https://ec.europa.eu/agriculture/sites/agriculture/files/trade-analysis/statistics/outside-eu/countries/agrifood-usa_en.pdf

Table 3-3: Top 10 destinations of EU agri-food exports in 2018

	Top Destinations	Value Mio €	% Share Extra- EU
1	USA	22 256	16.2
2	China	11 101	8.1
3	Switzerland	8 254	6.0
4	Japan	6 642	4.8
5	Russia	6 624	4.8
6	Norway	4 496	3.3
7	Saudi Arabia	3 814	2.8
8	Canada	3 707	2.7
9	Hong Kong	3 679	2.7
10	Australia	3 384	2.5

Table 3-4: Top 10 origins of EU agri-food Imports in 2018

	Top Origins	Value Mio €	% Share Extra- EU
1	USA	12 078	10.4
2	Brazil	11 910	10.2
3	China	5 711	4.9
4	Ukraine	5 617	4.8
5	Argentina	5 136	4.4
6	Switzerland	4 593	3.9
7	Turkey	4 482	3.9
8	Indonesia	4 341	3.7
9	Ivory Coast	3 361	2.9
10	India	3 153	2.7

Source: https://ec.europa.eu/agriculture/sites/agriculture/files/trade-analysis/statistics/outside-eu/countries/agrifood-usa_en.pdf

3.1.2. Trade agreements

Trade policies and trade agreements play an important role in the global agri-food chain. International trade in agri-food products falls under the remit of and should be fostered by the World Trade Organization (WTO) via multilateral negotiations. However, it is a fact that changes observed in the global economic and political landscape are making it more and more difficult to agree on shared solutions and a common way forward also, but not only, with regard to international trade of goods and services. The introduction of protectionist trade measures by several countries is a clear symptom of the difficulties referred to above.⁴¹

Faced with this deadlock, several countries have opted for developing and/or strengthening their own trade agenda, namely by engaging in bilateral trade negotiations with their key commercial partners. Overall, from an agri-food trade perspective, such agreements mainly aim at progressively liberalising trade in agri-food products by removing or reducing custom duties and/or import quotas that limit market access for foreign products. They may also foster harmonisation, equivalence and/or uniform application of rules on food safety, animal and plant health as well as provide a legal framework for the protection of geographical indications.⁴²

On the EU front, a study published by the European Commission in 2017 indicated that the economic impact of bilateral trade agreements can be significant to the extent that EU agreements with Mexico, South Korea and Switzerland have increased EU agri-food exports to those countries by 11%, 15%, 9%, respectively, which represents more than EUR 1 billion in total.⁴³ Accordingly, over the last decade the EU has embarked on the negotiation of a new generation of comprehensive and ambitious bilateral

trade agreements with Canada, Japan, Singapore, Vietnam, Australia, New Zealand and recently concluded trade talks with the Mercosur block.^{viii}

3.2. Economics of the value chain⁴⁴

The increasing global population together with a continuous urbanisation have an effect on the value chain. Due to increased GDP and urbanisation, people tend to consume more processed food, meat, fruits and vegetables, putting more pressure on production of these types of food. In a context of increasing global demand for food and specialisation possibilities offered by international trade, **the food supply chain is becoming increasingly vertically integrated, with large multinational companies collaborating with food processing, transforming, storage and retail industries at regional or local level.**

Farmers and contractors

In fact, agri-food value chains are becoming increasingly global, thus offering employment opportunities for low- and middle-income countries. However, they can create barriers for small-scale producers because of the difficulty in accessing large distribution channels (e.g. hypermarkets). To cope with increasing demand, agri-food value chains are investing in technology in order to introduce automated processes, which also could reduce labour requirements. Small-scale stakeholders have difficulties in coping with the financing, transport costs and market accessibility of integrated value chains. This results in a concentration of power among big supermarket chains, which allow them to request large amounts of stock from their suppliers. Economically, this practice helps large supermarket chains to quickly respond to a fluctuation of demand and maintain prices.

Currently, vertical integration occurs at the national level and across countries through the development of global value chains. Small-scale producers are able to benefit from those integrated value chains via fair contracts with traders or processors. With the presence of agricultural contractors, a farmer is contracted to produce and market a farm product. Contractors are also key in the contribution to the uptake of innovation and technology (e.g. Global Navigation Sattelite System and Earth Observation) that can help fight climate change.

Processors

When it comes to processed foods, the scope of food products is very broad. FAO defines processed foods as all foods that are not consumed fresh but are altered through processes that go beyond simple procedures such as washing, peeling and removal of non-edible parts, cutting, squeezing, mixing or refrigeration. Thus very common products like bread, cheese or even yoghurt are considered as processed foods. In fact, 70% of the agricultural output in Europe is used for processed food. Generally, processed foods are not necessarily unhealthy, even the opposite, they often are crucial in a healthy diet. Additionally, in order to feed the planet and ensure sustainable production, food production cannot be focused solely on fresh products. Processed foods can, in a lot of cases, help with bolstering a sustainable food production. Canned foods are a prime example that processed could play a substantial role in managing food availability and re-distribution due to their high shelf life.

Transport, storage and retail

Global value chains are increasingly using long-distance transport between production, process, retail and consumption. Such transportation risks producing higher greenhouse gas emissions in term of

^{viii} For the current status of the bilateral trade agreements negotiated by the EU please see https://trade.ec.europa.eu/doclib/docs/2006/december/tradoc_118238.pdf (updated July 2019).

transport therefore short value chains are seen as greener alternative. However, when evaluating the cost and benefits of creating shorter value chains, the entire life cycle of the agri-food system should be included in the analysis (e.g. constructions of more local factories).

The increasing importance of trade for the worldwide food balance requires an **efficient transportation, storage and retail system**, again increasing the importance of these sectors to the overall food value. While retail companies are increasingly important in order to bring enough quantities of food to different parts of the world, large multinational companies are contributing to facilitated global trade. Under current conditions, food producers with an international presence are benefitting from economies of scale, falling product costs and increasing competitiveness *vis-à-vis* smallholder farmers.

Consumers

One of the main changes expected to affect worldwide agriculture value chain by 2050 is the forecasted increasing shift towards the consumption of processed food, animal products and fruits and vegetables, one of the consequences of the expected increased urbanisation. This shift in consumption has been observed for the past decades and is expected to become even more accentuated with higher urbanisation.

3.3. Innovating food production systems and other elements

The food production system is undergoing profound changes to cope with climate change and new consumption patterns, and to meet the demand of an increasing population. In high-income countries different scenarios can be found depending on the market approach. **Europe appears to score high on innovation and precision farming, while in the US the size of farms calls for more automated processes.** The US and Brazil are looking for alternatives unavailable to most Europeans such as **larger scale production and openness to genetically modified seeds.** The industrial trend to use CRISPR **gene editing** (a method of manipulating and improving bacterial systems) to tackle allergens, boost flavours, create disease resistance and higher yields will offer greater choice of products. Low-income countries are trying to improve their profitability by promoting **online direct sales** and the **sharing of equipment, thus creating a sharing economy environment.** In contrast, many agri-food small-scale stakeholders do not have the necessary resources to invest in innovative approaches.

Available innovation will vary according to production size, foreseen benefits and the typologies of business. At the production level, different scenarios are predicted depending on resources and market approach. Europe is facing constraints by its available land and future demand and as a result is concentrating its efforts on finding a sustainable intensive approach using monitoring land tenure, crops adaptation, robotics and Internet of Things, so as to introduce new land management practices that might be conducive to a so-called "Agri 2.0".

In terms of **organic production**, Australia, Argentina, China and Spain are the countries with largest surfaces occupied by organic crops while most organic farmers are concentrated in **Asia** (India, Philippines), **Africa** (Uganda, Ethiopia, Tanzania) and **Latin America** (Mexico, Peru). In 2017, the organic retail sales reached 90 billion EUR with the **US and the EU markets** accounting for the largest share (44% and 38%, respectively).⁴⁵

In developed countries, several **different food processing trends** are currently being observed: a move towards local specialities, short food chains via internet platforms and small-scale exports and an acceleration of the adoption of changes in the food systems by end consumers. A boost in the development of **urban and in-store farming** is another trend that is being driven by increasing

demand for locally produced food⁴⁶. Currently, 200 million urban farmers supply food to 700 million people or 12% of the world's population.⁴⁷

3.4. Transformation of the marketplace

The food marketplace has already changed significantly over the past few decades and is expected to transform even more as new models mature. Digital platforms, in particular, are instruments that are increasingly being used by stakeholders of the agri-food chain globally. As such, those platforms may serve a wide range of purposes, including simplification and increased transparency of commercial transactions, greater efficiency in the production and commercialisation process of agri-food products, lower consumer prices and the establishment of horizontal and vertical collaborative partnerships within the agri-food chain.⁴⁸

From this perspective, business-to-consumers (B2C) **online food sales** by retailers, mass-caterers and other internet service providers have been growing over the past decade, notably in high-income countries. Several farmers, either individually or via their cooperatives or producer organisations, as well as some food manufacturers are also relying increasingly on direct-to-consumer (D2C) sales, both online and offline, as a way of shortening traditional commercial circuits involving intermediaries, wholesalers and retailers. Due to a lack of local facilities such as storage, packaging and processing plants, flower mills, slaughter houses and retail outlets, the transport distance is often unintentionally increased when locating close to the consumer.

In the **EU** in 2018, 25% of consumers shopping online relied on internet sales to make their food shopping, although other goods and services (e.g. clothes, sports goods, furniture, toys, travel and accommodation) still represent the most popular product categories.⁴⁹ In the **US**, food is the fastest growing segment in e-commerce, registering a 18% growth in 2019 on the previous year to reach an overall value of almost 20 billion USD.⁵⁰

Globally, internet food sales are expected to increase by an additional 15 to 20% by 2025, while market concentration should progressively decrease as more business operators opt for this retail model. Overall, convenience and faster delivery are the two main motivational consumer drivers of the current and future growth of e-commerce in the food sector⁵¹.

The number of **digital platforms** intended for business-to-business (B2B) transactions has also been growing in this sector. These platforms make it easier and quicker to meet the supply and demand of agricultural inputs (e.g. feed, fertilisers, equipment, machinery), raw materials and food products, among others, by limiting the number of business intermediaries involved in the supply chain as opposed to traditional commercial channels. B2B digital platforms in the agri-food sector may operate in national markets or on a global scale only^{ix}. They are widely present in **Europe** (e.g. Agrilocal, Agriconomie, Agrimarketplace), as well as **Africa** (M-Farm, M-Louma), and **Asia** (Agromart). Such platforms often provide complementary services for their users, including evaluation of suppliers, as well as insurance against business risks stemming from transactions and logistics. Digital platforms that facilitate horizontal collaboration between stakeholders operating at the same level of the agri-food chain (e.g. primary production) have also been developed: one example is WeFarmUp, a platform that allows farmers to share agricultural equipment that they lease.

