A meta-analysis of recent foresight documents in support of the 5th SCAR Foresight Exercise

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Foreword

The Standing Committee on Agricultural Research (SCAR) decided to carry out a new Foresight Exercise (FE), the fifth in a series started in 2007, that will have a timely and ambitious subject: **Natural resources and food systems: transitions towards a "safe and just" operating space**.

As for the previous FE, the objective is to provide useful insights and recommendations to the European Commission (EC), to Member States (MS) and Associated Countries (AC) in the adoption of policies and in the organisation of research for the composite field of the Bioeconomy[1].

Since the publication of the fourth FE in 2015, important events occurred that shape the current public debate on sustainable development. To name just three:

- **The Paris Accord**[2] of 2015 reached at the COP 21 on initiatives to contain the change of climate;
- The adoption of the **2030 Agenda**[3] of the United Nations (UN) on sustainable development, with its 17 Sustainable Development Goals (SDG) and 169 related targets;
- The 2018 Update of the EU **Bioeconomy** Strategy[4] launched in 2012.

There is a widespread perception of the interconnection of environmental and climatic issues that affect the very survival of the human race with social aspects and the legitimate ambitions of an increasing world population to a decent living. Tensions between different goals and between areas of the world for access to natural resources are no mystery.

Agriculture, Forestry, Fisheries, Aquaculture, the Food industry, the bio-based industries are both a source of concern and of possible solutions. They feed the world (albeit in a range of degrees) and provide materials and services but, so far, contributing to GHG emissions, land degradation, loss of biodiversity, pollution in large parts of the world.

The need to contain the climate change within hopefully tolerable limits, protect the physical and biological environment from further damage and, at the same time, the need to increase the levels of well-being of a large share of humanity, is a source of concern for possible conflicts and trade-offs.

Very appropriately, the fifth SCAR Foresight Exercise (FE#5) combines the concepts of environmental "**planetary boundaries**", that should not be trespassed, with social "**quality of life**" thresholds that should be ensured to every human being. How to reach that "safe and just"[5] space (Figure 1) is the subject of FE#5.

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[1] The bioeconomy comprises those parts of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals and micro-organisms – to produce food, materials and energy (https://ec.europa.eu/research/bioeconomy/index.cfm).

[2] https://unfccc.int/sites/default/files/english_paris_agreement.pdf

[3] http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

[4] https://ec.europa.eu/research/bioeconomy/pdf/ec_bioeconomy_strategy_2018.pdf#view=fit&pagemode=none

[5] The principle of social justice is embedded in European values. Article 2 of the Treaty of the European Union recites: "*The Union is founded on the values of respect for human dignity, freedom, democracy,*

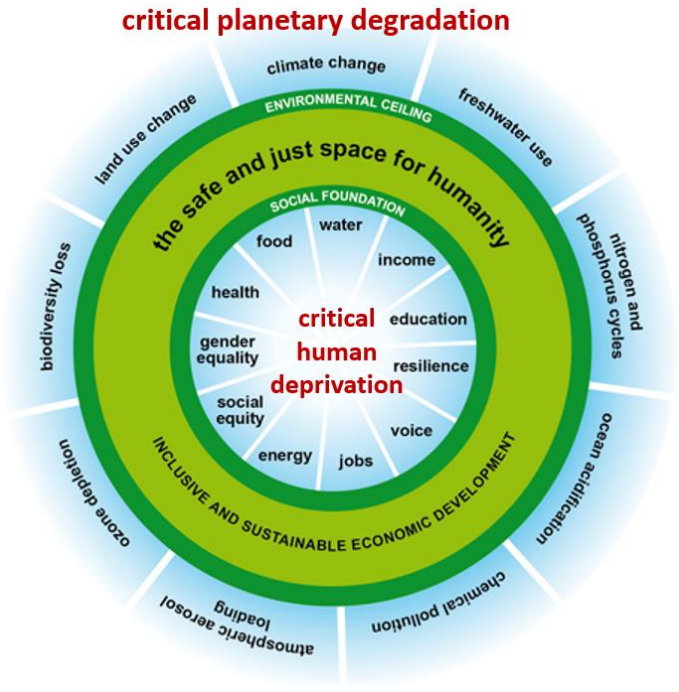


Figure 1 - "*The Doughnut: a twenty-first century compass. Between its social foundation of human well-being and ecological ceiling of planetary pressure lies the safe and just space for humanity*" (from: Raworth, 2017a, mod.)

The likelihood, the available pathways, the cost (economic and social) of the necessary transitions depend a great deal on the current state and trends of a broad range of variables, some more and some less predictable in their future dynamics.

There is a substantial amount of literature, reports of specialised agencies, horizon scanning, scenarios and foresight exercises that may provide useful inputs to the Experts that will carry out FE#5.

The aim of the meta-analysis is to identify reliable trends and main uncertainties, commonalities and divergencies, contrasting social, political and economic scenarios and to extract suggestions on areas that should be explored, potential game changers, possible societal developments, etc.

The purpose is to provide a background in order to speed up the "intelligence" phase of the FE and allow more time and effort on the "imagination" and "recommendations" phases.

It is not the purpose of the meta-analysis to limit the range of possible sources of information for the experts nor to limit in any way their autonomous analyses, evaluations and conclusions, but only to facilitate their operations by providing a neutral synthesis of the main contents of currently available materials.

The object of the contract for this CASA study is twofold:

equality, the rule of law and respect for human rights, including the rights of persons belonging to minorities. These values are common to the Member States in a society in which pluralism, non-discrimination, tolerance, justice, solidarity and equality between women and men prevail.

1. A survey of recent relevant documents that may provide factual inputs for the FE on aspects of general relevance and specific on agriculture and food systems.
2. A second analysis of documents specific to different sectors: forestry, fisheries and aquaculture, livestock.

The selection of documents has been based on their scope, relevance and time:

- Global or European approach
- Recent: mostly 2015 onwards
- Relevant for the subject of focus

Definitions

A range of different types of documents are considered in this analysis and therefore a simple set of definitions may be useful because sometimes terms are used in an interchangeable way causing confusion.

Trend – A trend is the direction in which something is developing or changing; trends are more or less predictable depending on the inertia of the system, the degree of dependence of a future state from the past.

Megatrends – are defined as "*long-term driving forces that are observable now and will most likely have significant influence on the future*"[6], or as "*large scale changes which are slow to form but once they have taken root they exercise profound influence on many human activities, processes and perceptions".* (OECD, 2016a).

Drivers – In a complex dynamic system subject to the influence of many different forces, drivers are the most influential in determining the direction of change. In this sense, trends and "megatrends" act as drivers of change. A trend is a direction, a driver is a cause of change.

Challenge – A road with obstacles and uncertainties towards a desired outcome, something that needs effort to obtain success.

Uncertainties – Key factors that are not foreseeable in their expression but may have significant effect on dynamic systems.

Forecast (often used interchangeably with '**Projection'**)– Quantitative extrapolation of future trends by the application of mathematical (often econometric) models to data from the past.

Scenario - Reilly and Willenbockel (2010) classify scenario studies in three categories, also adopted by Le Mouël and Forslund (2017): the first, 'Projections' corresponds to the above definition of 'Forecast'. The others are:

- **Exploratory scenarios** – that visualise possible futures with conjectured structural changes of systems.
- **Normative scenarios** – that start from a specific future (e.g. a desirable future) and work backwards to develop the conditions for its realisation. Sometimes it is used interchangeably with '**Backcasting**', but the latter, as 'Forecasting' usually implies a quantitative approach.

  Most scenarios and foresight studies contain a mixture of approaches, as some trends are too strong to be the subject of drastically different hypotheses.

Foresights – The ability (or the attempt) to foresee the future development of events. Foresights usually analyse the conditions leading to such development and their consequences.

Scenarios and foresights imagine possible futures without attaching probabilities; they are therefore more imaginative than rational, but at the same time can capture and depict futures that are considered possible, not

[6] https://ec.europa.eu/knowledge4policy/foresight_en . The European Commission has set up a Competence Centre on Foresight, **Megatrends Hub**, a collaborative space for information on 14 megatrends.

necessarily probable, including components, conditions, factors and situations that do not lend themselves to quantitative assessment but would be major elements of societal evolution.

Therefore, such elements as politics, public opinion, dominant values, international relationships can enter the picture. The value of scenarios and foresights derives therefore from a higher freedom for experts to think out of the box and open new windows.

The different scenarios then provide grounds for a "so … what?" kind of reasoning that analyses possible options for actions that would predispose organisations and society at large to such futures. Options and actions consistently optimal under contrasting scenarios would be obvious policy choices; in case of contrasts, early warnings of an approaching possible future could give time to predispose appropriate plans, much in the same way as the military prepare plans[7] responding to very different situations.