^{ix} For example, Tridge and Agriaffaires are two platforms operating at international level.

4. MAJOR CHALLENGES

KEY FINDINGS

The megatrends expected to affect the agricultural sector worldwide presented above will not only change food consumption and supply patterns, but also pose important challenges as industry, society and policy-makers will need to address an increasing demand for food, a more challenging environmental situation and a potentially lower food production due to a range of factors. This section presents the main challenges that the sector will possibly face in the upcoming decades in order to satisfy the nutrition needs of the world's population.

-) **Ensuring agricultural productivity.** Increasing population, urbanisation, economic growth and an ageing rural population are contributing to the challenge of the agri-food value chain to increase productivity, while having less resources and still protect the small-scale farmers.
-) **Conserving land and water resources.** Agriculture covers around 40% of the land surface, a figure that is expected to increase by 5% by 2050. It uses about 70% of all water and significant differences in water availability across the globe and within countries are expected to continue along with substantial water scarcity up to 2050. Agriculture is both a victim and a cause of pollution, contributing significantly to greenhouse gas emissions, deforestation and biodiversity loss. This constitutes a major challenge for food producers facing volatility of crops prices and a declining workforce.
-) **Maintaining public health, improving nutrition and dietary trends.** Combating hunger and undernutrition, while achieving satisfactory levels of food security, is a major challenge in most low-income countries and a key objective of the global sustainable development agenda.

4.1. Agricultural productivity

Considering the increasing demand and all the trends previously described affecting the agricultural production and consumption, it will be a real challenge for the agri-food value chain to **increase productivity, while having less resources and still protect the small-scale farmers.**

Food producers (farmers suppliers and farmers) **are facing many challenges** linked with the food availability and production, **such as unpredictable weather due to climate change, resulting in volatility of crops prices.** Farmers are also facing a challenge to build their technical skills and adapt new technologies to their needs. The importance of this challenge is becoming bigger especially when taking into consideration that rural communities are populated with older people. There is a risk of discrimination in terms of access to trainings, credits and participation in innovative initiatives.

As a consequence of the increase in food demand, the food systems are transforming into very large-scale distribution channels combined with big retailers. These capital-intensive and vertically integrated supply chains result in challenges such as **the production of high-calorie but low-nutrition food, reduced access of small-scale farmers to distribution channels, high levels of food loss and important ecological footprint.**⁵²

Global sales are increasingly being controlled by fewer and fewer retailers⁵³, with a growing bargaining power and tendency to concentration and consolidation is detected also in upstream stages of supply chains: **Multinational agribusiness** is becoming more important due to upgrading of logistics, communication and information technology, while **transport** is enabling fresh products to

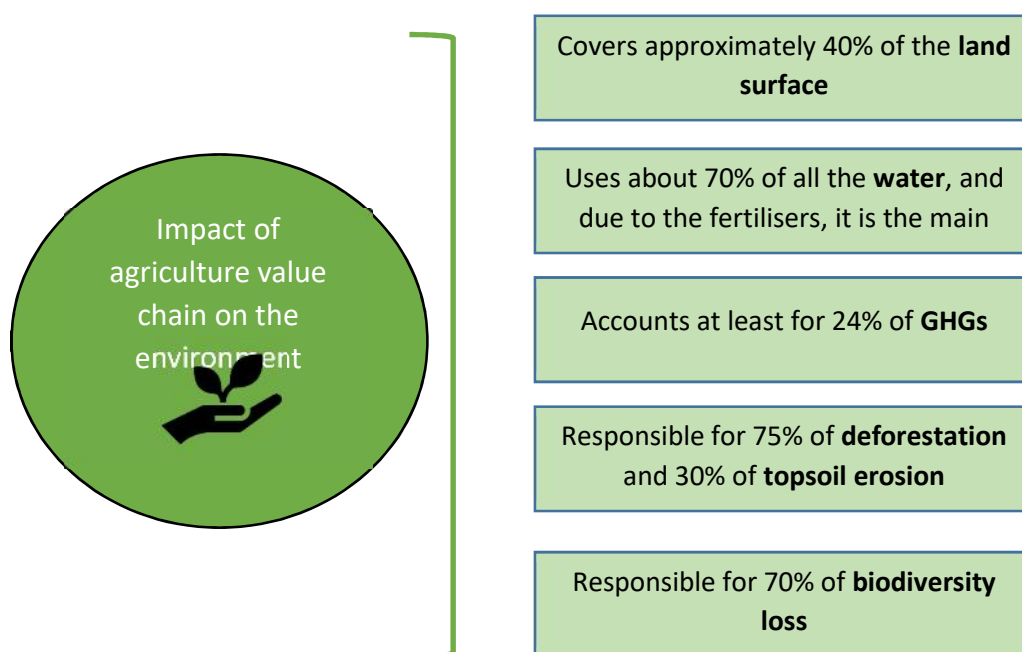
be transported from many origins and due to related increase of trade and investment and foreign direct investment in many countries (often developing countries) that are providers of the EU market.

Distribution channels have entered a digital race for the final mile. People are increasingly taking advantage of online shopping, but the increasing complexity of orders, storage and expertise of this home delivery trend attracts newcomers in the distribution channel with purely digital business models: in August 2017 Amazon acquired Whole-Foods, an US based organic grocery food chain, for € 14 billion, which could make it a key player in the retail business for fresh and healthy food.

4.2. Conservation of resources and environment

The agri-food value chain is essential for sustaining human life. Given its importance, it is necessary to take measures to conserve its resources, namely land and water. However, practices associated with it may have considerable impact on the environment. The most notable of these effects include the use of land surface and water, pollution and greenhouse gases, use of pesticides and fertilisers, deforestation, topsoil erosion and biodiversity loss.

Figure 4-1: Impact of agriculture value chain on the environment



Source: Arcadia

Currently, agriculture covers around 40% of the world's **land surface**. In this respect, FAO projects that, compared to 2009 levels, by 2050 the area of arable land will expand by 70 million ha (around 5%), comprising an additional 120 million ha (12%) in low-income countries offset by a decline of 50 million ha (8%) in high-income countries.⁵⁴ Almost all of this land expansion in low-income countries is forecasted to take place in **Sub-Saharan Africa** and **Latin America**.⁵⁵

Agriculture uses about 70% of all **water**. The use of water for food production varies greatly between the different regions of the world, ranging from 21% in **Europe** to 82% in **Africa**.⁵⁶ Currently, some regions have already reached alarming levels of water stress, including the **Eastern Mediterranean, North Africa** and **South Asia**. By 2050, significant differences in water availability across the globe and within countries are expected to continue and substantial water scarcity to persist.⁵⁷

Some measures have been implemented to avoid water scarcity – for example, substantial reductions of water through improved use of existing technologies,⁵⁸ more efficient irrigation equipment, good water management and the use of alternative sources of water, such as recycled water.

Currently, it is estimated that oceans account for half of the global biological production while a smaller portion of the latter is destined for human consumption. This situation is poised to change due to the nutritional needs of the world's growing population. As a result, it is necessary to preserve the resources that oceans harbour for the benefit of future generations⁵⁹ by combating against illegal, unreported and unregulated (IUU) fishing, reducing marine pollution and promoting sustainable wild capture and aquaculture.

Agriculture accounts at least for 21 % of greenhouse gases emissions in the world, with **Asia** being the largest contributor (44%), followed by **Latin America** (17%) and **Africa** (15%).⁶⁰ The use of fertilisers and phytosanitary products is one of the factors that most affects natural resources and the environment. The use of such substances is the main source of water quality problems, which consequently reduces its availability for beneficial use. In addition, the use of phytosanitary products affects air quality because of the production of some undesirable compounds, ultimately contributing to greenhouse gases emissions. As well as the use of fertilisers, enteric fermentation and the manure left on pasture are the largest emitters in agriculture.⁶¹

Agriculture has also a considerable impact on **deforestation** and **topsoil erosion**, being responsible for 75% and 30% of such phenomena, respectively.⁶² Regarding deforestation in particular, according to FAO data, **Brazil** and **Indonesia** are the countries with the highest forest losses, experiencing a loss of around 2 million and 1 million ha by year, respectively, between 1990-2015⁶³. **Biodiversity loss** is therefore a reality. Overall, **Australia** and **Indonesia** are the countries with the highest rate of biodiversity loss, for which agriculture is responsible for 70%.

Given the projected increase in food demand and the expected intensification of agriculture that should result from it, the future environmental impact of the agri-food chain will depend on the way in which global agriculture develops. Clearly, environmental protection and sustainability cannot be discounted, and efforts to increase food production and reduce environmental impact must go hand in hand. To this end, it is necessary to agree upon measures that help preserve our natural resources and implement them in a timely and effective way. From this perspective, the implementation of **international agreements** and **treaties** setting environmental actions and operational targets, such as the 1992 United Nations Framework Convention on Climate Change, including the Paris Agreement, and the Convention on Biological Diversity, play a key role in the conservation of natural resources.

4.3. Improvement of nutrition and public health

As it is designed, the current food system represents a global imbalance in terms of nutrition and public health while also being responsible for extreme polarisation. At one end, 821 million people (i.e. roughly 11% of the world's population) suffer from hunger and deficiencies in essential nutrients are causing an estimated 3.5 million deaths annually. These mortalities are concentrated among young children and pregnant women, mainly in low-income countries. At the other end, most high-income countries are witnessing a global obesity epidemic, with around 1.9 billion people classified as overweight, a condition which increasingly starts during childhood.

Food insecurity, undernutrition and food safety

Combating hunger and undernutrition, while achieving satisfactory levels of food security, is a major challenge in most low-income countries and a key objective of the global sustainable development agenda.⁶⁴

Although the prevalence of undernutrition, especially stunting (low height for age), has significantly decreased since the beginning of the 21st Century, the rate of the latter is not declining rapidly enough to achieve the global targets set by the WHO for 2025 (40% reduction).⁶⁵ Also, 16% of all new-borns in 2013 globally had low birth weights, with undernutrition being responsible for half of all deaths among children under five.⁶⁶

Food insecurity and undernutrition also contribute to the development of deficiencies in essential micronutrients, with a greater impact on the health of the most vulnerable section of society – i.e. children and women. For instance, iodine deficiency can be particularly damaging during foetal development and in the first few years of life. It is currently the most common cause of preventable brain damage, with an estimated 38 million new-borns coming to life with the deficiency and 18 million mentally impaired as a result.^{67 68} Lack of iron moreover represents a serious health threat for women as it contributes to the development of anaemia. In 2011 iron deficiency affected more than half billion of women aged 15-49 and accounted for 20% of all maternal deaths globally.⁶⁹

Furthermore, in countries facing food insecurity, the lack of sufficient food of high enough quality to satisfy nutritional needs of the population goes often hand in hand with food safety problems. From this perspective, food represents a widespread cause of morbidity and mortality (respectively, 600 million illnesses and 420,000 deaths in 2010) with greater incidence among children under five (40%) mostly in **Africa, South-East Asia** and in the **Eastern Mediterranean region**.⁷⁰

While food safety can be ensured by stepping up agricultural and manufacturing practices as well as by improving logistics and storage conditions, food security can be achieved by increasing the quantity and the range of food products present on national markets through domestic production and/or international trade while ensuring their affordability. In particular, the presence of efficient infrastructures (e.g. roads, means of transportation) is key to guaranteeing that food supply takes place with no interruption and ensuring access to safe and nutritious food often produced in remote rural areas. Trade liberalisation is often pointed out as a major driver for ensuring a stable food supply, although the outcomes of increasingly open trade policies tend to diverge across countries in terms of food availability as well as of higher income for producers and employment opportunities.⁷¹

Overweight and obesity

In 2016, globally, 39% of women and 39% of men aged 18 and over were overweight – i.e. with a Body Mass Index (BMI) equal to or higher than 25 kg/m².

Overall, obesity is the result of the development of unhealthy consumption patterns that involve increased consumption of foods that are energy-dense and high in fats, added sugars and salt. They are generally associated with sedentary lifestyles and growing urbanisation and tend to be higher among social classes with lower education backgrounds. Obesity is a key risk factor for the development of non-communicable diseases (NCDs), including diabetes (accounting for 44% of all cases), cardiovascular diseases (23%) and certain type of cancers (7-41%). From this perspective, obesity constitutes a significant economic burden for society as a whole, especially on healthcare services. The heaviest burdens can be found in low- and middle-income countries.⁷²

The highest prevalence of overweight people among the adult population (>60%) was registered in **North-America, Oceania**, in the **Eastern Mediterranean region** (e.g. Egypt, Iraq, Iran and Turkey) in certain countries in **Latin America** (e.g. Argentina, Chile and Venezuela) and in **Europe** (e.g. Bulgaria, Czechia, Greece, Ireland, Spain and the UK). In 2016, the prevalence of adults considered to be obese (with a BMI equal to or higher than 30 kg/m²) was higher than 30% in several countries around the globe, including the US, New Zealand, Egypt, Iraq, Turkey and Saudi Arabia.

For children and adolescents, 18% of individuals aged 5-19 were overweight or obese in 2016. In the same year, the highest obesity rates were registered, among others, in **North America, Oceania** and in some countries in **Asia** (namely, China and Thailand), **Europe** (e.g. Italy, Hungary, Spain and the UK) and the **Eastern Mediterranean region** (e.g. Egypt, Iran, Iraq and Turkey).⁷³

Against this background, a change in current consumption patterns is urgently required, with a view to making them healthier and, in so doing, more sustainable in the long run. Although dietary guidelines need to be adjusted to account for different factors (e.g. age, sex, nutritional deficiencies), a universal reference diet may be envisioned: it consists largely of vegetables, fruits, cereals, legumes, nuts and unsaturated oils, involves moderate consumption of fishery products and poultry, and comprises low or no consumption of red meat, added sugars, refined grains and starchy vegetables.⁷⁴

A transition towards healthy diets should be supported and can only be achieved through the action of a wide range of actors, including policy-makers, food operators, the media and civil society, at international, national and local levels. This may involve, among others, legislative measures (e.g. labelling requirements, maximum limits for certain nutrients, advertising restrictions), fiscal disincentives (e.g. taxes targeting foods high in fats, sugar and salt), self-regulation initiatives (e.g. product reformulation, code of conducts) and education campaigns^x.

^x For example, in the UK providing nutritional information on the front of pre-packaged foods and drinks is voluntary (under the Food Information Regulation) but most of the major supermarkets and many food manufacturers comply.

5. SCENARIOS ELABORATION AND POLICY OPTIONS

KEY FINDINGS

Based on the development of the drivers, forces and challenges, four contrasting scenarios could shape the future of the agri-food system:

-) **SCENARIO 1 “Small steps but no goals achieved”**, which represents the business-as-usual situation, where despite some efforts, the main challenges of environmental sustainability and food security are not fully addressed. Following the business-as-usual approach, the environment will be strongly degraded by 2050, and food demand will hardly be met.
-) **SCENARIO 2 “Mass production at all cost”**, is a scenario where the boundaries of natural resources are pushed to an extreme and actions are undertaken only in the direction of producing more agricultural output to cope with the food demand without taking into consideration sustainability. In this scenario food security is achieved at an unknown cost to climate change and environmental degradation.
-) **SCENARIO 3 “Local survivors”** represents a situation where worldwide, many countries and regions move towards securing food supply based on domestic or regional production, abandoning global free trade and weakening international institutions.
-) **SCENARIO 4 “Sustainability and food for all”** is a very optimistic and proactive scenario, where a lot of actions towards sustainable food and agricultural systems are put in place, leading to a decrease in environmental impact and an increase in food production, ensuring both food security and sustainability by 2050.

The likelihood of the scenarios depends on the policy options that could be adopted in order to respond to the agri-food trends and challenges.

5.1. Scenarios and policy options

Based on the trends, drivers and challenges that the agri-food sector is facing, different scenarios can be elaborated in order to prepare adequate policy responses. The study identifies four possible scenarios and explores the possible path towards a “great food transformation”, necessary to meet global demand while achieving sustainability.

The following main **assumptions** have been taken for the scenarios:

-) The population growth and the demographic situation is the same for all scenarios.
-) The demand for food is also estimated to be equal.
-) The economic growth trends are also considered not to change across the scenarios.
-) More in-depth economic factors such as employment, wages, investments are not part of the study scope.

The following table presents the drivers’ characteristics of each scenario.

Table 5-1: Overview of the drivers' characteristics per scenario

Drivers/Scenarios	1.Small steps but no goal	2. Mass production at all cost	3.Local survivors	4.Food and sustainability for all
Consumption patterns	Continuation of current trends towards more processed food in Low income countries and more fresh food in High income countries.	Focus only on personal needs and environmental goods seen as luxury only for elites.	Consumption of local products and support to local production.	Change towards sustainable consumption: higher willingness to pay for social and environmental services and goods.
Technological change	Continuation of current trends.	Innovation is focused on automation for labour saving and mass production rather than sustainability.	Moderate adoption of technological change, tendency to go back to the traditional way of working.	High level of technological penetration.
Policy context	Measures undertaken fail to attain the goal.	Policy options to stimulate the land usage and increase production by any means.	Local policies, increase in trade barriers and no global agreements.	Robust and ambitious policies are undertaken to increase food availability through a sustainable distribution. The implementation of a circular economy will help steer towards a greener agriculture sector.
Global trade	Continuation of current trends: several bilateral trade agreements with modest tariff barriers and focus on non-tariff barriers.	Increase in global trade. Trade agreements without quotas or local protection without focus on food safety, environmental standards and rules.	Abandonment of global free trade. Regional exchanges. High tariff and non-tariff barriers.	Free trade contributes to meet food demand worldwide.
Climate change	Continuation of current trends: average temperature increasing by 3-4 degrees by the end of the century.	Further degradation and temperature increases by 4-5 degrees by end of the century	Only regional actions are taken leading to very small impact.	Robust and ambitious global measures are undertaken, enabling to successfully reduce temperature increase.
Depletion of natural resources	Continuation of the current trends in terms of depletion of natural resources and the degradation of land.	Even further degradation. Higher risk of loss of biodiversity, deforestation and depletion of freshwater resources.	Sustainable use at local level. No steps taken at high level governance so there is no consistency in the preservation of natural resources across regions.	Sustainable use of natural resources.

Table 5-2: Overview of the challenges impacting the scenarios

Challenges/Scenarios	1.Small steps but no goal	2.Mass production at all cost	3.Local survivors	4.Food and sustainability for all
Agricultural productivity	Due to current unsustainable actions climate change will lead to severe weather events such droughts and floods, tropical storms and heat waves along with wildfires, which will negatively affect production.	Difficult for small and innovative food producers to enter the market.	Greater reliance for food safety on local players engaging in food production.	Difficulty to implement new sustainable practices and difficulty of finding funds for farmers and other value chain players. Slow or partial implementation of international agreements.
Conservation of resources and environment	Negative impact on crop yield due to growing GHG emissions. Ineffective way to increase productivity via technology. Decrease in agricultural workforce.	Climate change degradation due to high GHG emissions. Further expansion of land usage, unsustainable use of water, overuse of fertilisers and plant-protection products.	Unaddressed climate change issues affecting the quality and the quantity of the agricultural output.	Resistance to change regarding sustainability and ecological behaviour. Risk regarding willingness to pay for eco products, which have higher costs, leading to need of complementary measures to ensure food availability
Improvement of nutrition and public health	Increased obesity levels in high-income countries due to bad dietary habits combined with shortages of fresh produce and food poverty in low income countries.	Increased obesity levels in high and medium income countries due to dietary habits. Decreased availability of fresh produce.	Failure to provide appropriate food safety information to the consumers. Risk of shortages of fresh produce and food poverty.	Long process of changing consumers behaviour in terms of consumption patterns.

5.1.1. Scenario 1 “Small steps but no goal”

Scenario 1, corresponding to the current situation, is no longer a viable approach to respond to increasing food demand and the need to be sustainable. The current situation has already caused massive deforestation, loss of biodiversity and a high level of GHG emissions.

- J **Limited efforts to reduce food loss and waste.** The situation regarding food losses and waste remains the same or is partly reduced. Climate change, GHG emissions will continue along the current trends. The first consequences of climate change are already present. Extreme weather conditions are occurring.
- J **The production systems do not change compared to the current situation.** The Scenario 1 presents the current situation of the agri-food sector where there is coexistence among small- and large-scale farmers. It is also characterised with intensive livestock production. The land per unit of output ratio tends to decrease, as crop yield is increasing due to technology integration. The diversification of crops is limited.
- J **Consumers show limited willingness to pay for environmentally friendly food.** Consumers continue to follow the current trend in terms of consumption patterns and the change towards more healthy diets is very low.
- J **Investment in R&D is insufficient, and policies are not covering food security issues.** The technological innovations are still modest due to lack of investments and not enough focus on sustainability. Current regulation on consumer protection continues to limit the extended use of inputs, such as fertilisers, but their use is still promoted.

Policy options

In order to keep business as usual, the overall policy framework should remain almost unchanged. To address the food security the EU should improve production potential by using **current CAP instruments**.