Creating options for the future allow society to be prepared for the unknown, to adapt to new, so far uncertain, social, economic, political and environmental conditions.

[7] *"No battle was ever won according to plan, but no battle was ever won without one."* (Dwight D. Eisenhower)

Setting the scene: major trends

Some trends are more predictable than others due to the inherent inertia (in the meaning the word has in physics) of the systems, the long lag-time between the causes of change and the visibility of the effects.

We focus here on two areas that are also considered **major drivers** in the evolution of social and economic systems: **Demography** and **Climate**.

Demography

Demography is probably the most predictable driver over the next decades, due to the inherent inertia of reproductive cycles. With declining child mortality, most babies that are born today will stay in reproductive age for a couple of decades twenty years from now and many will reach old age in sixty to eighty years from now.

Unless pandemics, global wars or sudden climate disruptions, the demographic evolution of the world will follow a foreseeable pattern mainly due to the age structure in the different regions.

The United Nations, Department of Economic and Social Affairs regularly publishes (mostly every other year) updated statistics and prospects on world population. As they are the most authoritative sources, these statistics are the basis of almost all scenarios and foresight and they are therefore the only reference cited in this study (UN/DESA/PD, 2017).

The following Table 1 (in numbers) and Figure 2 (graphic) show the low, medium and high variants of projected world population of the year 2050 made since the year 2000.

Table 1 - Population of the world in millions as projected by the UN World Population prospects in the periodic revisions 2000-2017 according to the low, medium and high variant projection. (Source: United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects, Revisions of the years 2000, 2002, 2004, 2006, 2008, 2010, 2012, 2015 and 2017).

United Nations World Population Prospects	Estimate for the year 2050		
	Low	Medium	High
Revision 2000	7866	9332	10934
Revision 2002	7408	8919	10633
Revision 2004	7680	9076	10646
Revision 2006	7791	9191	10756
Revision 2008	7959	9150	10461
Revision 2010	8112	9306	10614
Revision 2012	8342	9551	10868
Revision 2015	8710	9725	10801
Revision 2017	8753	9772	10849

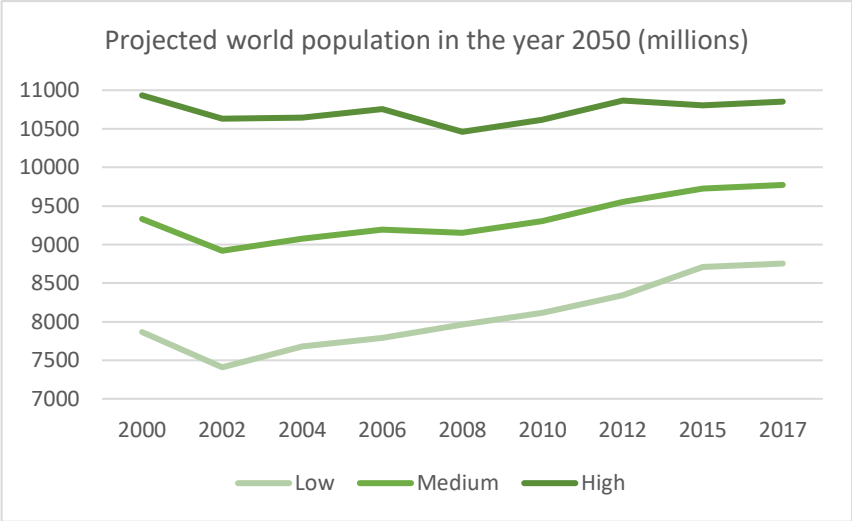


Figure 2 - Population of the world in millions as projected by the UN World Population prospects in the periodic revisions 2000-2017 according to the low, medium and high variant projection. (Source: United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects, Revisions of the years 2000, 2002, 2004, 2006, 2008, 2010, 2012, 2015 and 2017).

The most remarkable fact is that almost **at each revision** in the last 18 years (only exception the year 2002) **the forecasts have moved upwards**. This casts a shadow on the reliability of a number of scenarios on food availability carried out in the last 10-15 years. Predicted food production in the world and its regions should have been divided by higher population numbers to calculate prospective per capita shares.

Table 2 - Population (in millions) of the world and regions (2017, 2030, 2050 and 2100) according to the medium variant projection. (Source: UN/DESA/PD, 2017)

	2017	**2030**	**2050**	**2100**
World	*7550*	*8551*	*9772*	*11184*
Africa	1256	1704	2528	4468
Asia	4504	4947	5257	4780
Europe	742	739	716	653
Latin America and the Caribbean	646	718	780	712
Northern America	361	395	435	499
Oceania	41	48	57	72

Geographical differences are remarkable not only in absolute values, but also as trends. Whereas **Europe will face a decline of its population** and will represent in 2050 a mere 7.3% of the world population (down from 9.8% of 2017), **Africa will double its population** in the same interval, representing the largest regional increase also in absolute value (almost 1.3 billion) despite the fact that Asia starts (in 2017) with a population that is 3.5 times higher.

The increase in Africa is due to the high (although decreasing) fertility rate, to the young average age of its population (the strongest cause) and to increased life expectancy. This latter figure, despite remaining the lowest of all the continents (60.2 as compared with the world average of 70.8 years) has seen the highest increase in the last decade (6.6 years).

It can be said with great confidence that Africa will be the focus area of human demography in the next decades of the twenty-first century.

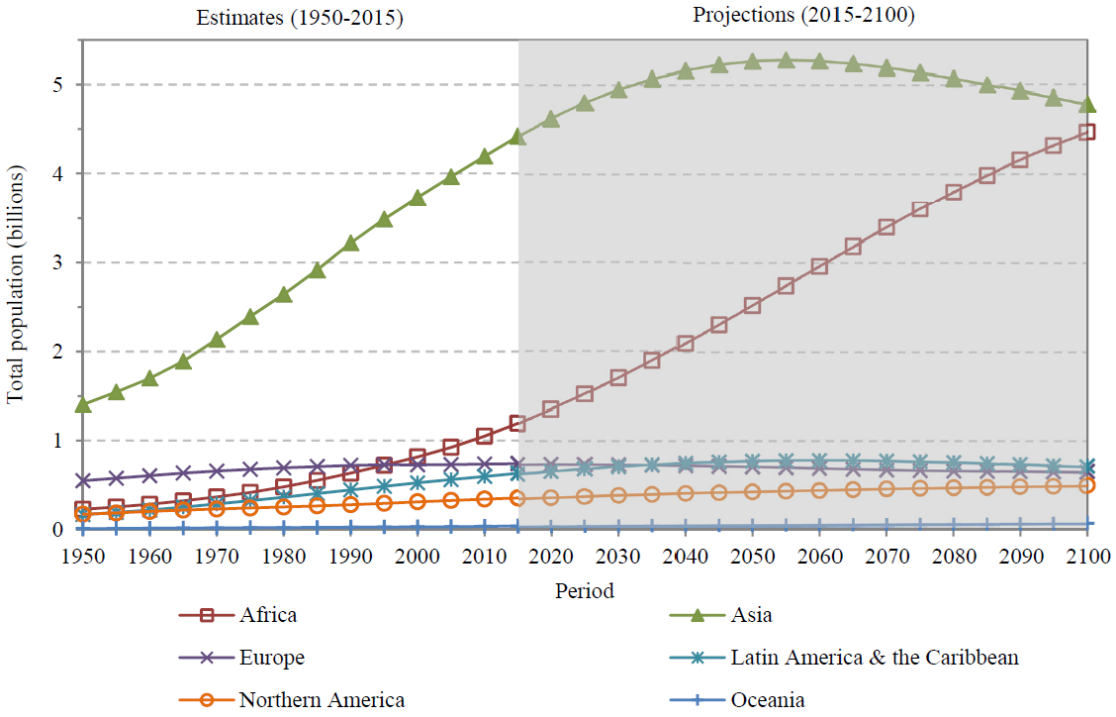


Figure 3 - Population by regions: estimates, 1950-2015, and medium-variant projection 2015-2100 (Source: UN/DESA/PD, 2017)

The main reason for a persisting upwards trend of the world population, despite decreasing fertility rates almost everywhere (even in Africa) lies in

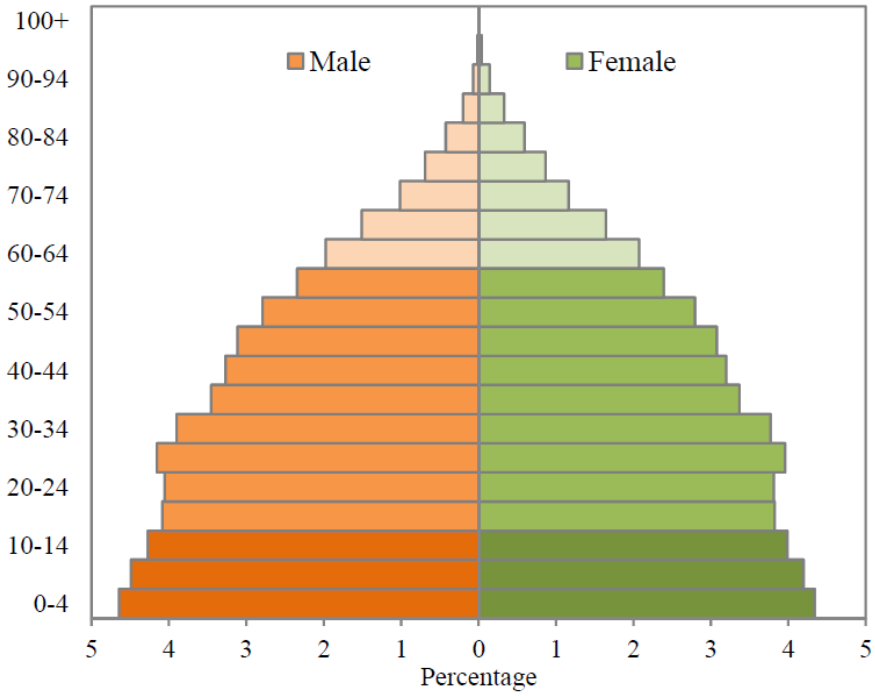


Figure 4 - Distribution of the world's population by age and sex, 2017 (Source: UN/DESA/PD, 2017).

the very shape of the distribution by ages, larger at the bottom than in the upper layers. The three classes with the highest numbers are the three at the bottom; these classes will enter the reproductive age between zero and fifteen years and they will stay there for at least another twenty years; unless unforeseeable dramatic drops of fertility, the absolute number of new children will increase.

Another remarkable fact is that **population growth will be mainly concentrated in the poorest countries** (Least Developed Countries, LDC) mainly in Africa, which will make it very difficult to eradicate poverty, eliminate hunger and malnutrition, improve health, education and services; Sustainable Development Goals in those countries will be never reached without a radical change in the political and economic relationships between the rich and poor Nations of the world.

It should be mentioned here that "The Global Land Outlook" (UNCCD, 2017) provides three scenarios based on the "Shared Socio-economic Pathways" (Kriegler *et al.*, 2012; see the chapter on "Scenarios and Foresights"); two of them (SSP 2 and SSP 3) hypothesise world population dynamics that are comprised between the 95% probability interval of the World Population Prospect for the year 2050. A third scenario (SSP 1: Sustainability) conceives a significant lower population (around 8.5 billion).

What about Europe? Fertility rates are expected to rise slightly until 2050, moving from 1.6 to 1.8 births per woman, but well below the natural replacement level of about 2.1. Low fertility rates and an age structure already poor of young classes, makes the decline of population an extremely reliable prediction.

Table 3 - Expected population (thousands) in Europe until 2050 by subregions (Source: UN/DESA/PD, 2017)

Year / ***Europe***	***2020***	***2025***	***2030***	***2040***	***2050***	***Trend***
	743390	***742544***	***739456***	***728823***	***715721***	***Decreasing***
Eastern[8]	290776	286799	281413	269143	258519	Decreasing
Northern[9]	105863	108409	110635	114313	117583	Increasing
Southern[10]	151553	150250	148825	145252	140123	Decreasing
Western[11]	195197	197086	198584	200115	199496	Increasing

The implications of sustained population growth in Africa and of a decreasing but wealthy population in Europe on the issue of migrations that currently stirs political debate in Europe are evident. However, immigration, strongly dependent on persistent asymmetries in the economic situations and in demography, can be viewed as a threat (as it is currently perceived by a large

[8] Eastern Europe: Belarus, Bulgaria, Czechia, Hungary, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia and Ukraine.

[9] Northern Europe: Channel Islands, Denmark, Estonia, Faeroe Islands, Finland, Iceland, Ireland, Isle of Man, Latvia, Lithuania, Norway, Sweden, United Kingdom.

[10] Southern Europe: Albania, Andorra, Bosnia and Herzegovina, Croatia, Gibraltar, Greece, Holy See, Italy, Malta, Montenegro, Portugal, San Marino, Serbia, Slovenia, Spain, TFYR Macedonia.

[11] Western Europe: Austria, Belgium, France, Germany, Liechtenstein, Luxembourg, Monaco, Netherlands, Switzerland.

share of the Europeans) or as an opportunity: more and younger workforce to sustain an ageing population.

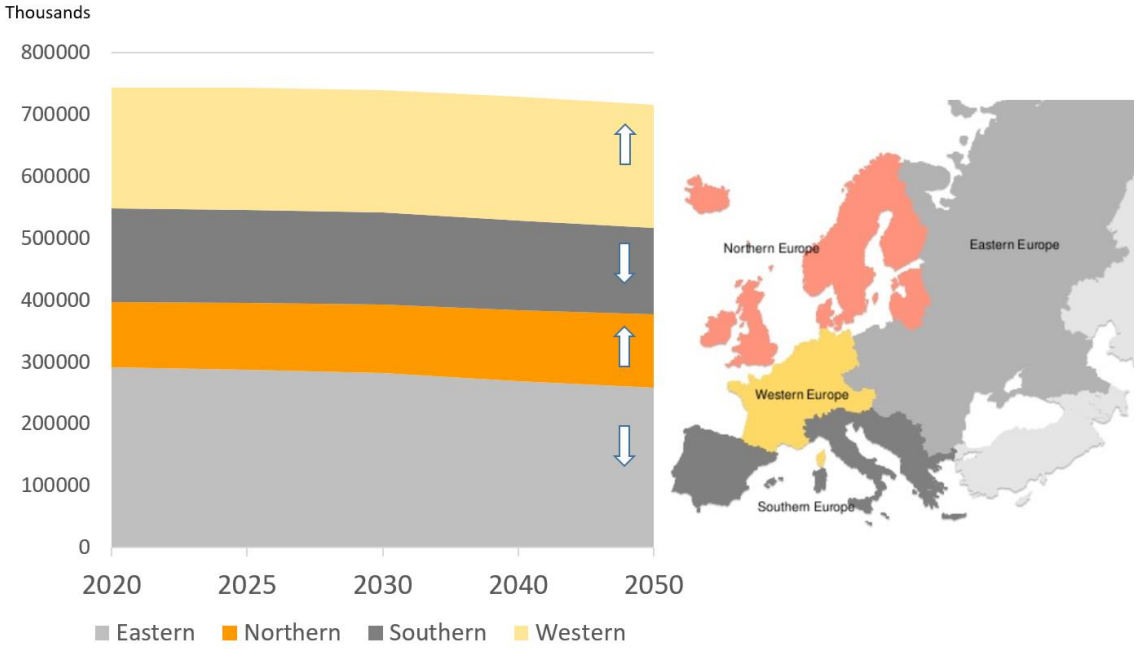


Figure 5 - Expected population (thousands) in Europe until 2050 by subregions (Source of data: UN/DESA/PD, 2017)

A relevant aspect of demographic dynamics is **ageing**. Life expectancy is increasing worldwide, although at a lower rate in developed countries, where it is already high, than in developing countries.

As living standards, nutrition levels, availability of health services all play a significant role on life length, this figure could be more susceptible to variation from projections based on past trends (in some regions of Europe, hit by the economic crisis of 2008, it has actually slightly declined). However, as for the global population, also the older fraction of the population is going to increase as a direct consequence of the age structure and of declining birth rates worldwide (UN/DESA/PD, 2017).

The ratio of working age people vs retirees can be an indicator of the **"strain" on welfare systems** (pensions as well as health services) determined by an ageing population: in 2017 Africa has 12.9 persons aged 20 to 64 for each person aged 65 or above; Asia has 7.4, Northern America 3.8 and Europe 3.3 (UN/DESA/PD, 2017).