In terms of climate change, the EU should **continue to support global initiatives to reduce GHG emissions** (e.g. Paris Agreement) and biodiversity losses as well as to **ensure that all bilateral trade agreements negotiated by the EU duly consider environmental protection**. Another important action, where the EU could play a role in the preservation of the environment is the **increase of incentives under the CAP proposal for resource-efficient and climate-friendly agriculture technologies**.

In order to support the farmers, the EU should **ensure fair revenue through CAP direct aid system**. **In addition, it is recommended to prioritise innovation and technology through Rural Development investment support, notably by supporting farmers (in particular young farmers) with infrastructure and credit facilities, and by further digitalising the CAP.**

Alongside with the food security, the food safety should also be continuously ensured. To do so, the EU should **continue to monitor that European food safety and quality standards are applied** by all local and national food producers as well as in the countries from where EU imports originate.

Last but not least, policy options targeting the consumers should be maintained. The EU should **continue to support and invest in education regarding healthier lifestyles and diet habits** among future generations (e.g. EU school fruit, vegetables and milk scheme). Moreover, it is recommended to **contribute towards the development of a fully-fledged EU nutrition policy** (e.g. consumer

information, content of nutrients relevant from a public health perspective) through regulation and self-regulation as appropriate.

5.1.2. Scenario 2 “Mass production at all cost”

In this scenario, food demand is managed but at the unmeasurable price of environmental degradation. It is based on large corporations for mass production, with small farmers only producing for high-income countries, as sustainable, high-quality and eco products are seen as a luxury.

-)] **Agri-food systems focus only on expanding agricultural production without environmental concern.** The harvested areas are greatly expanding, thus harming the biodiversity and producing low-quality agricultural output, owing to unsuitable land being used for agriculture. The crop diversification is very low because of the focus on mass production. Due to limited regulation there is abusive use of fertilisers, hormones, antibiotics and other chemicals that support mass production. The mass production relies on heavily processed food. In addition, due to extreme climate conditions, farmers are facing crops losses. Agricultural prices are expected to remain stable or decrease over time due to increasing offer (economy of scale).
-)] **R&D investments only for productivity and no further policy options focusing on the environment.** With regards to climate change, the intensive use of chemicals for mass production and processed food results in high levels of GHG emissions. Natural resources such as water are put under severe stress, and no actions are taken to prevent climate change. Innovation only focuses on reducing labour and increasing efficiency of production.
-)] **Consumers are focusing on satisfying their needs and food preferences, without environmental awareness.** People remain uneducated about food security and increasingly continue to waste food. Consumption growth in food and energy is very high, leading to further pressure on water and land resources.

Policy options

In order to achieve Scenario 2, the policy framework should mainly focus on production. The EU should **ensure that food production and supply in the EU reaches the appropriate level to feed all population in the long term.** To mitigate risks, the EU should **develop crisis management plans for situations in which EU production or supply are disrupted because of market or natural occurrences** (e.g. weather conditions, animal and plant diseases etc.). The climate change issue is deprioritised across relevant EU policy areas.

In order to support the farmers, the EU should **increase CAP support to farmers revenue with shift from decoupled aid system towards coupled aid and price support mechanisms linked to food security objectives.** In addition, an appropriate policy option for this scenario is to **establish compulsory priority mechanisms of investment in technology uptake as well as to allow EU farmers to have access to existing and new biotechnology techniques.**

Alongside the issue of food security, food safety should also be tackled. To do so, the EU should **monitor and ensure that European food safety and quality standards are applied** by all local and national food producers as well as in the countries from where EU imports originate.

Last but not least, policy options targeting the consumers should be improved. The EU should **support and invest in education regarding obesity and undernutrition to achieve healthier dietary habits** among future generations (e.g. EU school fruit, vegetables and milk scheme). Another policy option

targeting the end consumer is the **investment in R&D and provide subsidies to increase the production of fresh and minimally processed food and guarantee its affordability.**

5.1.3. Scenario 3 “Local Survivors”

In Scenario 3 the production system is largely based on small local producers, however food security and climate change are global issues resulting in very complex links that do not have geographic borders. These challenges need to be collectively addressed at global level throughout strong cooperation among regions. The Scenario 3” Local survivors”, in which separate national or regional actions are undertaken without cooperation is very unlikely to be efficient.

-) Limited actions undertaken for the reduction of GHG emissions.** Local initiatives are undertaken, but insufficient to mitigate global climate change risks. Farmers have difficulties to adapt to changes in weather and soil. Technological innovation will digitalise farming processes, which will be an incentive for young people work in farming. Urban infrastructure will move to rural areas to support this movement. Small farming initiatives like rooftop farming will continue to expand and locate some agricultural production to cities.
-) The quantity of land increases as local production and urban agriculture are supported in order to meet food security needs,** this potentially generates a risk of decreased biodiversity. As in Scenario 2, the diversification of crops is high (limited to the availability of the region), in order to reduce the risks and increase resilience. Local farmers might be favouring organic and bio production.
-) Customer choices are driven by health, local production and environmental protection.** Diets are mainly comprised of food produced locally/seasonally with lower consumption of meat.
-) Trade policies and agreements are left behind,** as trade happens mainly within a particular region (e.g. Europe). The implementation of innovative solutions is very fragmented, which leads to inhomogeneous productivity increase.

Policy options:

In order to become an isolated “Local Survivor”, the policy framework should be very EU-centred. To address the food security the EU should apply a state-by state approach. Overall the policy options should be oriented toward investment in technology innovation to grow products under specific conditions and guarantee enough production in terms of quantity.

In terms of climate change, the EU would then stop addressing the issue in a global way through cooperation but rather **focus on the increase of incentives under the CAP proposal for resource-efficient and climate-friendly agriculture technologies.**

There should be an **improvement of farmers revenue in areas where agriculture policies exist already (e.g. CAP, Farm bill).**

Alongside with the food security, the food safety should also be monitored in order to ensure that European food safety and quality measures are applied by all local and national food producers.

Last but not least, policy options targeting the consumers should be put in place such as **the design and implementation of protectionist policies that encourage consumers to buy domestic and local food products and as a result compartmentalise the international agri-food market.**

5.1.4. Scenario 4 “Sustainability for all”

Scenario 4 is the only path that addresses an increasing population in a sustainable way, while adopting healthy diets and preserving the environment. This Scenario is corresponding to the “Great Food Transformation” which refers to “substantial global shift towards healthy dietary patterns, large reductions in food loss and waste, and major improvements in food production practices.”^{xi}

)] **The production systems are transformed to accommodate climate-smart and ecological agriculture and are becoming part of the circular economy.**

The first stage in the agri-food chain, the agricultural stage, can implement the circular economy concept by reusing resources and recycling waste. The concept aims to improve farming practices, so the quality of agricultural products rises, which in turn keeps waste down. This leads to manufacturers working together with farmers to improve storage and logistics to keep products fresh for a longer time or helping farmers to turn agricultural waste into fertiliser⁷⁵. The second stage in the value chain, the food processing to consumer link, aims to implement the concept of circular economy by preventing food loss, distributing edible but non-sellable food to people, recycling by-products by using it as animal feed or input to other industries and innovating package design to reduce packaging waste⁷⁶. The last stage in which a circular economy can be implemented is household consumption (which accounts for the largest share of waste in the EU). In this scenario, food processors are contributing by raising awareness on food waste. Optimising the use and storage of food products and offering a larger variety of portion sizes are both initiatives that can help battle food waste⁷⁷.

)] **Improvements in food production practices are made.** The quantity of land per unit does not decrease too much in order to preserve the soil quality and the quality of the products. The diversification of crops is high in order to reduce the risks and increase resilience. The use of inputs such as fertilisers is minimised, and production moves towards organic agriculture, supported by precision agriculture. High technological innovation is put in place, such as precision agriculture and other methods to preserve energy and water and to decrease GHG emissions.

)] **Consumer are adopting healthy dietary patterns.** In this Scenario, consumer awareness is high. Consumers are adopting more balanced diets that are less rich in animal products, which triggers a reduction in livestock units and GHG emissions.

)] **Investments in R&D and policies are implemented.** With regards to climate change, a significant decrease in GHG emissions occurs thanks to a global investment in R&D and practical changes to reduce GHG emissions from animal and crops production. Strict actions are taken at global level to mitigate climate change risks. Agriculture prices are slightly higher to reflect the pressure on the demand, limited resources and the adoption of more sustainable consumption, which will not pose a challenge because supply will increase thanks to technological innovation, thus re-balancing the prices along with an increase of global GDP.

^{xi} The “Great food transformation” is a concept introduced by the study titled “Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems.” published on January 2019.

Policy options:

In order to arrive to this preferred scenario, the policy framework should undertake important changes. To reconcile the need for an eco-friendlier agriculture with food security, the EU should **foresee incentives under the CAP to move to new farming practices and adapt production to new healthy dietary patterns while at the same time making sure that food demand is met**. In addition, a policy action would **require fostering uptake and knowledge-sharing of technology and digitalisation in agricultural production as driver for food security In terms of climate change**.

In terms of climate change, the EU should **continue to support global initiatives to reduce GHG emissions** (e.g. Paris Agreement) and biodiversity losses as well as to **ensure that all bilateral trade agreements negotiated by the EU duly consider environmental protection**. More precisely, the EU should **ensure effective and timely implementation of EU requirements at reducing GHG emissions**, including in agricultural production.

In order to support the farmers, a relevant policy option is to **increase CAP spending for farmers with environment friendly practices and production adapted to new diets (e.g. vegetal proteins), which could imply more coupled aids to specific product with health and food security objectives**. In addition, it would require **establishing minimum thresholds for Member States to support investments with high degree of innovation and technology uptake**.

Alongside with the food security, the food safety should also be ensured. To do so, the EU should **monitor that EU food safety standards are necessary, proportionate and consistent with other policy objectives so that ultimately food safety is not detrimental to food security**. The EU should continue to **monitor and ensure that European food safety and quality standards are applied** by all local and national food producers as well as in the countries from where EU imports originate.

Last but not least, policy options targeting the consumers should be established. To arrive to "Sustainability for all", the EU should **increase support and investment in education regarding environmental protection, obesity and undernutrition to achieve adoption of healthier lifestyle and diet habits of future generations** (e.g. EU school fruit, vegetables and milk scheme) as well as to **develop of a fully-fledged EU nutrition policy** (e.g. consumer information, content of nutrients relevant from a public health perspective) through regulation and self-regulation as appropriate.

CONCLUSION

By 2050 the world's population will reach nearly 10 billion people. This increase will mainly occur in developing countries, with urbanisation continuing to accelerate. Income levels will rise, but in order to feed this larger, more urban and richer population, current food production must double.

The report analysed the megatrends influencing food production and consumption, the main forces affecting the agri-food systems and chains, and the challenges that are faced by the sector. Following these findings, the report analysed four different global scenarios: *small steps but no goal; sustainability for all; local survivors; and mass production at all cost*. Each of the scenarios is defined by different characteristics linked with the drivers, and the challenges. Based on those challenges, a set of policy actions and measures are presented.

Due to increased food demand, agricultural production is under pressure and therefore the expansion of agricultural land is threatened. However, can agricultural output be increased within the boundaries of the available natural resources (water and land) without causing irreversible damage to the planet? The excessive expansion of agricultural land can lead to environmental problems, such as loss of biodiversity. Moreover, using additional land, not suitable for agriculture, may actually provide lower yield and require much more expensive inputs. As shown by the report, sustainable and efficient use of land and water via technological support can increase crop yields without the need to expand agricultural land. Increasing the efficiency of water use is also becoming crucial.

To address these challenges people need to change their dietary habits and undergo a "Great food transformation" process. Raising awareness on environmentally sustainable diets and regulating food waste could substantially aid transformation towards sustainable agri-food consumption and production. Especially in high-income countries, it will enhance the adoption of more balanced diets comprising fewer animal products and more fruits and vegetables.

Trade-offs should be made between economic, environmental and social sustainability. In order to achieve agriculture and climate sustainability, the prices of agricultural goods should also increase, reflecting the environmental cost. In contrast, under-priced food can encourage the overuse of natural resources and excessive consumption that leads to health problems and food waste. However, this could be an important challenge for low-income countries where undernourishment and poverty are prevalent. Globally, poor rural areas should be given increased opportunities for work, education, know-how and improved credit facilities for farmers. These options should be considered in global trade strategies and agreements.

One of these challenges is climate change, which already has an impact on yield, soil quality and animal and plant resilience to diseases among other effects. The agricultural sector is affected by climate change, but it is also a large producer of GHG emissions. The concern is therefore to ensure that agricultural systems can contribute towards reducing GHG emissions while still being able to provide enough food for growing populations and demand. To achieve sustainability, substantial investments are needed in order to decrease GHG emissions and minimise the impact of agri-food systems on climate change.

Firm public action and innovation from both public and private sector are much needed to increase agricultural productivity without over-expanding agriculture land and causing soil degradation. Technological improvements and wider adoption of sustainable agricultural practices can result in a reduction of agricultural GHG emissions and more effective water use, while supporting the battle to reverse climate change. By implementing these actions, the EU would contribute to the achievement of Scenario 2 "Sustainability for all" by 2050.

In order to do so all stakeholders from the agri-food value chain should undertake changes. The reduction of GHG emissions should be a common goal for the entire agri-food value chain. These changes should be undertaken by both low- and high-income countries in a collective way.

According to FAO it won't be necessary to increase agricultural production even by 50% (from 2012 to 2050) in order to meet the SDG targets for ending hunger and achieving food security. These targets could be met with lower expansion of agricultural output, as long as agri-food systems become more sustainable by supporting the introduction of innovation to increase productivity and pursuing climate change reduction at the same time. Therefore, the only recommended scenario is "Sustainability for all". To achieve this Scenario, a numerous policy options should be considered.

To ensure food safety and availability the policy makers should focus on the agricultural productivity and foresee incentives under CAP proposal for increasing and/or maximising agricultural production in the EU as well as to foster uptake and knowledge-sharing of technology and digitalisation in agricultural production as driver for food security.

All of the above should take into consideration the climate change problematic and target sustainability at all agri-food levels of the value chain. This should be recognised and addressed from both business and public perspective. As a leading power, the EU should continue to support global initiatives to reduce GHG emissions (e.g. Paris Agreement) and biodiversity losses as well as to ensure that all bilateral trade agreements negotiated by the EU duly consider environmental protection. In addition, the EU should ensure effective and timely implementation of EU requirements at reducing GHG emissions, including in agricultural production.

ANNEX 1: DEFINITIONS

The study uses the following terms throughout the report:

Following the World Bank classification⁷⁸, as of 1 July 2018:

-) **Low-income countries** are those with a GNI per capita of \$995 or less in 2017.
-) **Middle-income countries** are those with a GNI per capita between \$996 and \$12,055.
-) **High-income countries:** (definition): those with a GNI per capita of \$12,055 or more.

Regions:

High-income		East Asia and Pacific (excluding China)	Europe and Central Asia	Latin America and Caribbean	Near East and North Africa	South Asia	Sub-Saharan Africa	
Australia	Lithuania	Cambodia	Albania	Argentina	Algeria	Afghanistan	Angola	Mali
Austria	Netherlands	Democratic	Armenia	Bolivia	Egypt	Bangladesh	Benin	Mauritania
Belgium	New Zealand	People's	Azerbaijan	(Plurinational	Iran (Islamic	India	Botswana	Mauritius
Canada	Republic of	Republic of	Belarus	State of)	Republic of)	Nepal	Burkina Faso	Mozambique
Chile	Norway	Korea	Bosnia and	Brazil	Iraq	Pakistan	Burundi	Namibia
China,	Poland	Indonesia	Herzegovina	Colombia	Jordan	Rest of	Cameroon	Niger
Hong Kong	Portugal	Lao People's	Bulgaria	Costa Rica	Lebanon	South Asia	Central	Nigeria
SAR	Republic of	Democratic	Georgia	Cuba	Libya	Sri Lanka	African	Rest of
Taiwan	Korea	Republic	Kazakhstan	Dominican	Morocco		Republic	sub-Saharan
Province of	Rest of	Malaysia	Kyrgyzstan	Republic	Rest of		Chad	Africa
China	European	Mongolia	Republic of	Ecuador	Near		Congo	Rwanda
Croatia	Union	Myanmar	Moldova	El Salvador	East and		Côte d'Ivoire	Senegal
Czechia	Rest of high-income	Papua New	Rest of	Guatemala				Sierra Leone

Denmark	countries	Guinea	Europe and	Guyana	North		Democratic	Somalia
Estonia	Saudi Arabia	Philippines	Central Asia	Haiti	Africa		Republic of	South Africa
Finland	Slovakia	Rest of East	Romania	Honduras	Syrian		the Congo	South Sudan
France	Spain	Asia and	Russian	Jamaica	Arab		Eritrea	Sudan
Germany	Sweden	Pacific	Federation	Mexico	Republic		Ethiopia	Swaziland
Greece	Trinidad and	Thailand	Serbia	Nicaragua	Tunisia		Gabon	Togo
Hungary	Tobago	Viet Nam	Tajikistan	Panama	Yemen		Gambia	Uganda
Ireland	United		Turkey	Paraguay			Ghana	United
Israel	Kingdom		Turkmenistan	Peru			Guinea	Republic of
Italy	United		Ukraine	Rest of Latin			Kenya	Tanzania
Japan	States		Uzbekistan	America and			Lesotho	Zambia
Latvia	of America			Caribbean			Liberia	Zimbabwe
	Uruguay			Suriname			Madagascar	
				Venezuela			Malawi	
				(Bolivarian				
				Republic of)				

ANNEX 2: METHODOLOGICAL APPROACH FOR THE SELECTION OF THE COMMODITIES TO BE QUANTITATIVELY ANALYSED IN THE STUDY

The consortium performed a Multi-Criteria Analysis (MCA) approach in order to define which are the most relevant commodities in order to provide quantitative data of their future production/yield.

The following criteria were used:

Criterion	Rationale
Global value in billion USD	the extent to which global value of a particular commodity is likely to increase
Global production in metric tons	the extent to which the produced quantity of a particular commodity is likely to increase
Environmental impact	the extent to which the production of a particular commodity negatively impacts on the environment, considering amongst the others its level of CO2 emissions
Nutritional needs	the extent to which a particular commodity is expected to contribute towards the dietary needs of the world's population
Consumption patterns	the extent to which a particular commodity is likely to play in the actual world's population diet
Technology innovation	the extent to which the production of a particular commodity is likely to be impacted by technological innovation, including automatisisation, digitalisation and development of alternative production methods
Economic factors (costs and prices)	the extent to which production costs and consumer prices of a particular commodity are expected to increase
Policy context	the extent to which the production and consumption of a particular commodity is likely to be encouraged by policies developed and implemented by international and national decision-makers

	Cereals			Meat			Fish	Fruits		Vegetables	Roots and tubers		Others	
	Wheat	Paddy rice	Grain maize	Beef (cattle and buffalos)	Pig	Poultry	Fish	Bananas	Citrus fruits	Tomatoes	Cassava	Potatoes	Soybean	Sugar cane
	Score (1-5)													
Global value in billion USD	3	5	2	5	4	3	1	1	1	2	1	1	3	2
Global production in metric tons	3	4	5	1	1	1	1	1	1	2	2	3	2	5
Environmental impact	2	3	2	5	4	3	3	2	2	2	2	2	2	2
Nutritional needs	3	2	2	3	2	4	3	3	3	3	2	2	4	1
Consumption patterns	3	3	3	4	3	4	2	2	2	2	2	2	N/A	3
Technology innovation	3	3	3	4	4	4	2	3	3	3	3	3	3	3
Economic factors (costs and prices)	3	4	3	3	2	3	1	3	4	3	5	3	3	3
Policy context	3	3	3	2	2	3	4	3	3	2	3	3	4	2
TOTAL	23	27	23	27	22	25	17	18	19	19	20	19	21	21

	Global value in billion USD	Global production in metric tons	Environmental impact	Nutritional needs	Consumption patterns	Technology innovation	Economic factors (costs and prices)	Policy context
Wheat	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Less consumption of refined grains and more consumption of whole grains	More cereals to be consumed as healthy food in high-income countries Increased the consumption of wheat over the next 10 years (FAO, how to feed the world in 2050)	Cereals in general: More efficient use of fertilisers and water Use of more effective pesticides /biopesticides	According to Producer Price Index	Production and consumption to remain at current levels
Rice	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Less consumption of refined grains and more consumption of whole grains	More cereals to be consumed as healthy food in high-income countries Decreased the consumption of rice over the next 10 years (FAO, how to feed the world in 2050)	Cereals in general: More efficient use of fertilisers and water Use of more effective pesticides /biopesticides	According to Producer Price Index	Production and consumption to remain at current levels
Corn	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Less consumption of refined grains and more consumption of whole grains	More cereals to be consumed as healthy food in high-income countries	Cereals in general: More efficient use of fertilisers and water Use of more effective pesticides /biopesticides	According to Producer Price Index	Production and consumption to remain at current levels