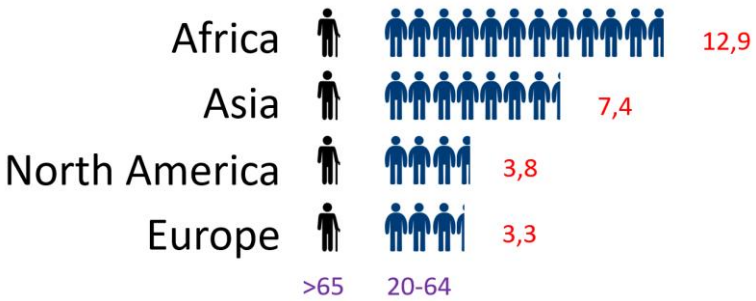


Figure 6 - Ratio of working age people vs elderly in Africa, Asia, N.America and Europe in 2017 (Source of data: UN/DESA/PD, 2017))

Urbanisation

Another strong demographic trend, but by no means 9an irreversible one, as unsupported by physical elements such as age structure, is a worldwide tendency for population to concentrate in cities.

The "BOHEMIA" foresight (Ricci *et al.*, 2017), the EC Megatrends Hub (https://ec.europa.eu/knowledge4policy/foresight_en) and the JRC Report "Global Food Security 2030" (Maggio *et al.*, 2015) consider urbanisation as a megatrend in its own right.

The move from rural areas to cities started to point upwards in the late 1800s and its rate has increased constantly. As for many other dimensions of human activities, it started accelerating around 1950 (Steffen *et al*., 2015b).

In 1950, the urban population represented less than one third of the world's population and mostly concentrated in developed countries, whereas the less developed countries remained largely rural. About 2008 humanity passed the milestone of the 50% population living in cities. In 2050 it is expected that two thirds will live in urban settlements.

According to Steffen *et al*. (2015b) *"on current trajectories there will be more urban areas built during the first three decades of the 21st century than in all of previous history combined"*.

Although Africa and Asia are still rural (40 and 48% urban in 2014), these two continents are urbanizing at a faster pace than the rest of the world (HLPE, 2017) and slums are expanding much faster than planned areas.

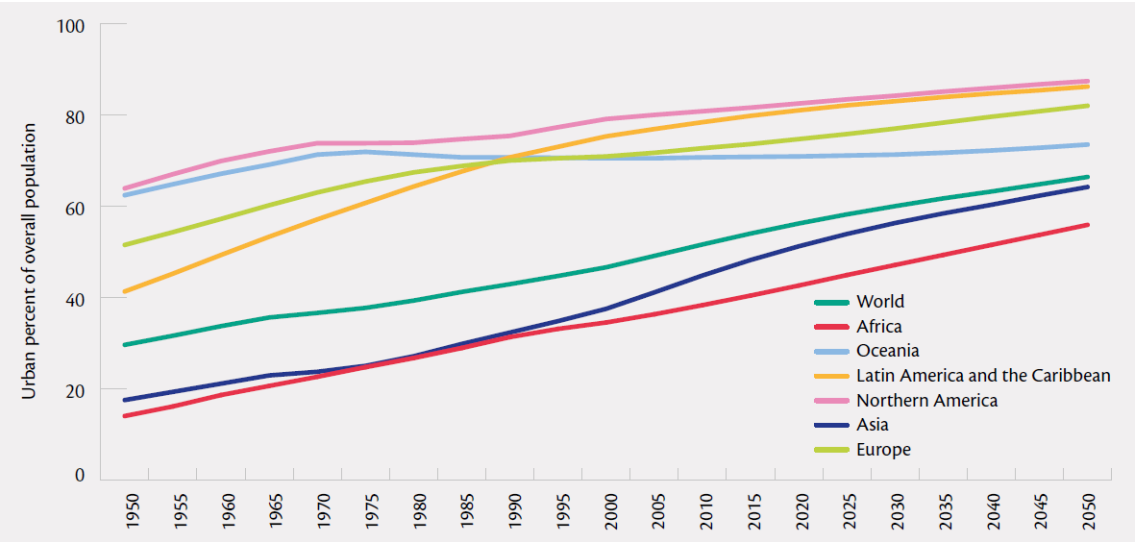


Figure 7 - Urban percentage of overall population by region, 1950–2050 (From: Global Panel on Agriculture and Food Systems for Nutrition, 2016)

Urban dwellers, as food consumers, are exposed to positive and negative situations, as synthesised in Table 4.

The fragility of urban settlements with respect to food security is the consequence of households depending primarily on markets for accessing food. As such, they are extremely vulnerable to price changes; food riots

often erupt first in urban areas, as was the case with the Arab Spring (FAO, IFAD, UNICEF, WFP, WHO, 2017)

Table 4 - Challenges and opportunities faced by consumers arising from urbanization (From: Global Panel on Agriculture and Food Systems for Nutrition, 2016)

Factors affecting consumers	**Opportunity for high-quality diets**	**Challenge to high-quality diets**
Increased access to fresh foods	Fresh foods such as fruits and vegetables are good for high-quality diets	Consumption of ASF above certain levels are not consistent with high-quality diets
Greater access to commercially fortified foods	Promotes access to micronutrients for vulnerable groups who can afford fortified foods	Improper fortification or high cost of fortified foods are a risk for high-quality diets
Accessing a greater share of food from markets	A greater range of processed foods such as legumes, vegetables and fruits are available	A greater range of high-energy-dense, low-micronutrient foods are available. Consumers are more vulnerable to food price changes due to international and domestic shocks
Demand for foods that require less preparation time	Availability of good quality prepared food saves time for other activities that are important for nutrition, such as child care	Foods may be unaffordable or low in nutrient quality or unsafe
Demand for foods outside home	Availability of good quality prepared food saves time for other activities that are important for nutrition, such as child care	Foods may be unaffordable or low in nutrient quality or unsafe

Urbanisation may give rise to vibrant poles of innovation due to the concentration of people, wealth, knowledge, business opportunities; but also the risk is also real of creating unmanageable agglomerations where food and water provision, sanitation, basic services become scarce and degrade any existing social fabric (Hudson *et al.*, 2015).

Increased urbanisation also shifts the balance of power towards the cities, for their sheer economic power and for the concentration of voters (at least in democracies).

According to the World Economic Forum "Global Risks Report 2019", *"the world's political geography is being transformed by surging migration from rural to urban areas, straining the web of connections between the two. Divergences are widening on numerous dimensions, such as values, age, education, power and prosperity … Greater bitterness and rivalry could lead to localized nativism and even violent clashes. Separatist movements might break through in wealthy city-regions that resent diverting revenues to poorer rural areas with which they feel diminishing affinity"* (Collins *et al.*, 2019).

The footprint of cities extends far beyond its borders. At present a mere 2-3% of the land area is urbanized and this figure is expected to increase to 4-5% by 2050, causing the loss of million hectares of prime agricultural land. In addition to using land directly cities have a footprint that reaches far beyond their boundaries of the city (UNCCD, 2017). According to the UNCCD

(2017), "*78 per cent of carbon emissions, 60 per cent of residential water use, and 76 per cent of wood used for industrial purposes are attributed to urban areas*".

Climate change and the environment

Although still debated and not officially recognised by the scientific community (especially Geologists) as an epoch of the earth system, the Anthropocene (from the Greek word ἀνθροπος=man) has gained popularity as a term that defines the impact of human activities on the biosphere and its climate. As such it was popularised by the Dutch scientist Paul J. Crutzen (atmospheric chemist, Nobel Prize for Chemistry in 1995).

No consensus has been reached on the beginning of the Anthropocene (some put it at the dawn of agriculture). Steffen *et. al.* (2004) proposed 1750 as a convenient date, as it marks the beginning of the Industrial Revolution. The year 1950 was identified as the beginning of "The Great Acceleration", when socio-economic and earth system indices started growing at an unprecedented almost exponential rate and showed a remarkable parallelism.

As a rule, correlation is no causation; but the interlinkages between socio-economic phenomena and modifications of some parameters of the earth system are so evident that almost no one denies that recent earth system changes are a consequence of the way humanity has used and is using natural resources (although some negationists survive).

The following graphs (from Steffen *et al.*, 2015b) are an update (with a few substitutions) of previous ones published a decade earlier (Steffen *et. al.*, 2004).