Beef	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Less consumption of beef	In general the consumption of meat will be increased specially in low-income countries. However, beef consumption should decrease in high-income countries.	"Meat in general: In vitro technology	According to Producer Price Index	Production and consumption to be reduced
Pig	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Less consumption of pig meat	In general the consumption of meat will be increased specially in low-income countries. However, pig meat consumption should decrease in high-income countries.	"Meat in general: In vitro technology	According to Producer Price Index	Production and consumption to be reduced
Chicken	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	More consumption of poultry	In general the consumption of chicken meat will be increased.	"Meat in general: In vitro technology	According to Producer Price Index	Consumption to be increased at the expenses of red meat
Fish	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	More consumption of fish rich in omega- 3	The consumption of fish will increase, including in highly populated countries	Further development of aquaculture as opposed to wild fish	According to Producer Price Index	Promotion of aquaculture to protect marine resources Consumption to be increased

Bananas	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Fruits in general: More consumption of fruits	Fruits in general: Increased consumption of fruits	Fruits in general: More efficient use of fertilisers and water	According to Producer Price Index	Consumption to be encouraged as a part of healthy lifestyles
Citrus fruits	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Fruits in general: More consumption of fruits	Fruits in general: Increased consumption of fruits	"Fruits in general: More efficient use of fertilisers and water	According to Producer Price Index	Consumption to be encouraged as a part of healthy lifestyles
Tomatoes	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Vegetables in general: More consumption of vegetables	General Vegetables: Increased consumption of vegetables	"Vegetables in general: More efficient use of fertilisers and water	According to Producer Price Index	Consumption to be encouraged as a part of healthy lifestyles
Cassava	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Roots and tubers in general: More consumption in low- income countries as a way to fight against food insecurity. Moderate consumption in high-income countries.	In general, the consumption of roots & tubers will be increased slightly (more in low- income countries) and in some regions will decrease.	"Roots and tubers in general: More efficient use of fertilisers and water	According to Producer Price Index	Production and consumption to remain at current levels
Potatoes	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Roots and tubers in general: More consumption in low- income countries as a way to fight against	In general, the consumption of roots & tubers will be increased slightly (more in low- income countries) and in	"Roots and tubers in general: More efficient use of fertilisers and water	According to Producer Price Index	Production and consumption to remain at current levels

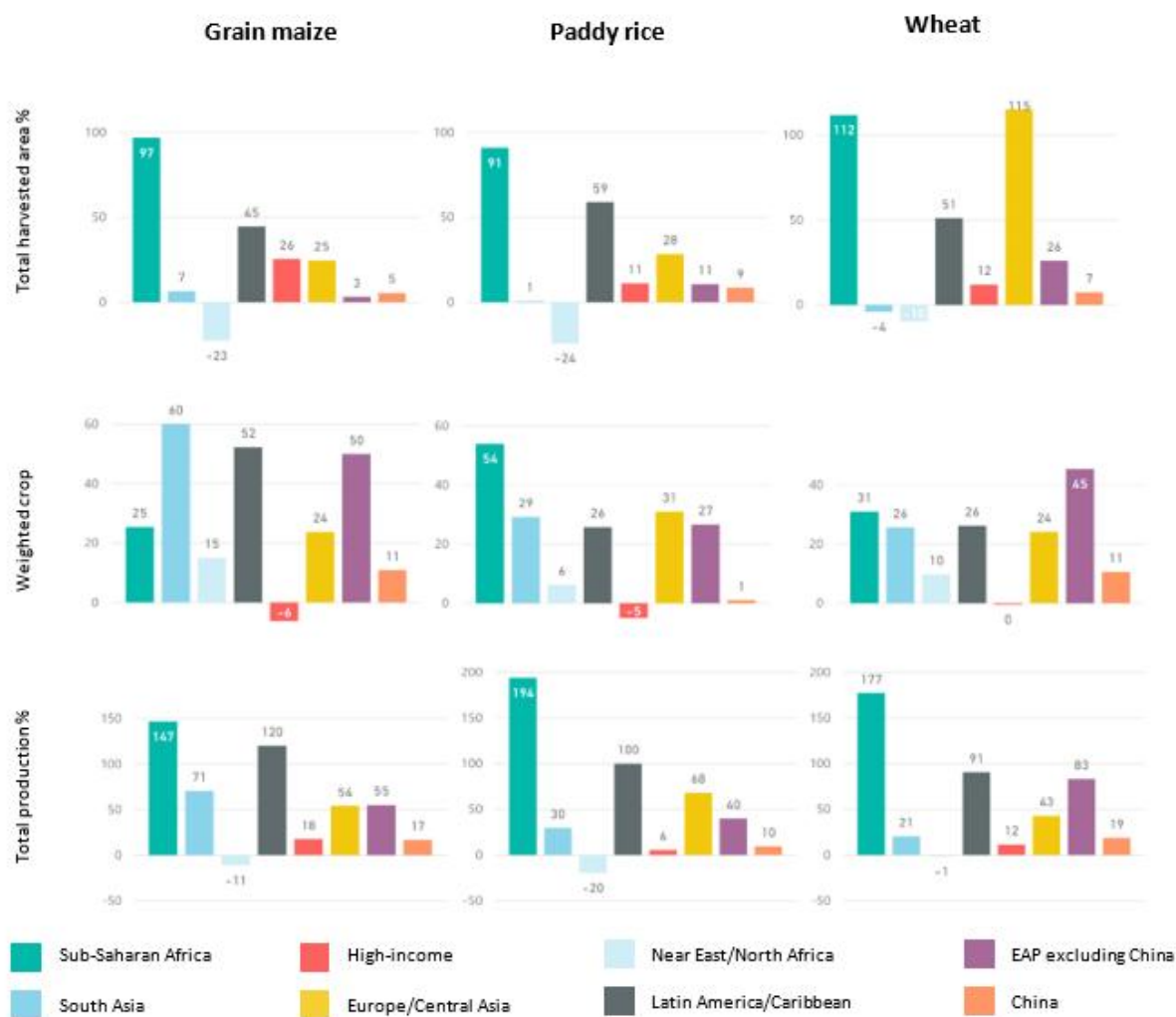
			ood-carbon-footprint-index-2018/)	food insecurity. Moderate consumption in high-income countries.	some regions will decrease.			
Soybeans (Feed)	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Soybeans promote lean biomass increase in the livestock animals, therefore improving meat quality and yield.	N/A	"More efficient use of fertilisers and water	According to Producer Price Index	Highly relevant for international trade and trade agreements as production is concentrated in a few countries Environmental concerns linked to its production (e.g. deforestation)
Sugar	According to FAO's ranking	According to FAO's ranking	Based on CO2 emissions. (source: FAO and https://www.nu3.de/c/food-carbon-footprint-index-2018/)	Less consumption of sugar	More consumption of sugar	More efficient use of fertilisers and water	According to Producer Price Index	Consumption in particular to be significantly reduced

ANNEX 3: DETAILED QUANTITATIVE DATA

Cereals

The selected commodities in this segment are wheat, paddy rice and grain maize. Their forecasted levels of production in 2050 are depicted in the graph below.

Figure -1: Cereals growth percentage in 2050 in relation to the levels of 2012 in the sustainability for all scenario



Source: VVA elaboration with data from FAO Database.

Analysis of the results across the three commodities highlights similar trends emerging in every region. **Sub-Saharan Africa** and **Latin America/Caribbean** present the highest growth in production levels, almost tripling in the first region and doubling in the second. These growth levels are enabled by a combination of an increase in the harvested area and the crop yield.

South Asia, Europe/Central Asia and **EAP excluding China** also show significant growth in their production levels, ranging from 20% to more than 80%. These growth levels are also driven by a combination of increased harvested area and crop yield, with the only exception of a decreased harvested area for wheat production in South Asia. It is also worth noting the significant increase in crop yield across the three regions.

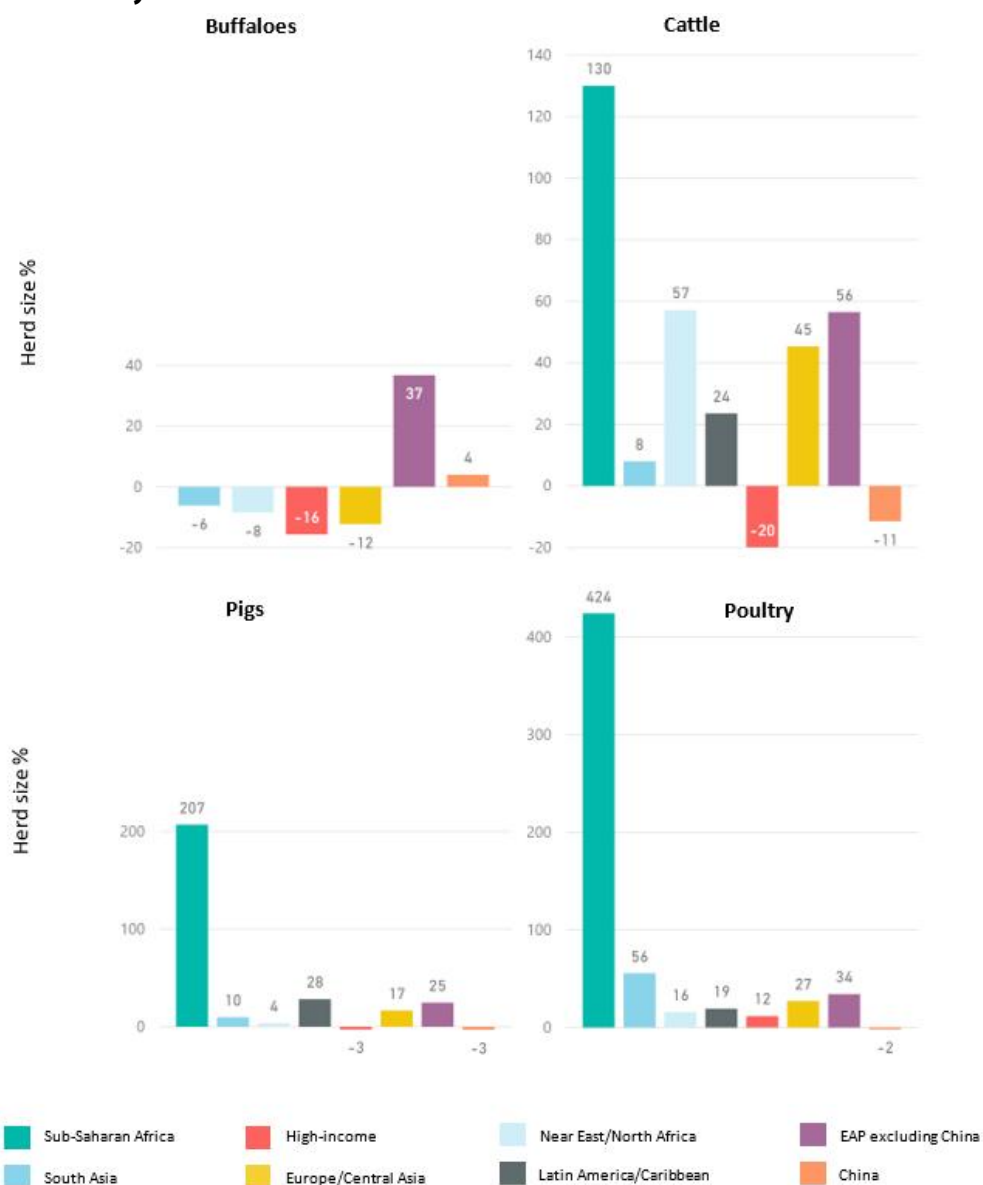
However, **China** and **high-income** countries will increase their production output by lower levels, ranging from 6% to 19%. In the case of China, this growth is enabled by a combination of increased harvested area and crop yield, but this is not the case for high-income countries. Their increase in production is exclusively driven by an expansion of the harvested area, although crop yields decrease almost in every case.

Finally, the only region with a decrease in its production level is **Near East/North Africa**, owing to a reduction of its harvested area of almost a quarter for grain maize and paddy rice, which is not compensated by the increase in crop yield.

Livestock

The selected commodities in this section are buffaloes, cattle, pigs and poultry. In the graph their expected levels of production in 2050 are shown.

Figure 2: Livestock growth percentage in 2050 in relation to the levels of 2012 in the sustainability for all scenario



Source: VVA elaboration with data from FAO Database.

Analysis of the result indicates that **Sub-Saharan Africa** is the region expected to increase livestock by the largest proportion (with the exception of buffaloes which are not raised in this area). The herd sizes are expected to more than double in the case of cattle, more than triple for pigs and increase by up to 424% for poultry.

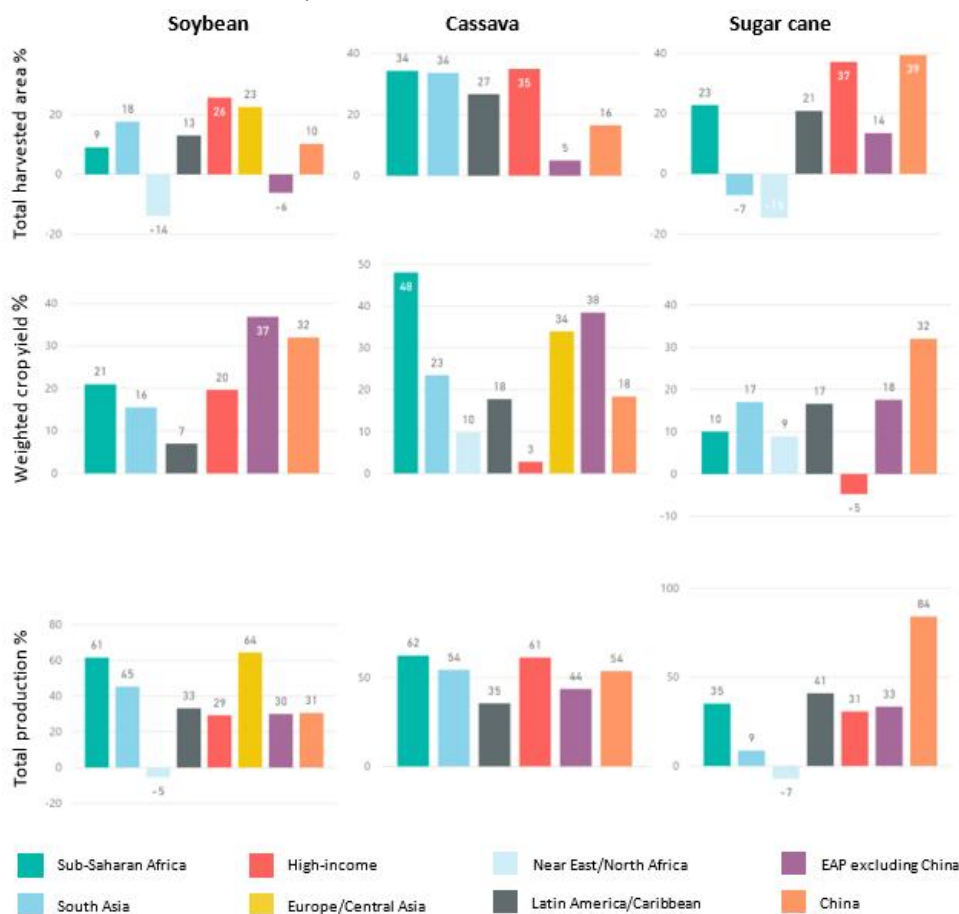
Another region showing a significant growth is **EAP excluding China**, with an average of around 30% for pigs and poultry, and 56% for cattle. The buffalo herd is expected to increase by 37% in the region, far greater than the only other area with an expected growth, i.e. **China** with 4%. Moreover, are the only analysed animal from the whose herd is forecasted to grow buffaloes in China, with cattle expected to decrease by 11%, and pigs and poultry by 3% and 2% respectively. Another region where only one animal is expected to increase is the **high-income** region, with an increase in poultry of 12%, while buffaloes and cattle are forecast to decrease by an average of 18% and pig by 3%.

Near East/North Africa, South Asia and **Europe/Central Asia** all present a similar trend, with an increase in the herd size of cattle, pigs and poultry, and a decrease in buffaloes, while **Latin America/Caribbean** shows an overall increase in the herd size of an average of 23%, excluding buffaloes that are not present in the region.

Others

The selected commodities in this segment are soybean, cassava and sugar cane. Their expected levels of production in 2050 are presented in the graph below.

Figure-3: Soybean, cassava and sugar cane growth percentage in 2050 in relation to the levels of 2012 in the sustainability for all scenario



Source: VVA elaboration with data from FAO Database.

Both **China** and **Sub-Saharan Africa** show the most significant growth in their outputs, powered by larger harvested areas and higher crop yields. **High-income** countries also display an increase in production levels, especially cassava that is expected to grow by 61% due to a large increase in the harvested land (more than 30% on average). Regarding crop yield, the growth rates are diverse, ranging from a 20% increase for cassava and 3% for soybean to a 5% decrease for sugar cane.

EAP excluding China shows a growth rate in production levels of above 30%, driven by significant crop yield increases. However, the region displays low harvested land growth compared to the other regions, even decreasing for soybean production by 6%. A similar decrease is to be found in **South Asia** in the production of sugar cane, where the harvested area is predicted to decrease by 7%. But a modest increase in production levels of 9% is nevertheless expected due to a 17% increase in crop yield. Regarding the other two commodities, the region ranks between the three areas with the highest production growth.

Finally, **Latin America/Caribbean** is expected to experience steady growth across the analysed commodities of around 35%, enabled by both an increase in the harvested land and in the crop yield.

ANNEX 4: SURVEY

In the framework of the study a survey was made among **21 agri-experts** to collect their view on the megatrends affecting the sector and the possible policy response from an EU perspective. More than 80% of the experts are coming from the private sector and more than 70% are international bodies. The respondents represented **stakeholders covering the entire agri-food value chain** in addition to innovation and research bodies, together with environmental protection representatives. According to the survey, the top 5 drivers which are likely to have the highest impact on the food supply and demand globally from now up to 2050 are:

Very high impact	Growing world population
Fairly high impact	Climate change
High impact	Depletion of agricultural and environmental resources and Ageing population
Medium impact	Technological progress, including agricultural automatization and Urbanisation
Small impact	Digitalisation, including precision agriculture, trade globalisation, policy and regulatory measures, evolving consumer patterns and economic imbalance between food chain stakeholders

The main challenges that a world population, destined to grow considerably, poses to the agri-food sector according to the respondents are:

1. Scarcity of water and insufficient agricultural workforce.
2. Insufficient agricultural investments.
3. Scarcity of other agricultural resources (e. g. forestry, livestock) and food availability (in terms of quantity).
4. Scarcity of agricultural land.
5. Scarcity of feed for food-producing animals.

All of the following resulting in maximisation of agricultural production, therefore increased pressure on environment and natural resources.

More specifically, when it comes to **climate change**, the top challenges are: (number one being the most important ones):

1. Risk of extinction of certain animal or plant species, adverse impact on agricultural productivity and quality.
2. Effective reduction of greenhouses gases resulting from agriculture, Sustainable forest management as a climate change mitigating factor, Lack of knowledge of all consequences engendered by climate change on agriculture.
3. Adverse impact on food safety and human health as well as plant and animal health.
4. Lack of knowledge of all consequences engendered by climate change on other stages of the food chain.

When it comes to **trade globalisation**, the top challenges are: (number one being the most important ones):

1. Effective access to global markets and increased competition.
2. Longer and more complex supply chains and lower selling prices compared to higher production costs.
3. Higher vulnerability of animals to diseases as well as vulnerability of plants to pests; loss of traditional food production or know-how.
4. Increased unbalance of the economic power of agri-food chain stakeholders.
5. Increased North-South economic and development cleavage and overall increase of social inequalities.

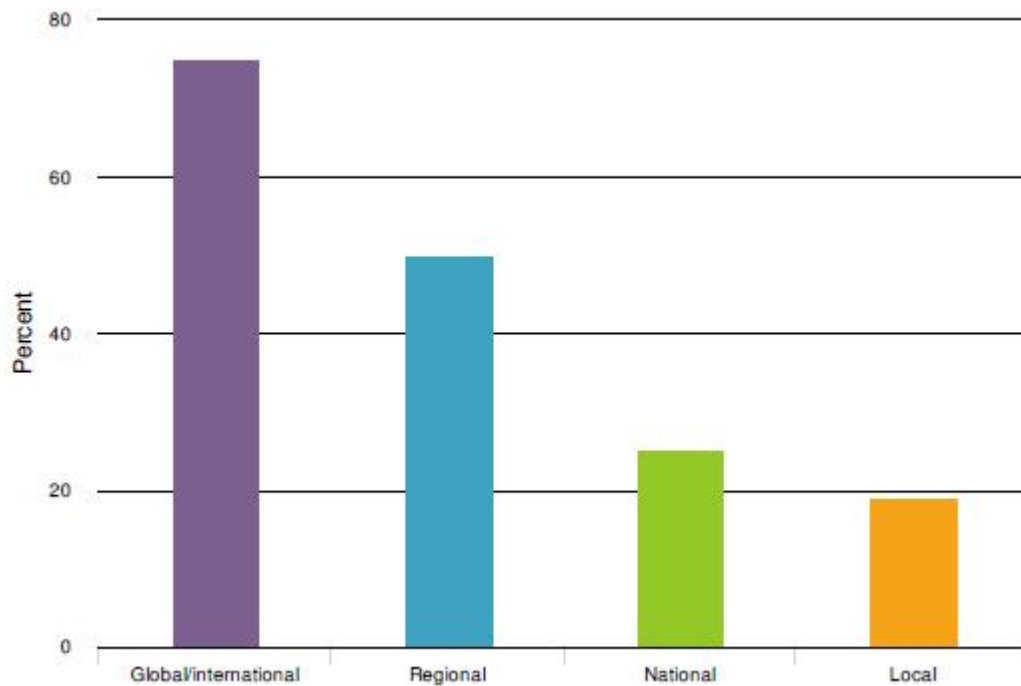
Regarding **current consumption patterns**, the top challenges are: (number one being the most important):

1. Transition to lower energy dense diets in developed countries.
2. Increased demand of food products with a lower environmental impact (e.g. organic, sustainably produced, alternative proteins sources).
3. Increased demand of locally sourced food products and high-quality food.
4. Eradication of hunger in developing countries and increased demand of foods produced in line with religious standards.