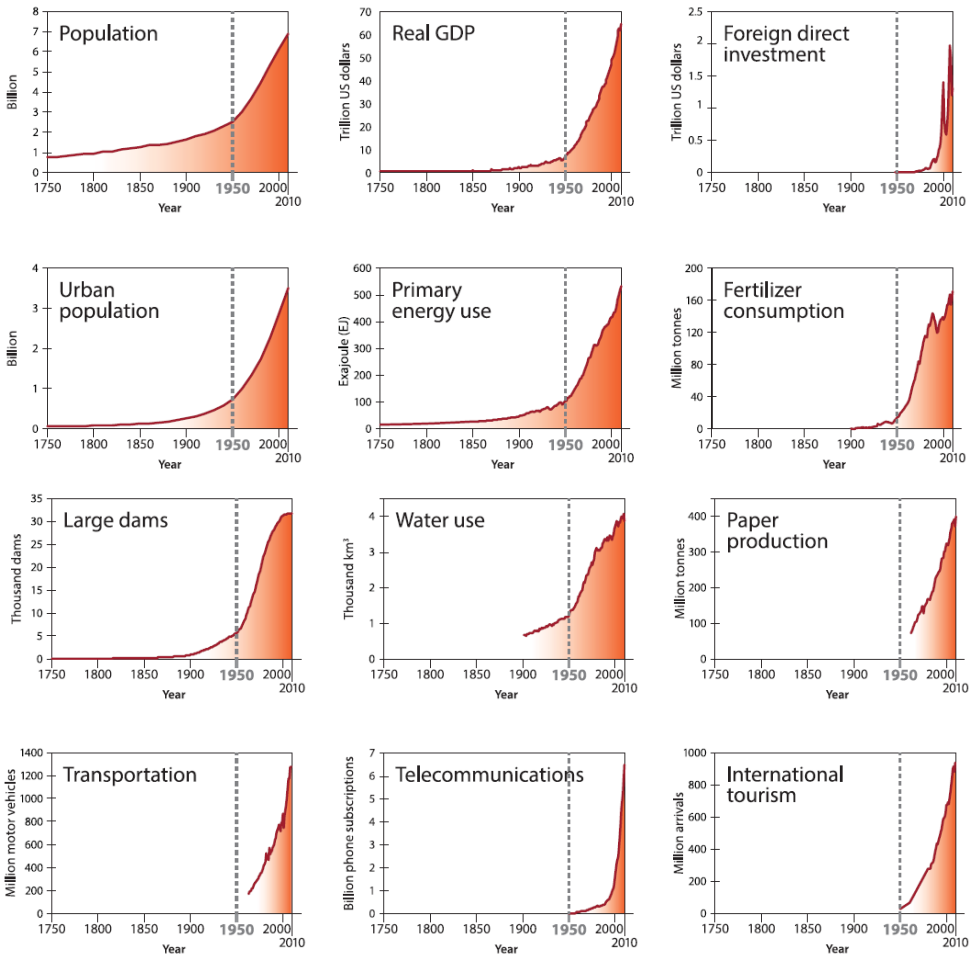


Figure 8 - Trends from 1750 to 2010 in globally aggregated indicators for socio-economic development (from Steffen *et al.*, 2015b; see paper for sources of data)

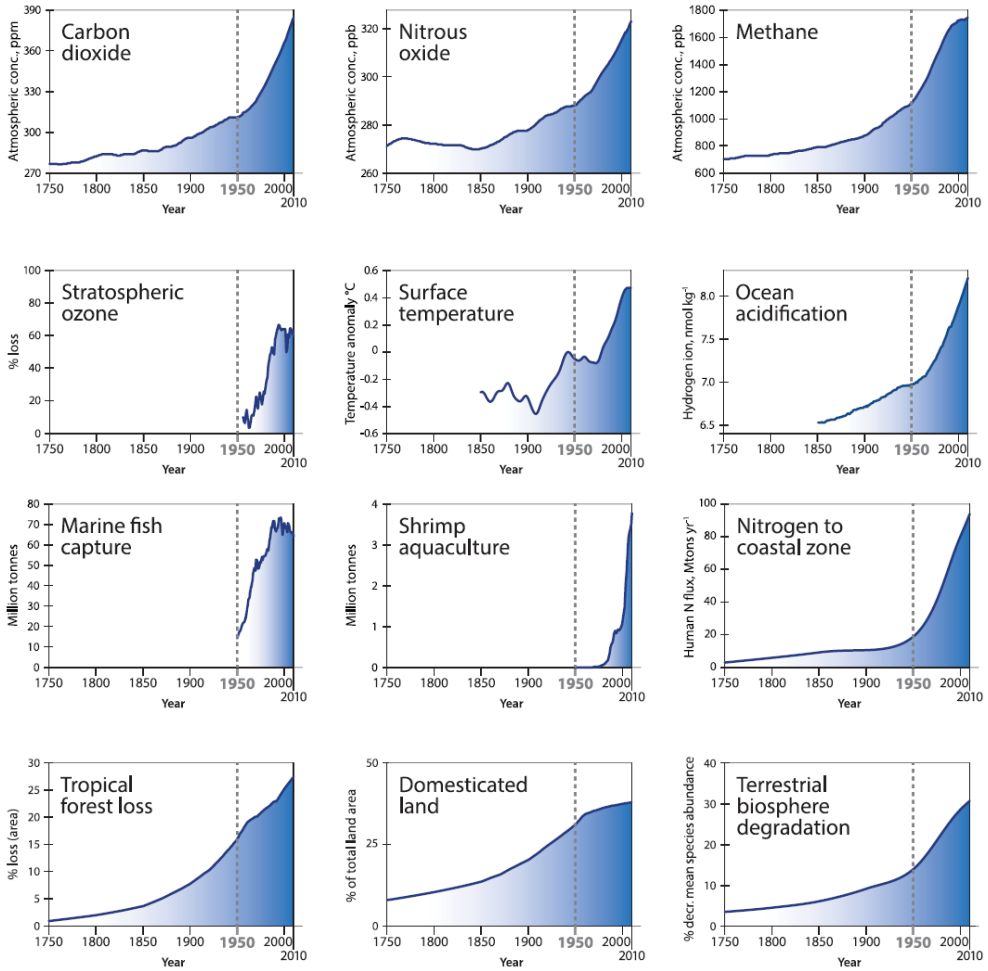


Figure 9 - Trends from 1750 to 2010 in indicators for the structure and functioning of the Earth System (from Steffen *et al.*, 2015b; see paper for sources of data)

Climate change and other environmental issues have been a constantly growing cause of concern also in business environments, even though little consequences in day-to-day business management could be observed.

Since the World Economic Forum (WEF) started publishing its yearly "Global Risk Report", the environmental challenges, such as rising temperatures, sudden and extreme weather events, loss of biodiversity, soil loss and degradation, pollution etc. have been progressively pushed in a quadrant of events with high potential impact and high likelihood of occurrence (Collins *et al.*, 2018; Collins *et al.*, 2019).

The report is based on a survey carried out among high profile stakeholders and business managers. The perceived risks are in the events themselves (potential damage) and in the transitions needed to mitigate their effects.

In the latest edition of the "Global Risk Report" (Collins *et al*., 2019), "Failure of climate-change mitigation and adaptation" is rated as the second most likely global risk for humanity (the first is extreme weather events) and the second most heavily impacting on our future (first in impact, but low in likelihood, is the use of weapons of mass destruction). The three other environmental risks considered ("Natural disasters", "Man-made

environmental disasters" and "Biodiversity loss and ecosystem collapse") are all placed in the first quadrant: high likelihood, high impact.

Greenhouse gases (GHG) are the main culprits for global warming and emissions due to human activities have reached the highest levels in history (Hart *et al*., 2017), increasing sharply after the years '70s of the last century, despite the mitigation efforts put in place after Kyoto.

CO_2 is the best known among GHG and for this reason all emission measures are expressed in CO_2 equivalent (CO_2eq). However other gases are more powerful in the absorption of infra-red rays. Table 5 reports the warming effect of different GHG adjusted for the degree of persistence in the atmosphere. Of special concern for agriculture are Methane (from enteric fermentation of ruminants) and Nitrous oxide (from manures and nitrogen fertilisers).

Table 5 - Global warming potential of selected GHG over a period of 1000 years (from IPCC, 2007b)

Industrial designation or common name	Chemical formula	Global warming potential for a 100-years time horizon
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Sulphur hexafluoride	SF_6	22,800
Nitrogen trifluoride	NF_3	17,200

The single sector responsible for GHG emissions in the world is energy production and use which accounts for approximately one third of GHG emissions (IEA, 2015).

In the energy sector some positive signs are starting to appear. For the first time in history in 2014 the world economy grew by approximately 3% and energy related emissions (beware, not all emissions!) stayed flat. This is partly due to the significant investments in renewable energy sources by some big players like China and Germany, but also US and Japan, favoured by steadily decreasing costs of renewable energy technologies, solar photovoltaic in particular, and significant investments in increasing efficiencies of industries and households (IEA, 2015).

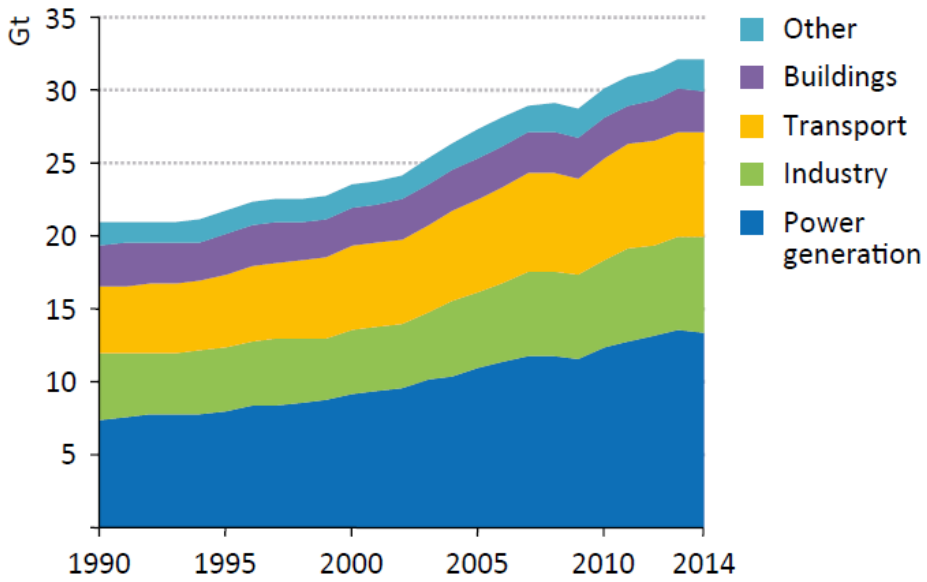


Figure 10 - Global energy-related CO_2 emissions by sector. Agriculture is included in "Other". (IEA, 2015)

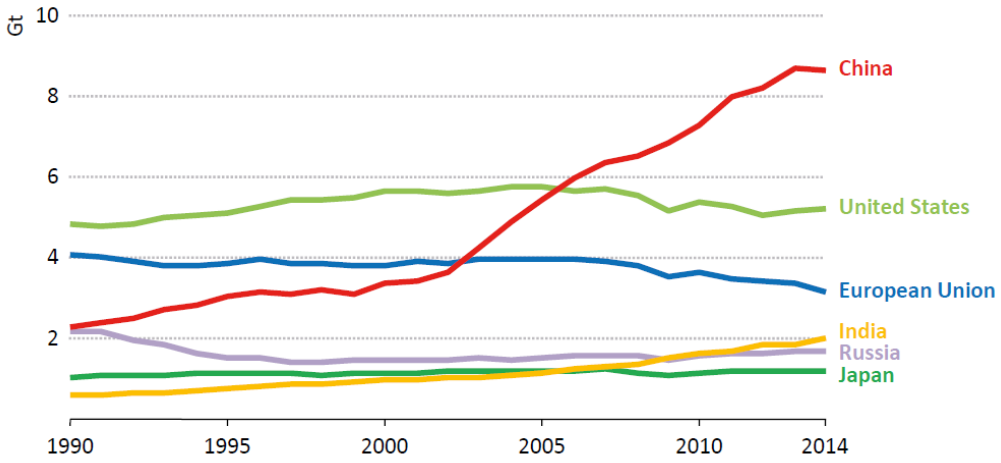


Figure 11 - Global energy-related CO_2 emissions by region (IEA, 2015)

The IEA (2015) raises the attention on the fact that, whereas around 11% of global energy related GHG emissions take place in areas where a carbon market is operating (albeit at a very low average price of 7 US$/t CO_2eq, a higher share (13%) comes from countries where energy produced with fossil fuels is heavily subsidised (i.e. encouraged!) at a staggering incentive value of 115 US$/t CO_2eq).

Europe is slightly more "virtuous" than other major players, as can be seen in Figure 11, with a steady, if slow, decline in energy-related GHG emissions. Figure 12 reports the changes in GHG emissions in Europe by aggregated sector. European Agriculture is responsible for 11.3% of EU GHG emissions, with a relative share that might increase in the next future due to the faster progress towards emission reductions in other sectors (energy, industry, residential and commercial). The rapid increase of emissions from biomass is remarkable: there is growing concern about the environmental and climatic

role of biomass as a source of energy. Biomass sources are mainly domestic (EU) but imports are also growing rapidly.

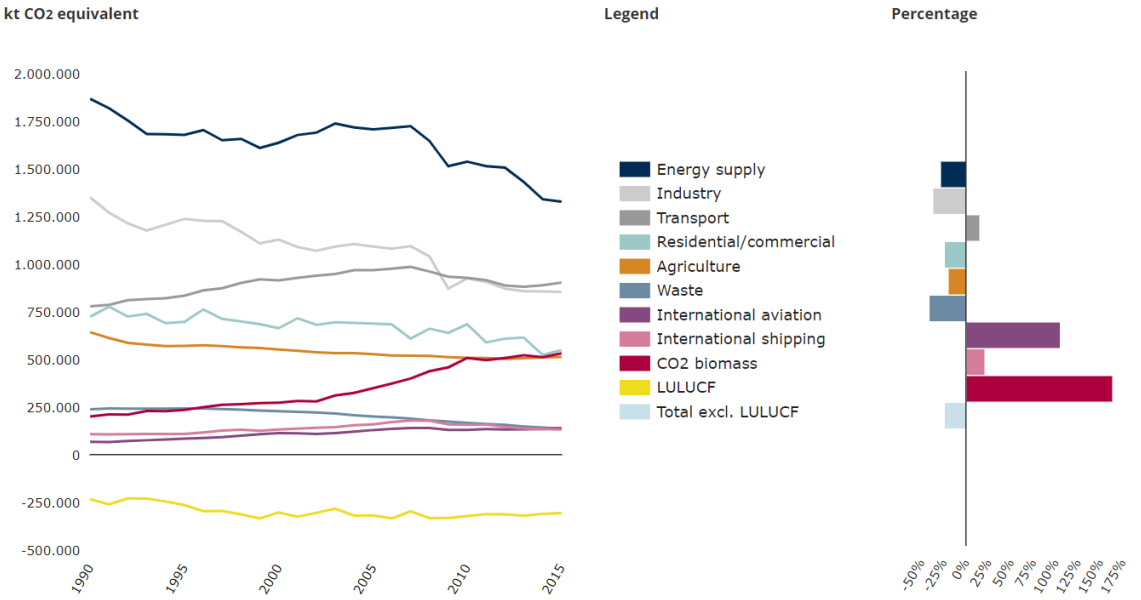


Figure 12 – European GHG emissions by aggregated sector (EEA, 2017).

Despite some positive results in reducing carbon emissions that will allow (it is expected) to reach the 20% reduction in the year 2020 with respect to 1990 levels, it seems that the -40% target for the year 2030 will be missed, let alone the even more ambitious targets of COP21 of net zero emissions by 2055. (Figure 13). For 2030 a reduction of EU GHG emissions of between 30% and 32% could be achieved according to Member States' projections reported in 2017.