There is overall agreement about the challenge of greater diversification in terms of dietary habits and increased demand of convenience food.

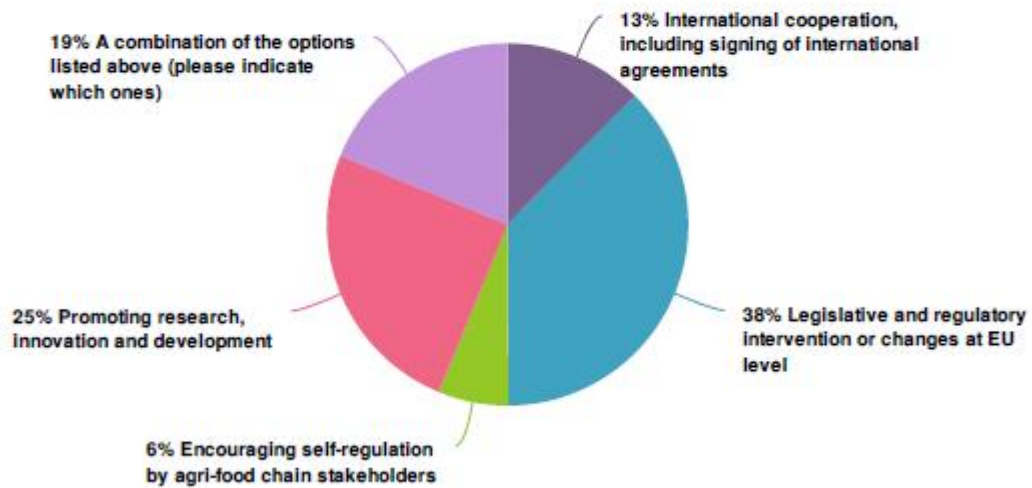
As mitigation actions, **75% of the respondents believe that these challenges should be solved at global and international level**, whereas 50% believe that these challenges should be solved at regional level, which suggest a solution that combines both a mix of international and regional measures.

Figure -4: At which level should solutions be sought for?



38% believe that the best option is to react first at EU level by creating EU specific legislative and regulatory interventions.

Figure -5: EU policy approach to tackle agri-food sector challenges



ANNEX 5: DETAILED POLICY OPTIONS

Focus	Policy options
“Small steps but no goal”	
Food security	<p>Improve production potential by using current CAP instruments and ensure well-functioning food chain.</p> <p>Making sure that EU food safety standards are necessary, proportionate and consistent with other policy objectives so that ultimately food safety is not detrimental to food security</p>
Climate change	<p>Public investment in sustainable practices and strong regulations to improve agricultural processes to reduce GHG emissions.</p> <p>Continue to support global initiatives to reduce GHG emissions, biodiversity losses (e.g. Paris Agreement).</p> <p>Increase incentives under the CAP proposal for resource-efficient and climate-friendly agriculture technologies.</p> <p>Continue to ensure that all bilateral trade agreements negotiated by the EU duly consider environmental protection.</p> <p>Continue to ensure effective and timely implementation of EU requirements aimed at reducing GHG emissions, including in agricultural production</p>
Farmers	<p>Ensure fair revenue for farmers through CAP direct aid system, decoupled and current coupled aid. Prioritise innovation and technology in Rural Development investment support.</p> <p>Support farmers with infrastructure, credit facilities, facilitate and further digitalise the CAP. Public support to support the motivation and education of younger farmers.</p> <p>Encourage small and medium enterprise development in the sector including support to young farmers, agribusiness start-ups.</p>
Food safety	<p>Monitor and ensure that European food safety and quality measures are applied by all local and national food producers.</p> <p>Continue to monitor and ensure that European food safety and quality standards are applied by all local and national food producers as well as in the countries from where EU imports originate</p>
Customer	<p>Raise awareness about future agriculture and the importance of adopting environmentally sustainable diets.</p> <p>Continue to support and invest in education regarding obesity and undernutrition to adopt healthier lifestyles and diet habits among future generations (e.g. EU school fruit, vegetables and milk scheme)</p>

	<p>Continue to contribute towards the development of a fully-fledged EU nutrition policy (e.g. consumer information, content of nutrients relevant from a public health perspective) through regulation and self-regulation as appropriate</p>
<p>” Food and sustainability for all”</p>	
<p>Food Security</p>	<p>Foresee incentives under CAP proposal for increasing and/or maximising agricultural production in the EU</p> <p>Foster uptake and knowledge-sharing of technology and digitalisation in agricultural production as driver for food security</p> <p>Step up support towards agricultural production of low-income countries on whose food exports the EU currently relies</p> <p>Develop crisis management plans for situations in which EU production or supply are disrupted because of market or natural occurrences (e.g. weather conditions, animal and plant diseases etc.)</p> <p>Making sure that EU food safety standards are necessary, proportionate and consistent with other policy objectives so that ultimately food safety is not detrimental to food security</p> <p>Increase the current level of food security through improvement of production potential throughout changes in farmers support and improvement of food chain functioning.</p>
<p>Farmers</p>	<p>Increase and improve CAP spending to support EU farmers through decoupled aid system as well as coupled aids to specific product with food security objectives. Increase the support of young farmers entrance. Establish minimum thresholds for Member States to support investments with high degree of innovation and technology uptake.</p> <p>Invest in local communities and support small farmers. Identify local sustainable practices and promote their wide implementation across other areas.</p> <p>Support farmers with infrastructure, credit facilities.</p> <p>Authorise and provide access for new plant breeding innovation techniques to increase productivity.</p> <p>Ensure fair prices of agriculture products</p> <p>Encourage small and medium enterprise development in the sector, agribusiness start-ups</p> <p>Support farmers with infrastructure, credit facilities, facilitate and further digitalise the CAP</p> <p>Public investment into the motivation and education of younger farmers</p>

	Identify local sustainable practices and promote their wide implementation across other areas
Climate change	<p>Ensure that all international trade agreements consider environmental protection.</p> <p>Push for technology and enhance cooperation</p> <p>Subsidies and provide more support to less developed regions.</p> <p>Increased public support for the development and implementation of sustainable practices</p> <p>Continue to support global initiatives to reduce GHG emissions (e.g. Paris Agreement) and biodiversity losses</p> <p>Continue to ensure that all bilateral trade agreements negotiated by the EU duly consider environmental protection</p> <p>Ensure effective and timely implementation of EU requirements at reducing GHG emissions, including in agricultural production</p> <p>Provide increased economic and technical support to less developed regions so that effects of agricultural production on the environment and climate are mitigated</p>
Consumer	<p>Continue to create incentives for consumers to buy food from sustainable agriculture systems.</p> <p>Support and invest in education regarding obesity and undernutrition to achieve adoption of healthier lifestyle and diet habits of future generations.</p> <p>Establish EU Policy framework for Circular economy.</p> <p>Create incentives for consumers to buy food from sustainable agriculture systems</p> <p>Increase support and investment in education regarding obesity and undernutrition to achieve adoption of healthier lifestyle and diet habits of future generations (e.g. EU school fruit, vegetables and milk scheme)</p> <p>Develop of a fully-fledged EU nutrition policy (e.g. consumer information, content of nutrients relevant from a public health perspective) through regulation and self-regulation as appropriate</p>
Scenario 3“Local survivors”	
Main challenges	Policy options
Food security	<p>Improve food security in areas in a non-uniform and global way.</p> <p>Address food security in a non-structured and inhomogeneous way</p>

	Invest in technology innovation to grow products under specific conditions and guarantee enough production in terms of quantity
Farmers	Improve farmers revenue in areas where agriculture policies exist already (e.g. CAP, Farm bill).
Food safety	Monitor and ensure that European food safety and quality measures are applied by all local and national food producers.
Climate change	Stop addressing climate change in international fora and via international cooperation Invest in the protection of agriculture at domestic level.
Consumers	Invest in consumers education related to seasonal availability of foods and nutritional characteristics to food.
Scenario 4“Mass production at all price”	
Food security	Improve food security through CAP incentives, better food chain and technology access. Ensure that food production and supply in the EU is maintained at the appropriate level to feed all population in the long term Develop crisis management plans for situations in which EU production or supply are disrupted because of market or natural occurrences (e.g. weather conditions, animal and plant diseases etc.)
Farmers	Increase CAP support to farmers revenue with shift from decoupled aid system towards coupled aid and price support mechanisms linked to food security objectives. Establish compulsory priority mechanisms of investment in technology uptake. Allow EU farmers to have access to existing and new biotechnology techniques. Improve transparency and balance of food chain forbidding Unfair Trade Practices and creating tools and mechanisms to reduce food losses.
Food safety	Review current European food safety and quality measures to eliminate EU food production potential. Monitor and ensure that European food safety and quality standards are applied by all local and national food producers as well as in the countries from where EU imports originate
Climate change	Deprioritising climate change across relevant EU policy areas
Consumers	Support and invest in education regarding obesity and undernutrition to achieve healthier dietary habits among future generations. Invest in R&D and provide subsidies to increase the production of fresh food and raise affordability.

	<p>Create incentives and support the introduction of healthy food diets.</p> <p>Support and invest in education regarding obesity and undernutrition to achieve healthier dietary habits among future generations (e.g. EU school fruit, vegetables and milk scheme)</p> <p>Invest in R&D and provide subsidies to increase the production of fresh and minimally processed food and guarantee its affordability</p> <p>Continue to create incentives for consumers to buy food from sustainable agriculture systems</p>
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This study addresses the megatrends in the agri-food sector influencing the growing food demand by 2050. It analyses the needed production in several agriculture outputs, addresses the main forces affecting the agri-food value chains and the major challenges faced by the sector. It also suggests possible scenarios and presents policy and recommendation options.

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