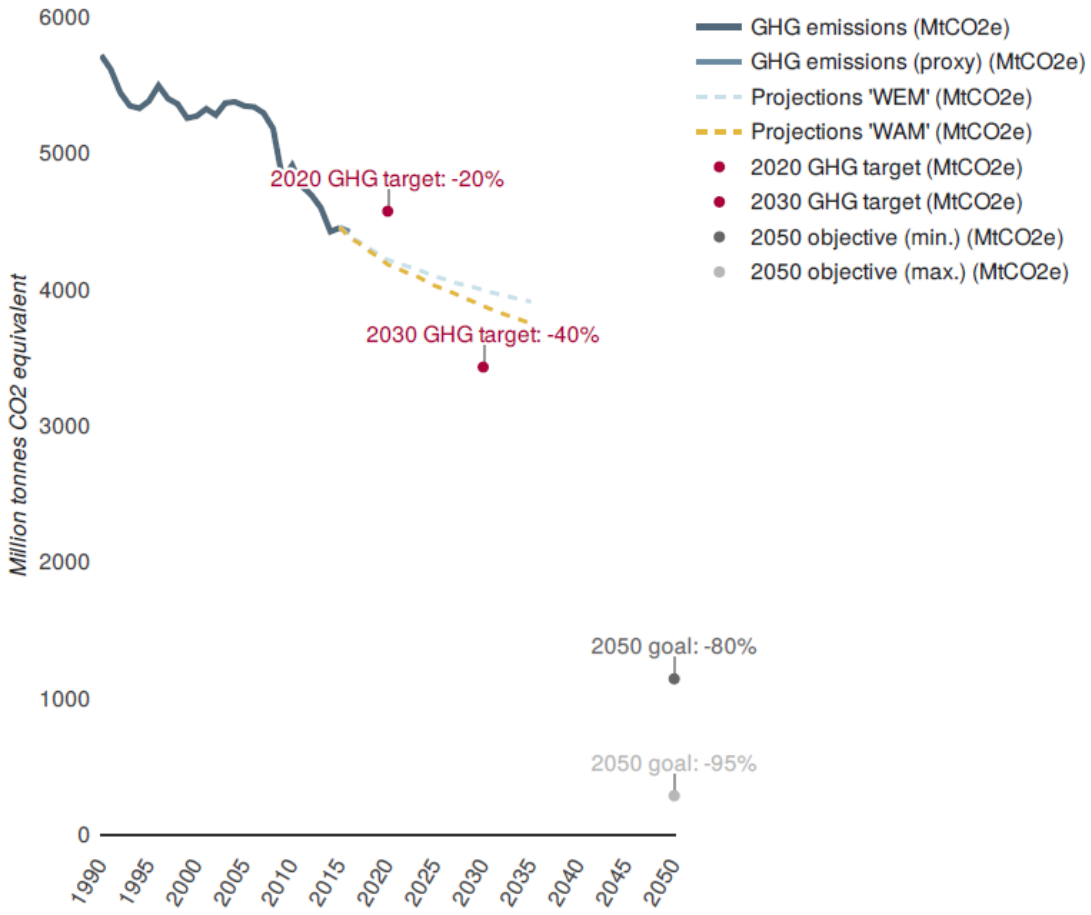


Figure 13 - Greenhouse gas emission trends, projections and targets in the EU (EEA, 2017).

The Paris Accord of 2015

The agreement reached in Paris at the 21st Conference of Parties of the UNFCCC represents a significant political achievement. It was signed by the representatives of 195 countries that produced a list of "Intended Nationally Determined Contributions (INDC) that represent their commitments towards the achievement of the iconic objective to hold "*the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels"* and provide a "*bridge between today's policies and climate-neutrality before the end of the century*" (Hart *et al*., 2017).

Recorded temperatures point at an already reached level of +1°C (±0,2°C), although not yet as a 10-years average, so that the residual operating space is narrow indeed. (IPCC, 2018)

The Paris Agreement entered into force on 4 November 2016, a month after the ratification by at least 55 Parties to the UNFCCC accounting for a total of least an estimated 55% of the total GHG emissions. The EU ratified the agreement in October 2016 (Hart *et al*., 2017).

Despite the political success of such a large consensus on the objectives (and some remarkable subsequent withdrawals, such as the US), the Paris Accord

is weak in its power to enforce the enactment of "Nationally Determined Contributions" (as the INCD are called after ratification).

Unlike the Kyoto protocol, there is no legal mechanism to oblige countries to set specific targets and dates on NDCs, nor to enforce the NDCs. The political will and societal consciousness of individual countries is essential.

The United Nations Environment Programme published an "Emission Gap Report" in 2017 (UNEP, 2017) and noted that the NDCs cover only about 1/3 of the emissions reductions that would be necessary to stay within the 2°C temperature increase. Even under the hypothesis that NCDs were fully implemented, the emissions "budget" compatible with the +2°C target would be 80% exhausted by the year 2030; and all the "budget" compatible with the +1.5°C target.

The gap between the reductions needed and the national pledges made in Paris is alarmingly high.

Responding to an invitation by the COP 21, the IPCC produced a special report on "*the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*" (IPCC, 2018), produced at the 48th Session of the IPCC in Incheon, October 2018, as a contribution to the UNFCCC COP 24 held in Katovice, Poland, December 2018.

The report addresses the actions required to adhere to the 1.5°C target and compares them and their consequences with the +2°C target. Having been developed after the publication of the United Nations Sustainable Development Targets of 2015, the IPCC Report also analyses the impact of climate change on the SDGs, with a special attention synergies and conflicts between mitigation and adaptation actions.

The current rate of global warming is estimated at 0.2°C per decade; consequently, if no actions to moderate it are taken immediately, the +1,5°C warming will be reached between 2030 and 2052.

The IPCC observes that "pathways reflecting current nationally stated mitigation ambition until 2030 are broadly consistent with cost-effective pathways that result in a global warming of about 3°C by 2100, with warming continuing afterwards" (IPCC, 2018). In other words, the world is not on the right track.

Averages, however, tell part of the truth because significant regional variations have been observed. For instance, the increase observed in the Arctic is two or three times the global average.

Two figures taken from the IPCC (2018) special report are very effective in portraying the current situation and perspectives for the future.

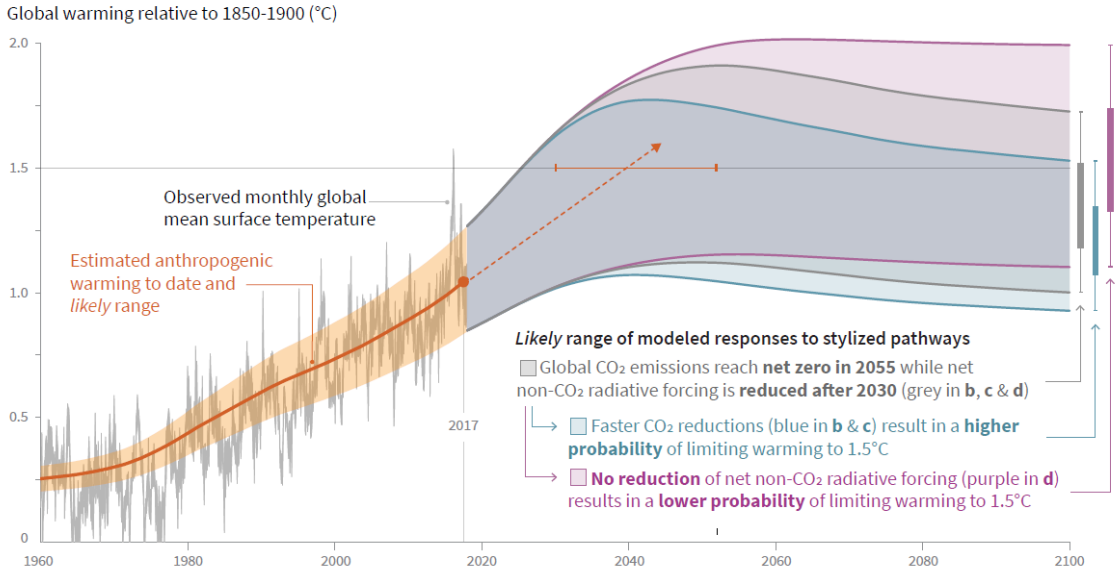


Figure 14 - Cumulative emissions of CO_2 and future non-CO_2 radiative forcing determine the probability of limiting warming to 1.5°C. Observed global temperature change and modelled responses to stylized anthropogenic emission and forcing pathways (see below) (From: IPCC, 2018).

The red dotted line represents a BaU temperature trend that, as stated previously, would trespass the +1.5°C threshold between 2030 and 2052.

The area bounded by grey solid lines represent likely temperatures up to the year 2100 in the hypothesis of reaching zero net emissions by 2055 together with a reduction of non-CO_2 radiative forcing (such as caused by methane, nitrous oxide, hydrofluorocarbons, etc.) after 2030.

A more ambitious (almost science fiction) hypothesis of zero net emissions by 2040 (area delimited by green lines) or a more pessimistic hypothesis of inability to reduce non-CO_2 radiative force after 2030 (area delimited by magenta lines) would increase and decrease, respectively, the likelihood of staying within the 1.5°C increase.

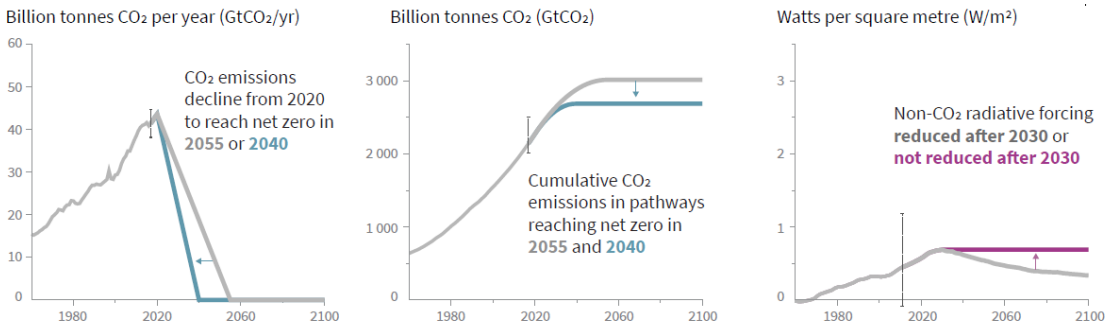


Figure 15 - Left: Stylized net global CO_2 emission pathways; Centre: Cumulative net CO_2 emissions; Right: Non-CO_2 radiative forcing pathways (From: IPCC, 2018).

The three hypotheses are represented in Figure 15 in terms of net emissions (flows), cumulative GHG in the atmosphere (stock) and radiative force (energy).

The first one (left) is quite eloquent in showing the drastic U-turn that net CO_2 emissions should display from now on.

A look into the future

Current NCD point at a global GHG emissions of 52–58 $GtCO_2eq/y$ in 2030, up by around 20% with respect to current emission levels. "*Pathways reflecting these ambitions would not limit global warming to 1.5°C, even if supplemented by very challenging increases in the scale and ambition of emissions reductions after 2030*" (IPCC, 2018).

The transitions needed to limit temperature growth within 1.5°C require rapid and effective actions in many areas: energy production, transport, buildings, industries and other infrastructures. Most of them are not limited by the current availability of technologies but by the unprecedented scale of investments required that need a strong political will (IPCC, 2018).

The signals coming from today's economies are not really encouraging. Despite the weakening of the correlation between growth (as measured by GDP) and emissions, these are constantly rising. Renewables are projected to represent over half the new investments after 2030, but the decline in fossil energy is much slower than would be necessary. Even coal as a source of energy declines slowly (IEA, 2015).

The majority of China's coal-fired electricity power plants have been built after the year 2000 and are likely to stay in operation until 2030-2050; it must be acknowledged, however, that China has invested a great deal of resources in high efficiency and clean(er) technologies and that it already has plans to stop the operations in the most inefficient infrastructures (IEA. 2015).

New investments in fossil fuel-based energy make the new energy infrastructures dependent on these types of fuel for the next 30-40 years thus creating a "path dependence" for decades to come (IEA, 2015).

It must also be considered that, even if actions to stay within the +1.5°C were effective, even this limited global temperature increase would have significant effects on climate, more drastic than those already observable: melting ice caps, extreme meteorological events (droughts, floods, storms), rising sea levels, ocean acidification, …). Adherence to COP 21 objectives will therefore limit the damage, not avoid it or reverse the climatic trends; to achieve that, net negative emissions (i.e. CO_2 capture) will be necessary.

A combination of approaches will be necessary, as no single strategy is likely to meet with success. Figure 16 lists a number of options to capture carbon from the atmosphere that have been suggested by scientists. They differ in cost, effectiveness, short-term feasibility and risk of unintended negative consequences (UNEP, 2017).

Carbon dioxide removal technologies and practices aimed at removing carbon dioxide from the atmosphere are represented by both biological and engineered options. The former ones are based on a long time experience. Engineered options (such as BioEnergy combined with Carbon Capture and Storage, or BECCS) have potential but are still in their infancy (UNEP, 2017)

According to the IPCC (2018) adaptation and mitigation options need to be implemented in a participatory and integrated way in order to trigger and achieve the systemic transitions required. However, measures envisaged by the IPCC to achieve the +1.5°C target may imply drastic changes in economic and social systems and in individual lifestyles:

- Strong immediate reduction of CO_2 emissions from all sources
- Rapidly diminishing energy demands and increasing share of renewable energy
- Reduction of coal, oil and gas as energy sources
- Increased share of nuclear energy (obviously controversial!)
- Bioenergy crops (likely trade-off with food production)
- Reduction of agricultural CH_4 and N_2O emissions

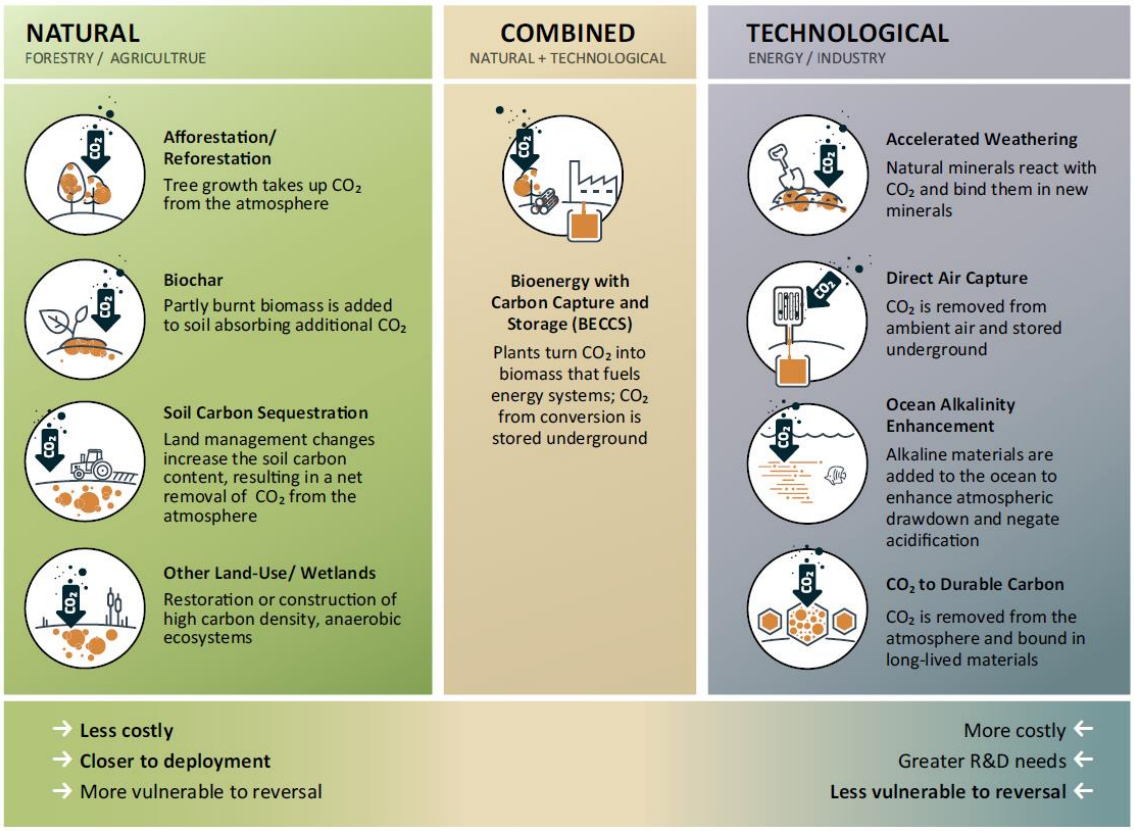


Figure 16 - Major strategies for negative emission technologies (UNEP, 2017)

Changes in building techniques, transports, infrastructures would be necessary, some of which require long transitions and high costs. A synergy between local and national governments and an effective global coordination are essential prerequisites. Any change that implies high costs to a minority and small benefits to all is very likely to be disregarded unless an effective supra-national global governance is established to ensure a really worldwide joint effort. Nothing of this kind is within sight today.

More invasive technologies, such as "geo-engineering", or the deliberate injections of aerosols into the atmosphere or stratosphere to filter out incoming sun radiation thus reducing temperature, are likely to have unintended effects on crop production due to reduced availability of light for photosynthesis. Indeed, such techniques, (already controversial and not yet in use) are listed in the latest WEF risk report (Collins *et al*., 2019) as a global threat, as they could be used to maliciously alter weather patterns.

The role of seas and oceans

Another important fact to consider is the buffer effect of physical/chemical systems: the ocean currently absorbs about a quarter of the carbon dioxide added to the atmosphere from human activities each year, thus reducing the level of CO_2 in the atmosphere with respect to net emissions and moderating its effect on global temperature (Steffen *et al*., 2015b). Apart from the negative effect of ocean acidification and increased temperature on marine ecosystems, this means that the heat and CO_2 would be returned to the atmosphere in the desirable case of an effective global action achieving negative net CO_2 emissions in the future and that would slow down recovery.

The two direct consequences of increasing CO_2 and temperature increase on seas and oceans are:

- **Sea level rise**: According to the IPCC (2018), a 2°C increase will cause sea levels to rise between 0.30 metres and 0.93 metres by 2100. It has been estimated that already by 2050 could number over 800 million people, living in 570 cities"[12].
- **Ocean acidification:** sea water pH decreases as CO_2 in the atmosphere increases, with negative implications on coral reefs and carbonate dependent shellfish (Steffen *et al*., 2015b).

Climate change and agriculture

Agriculture is both affected by and has an impact on climate change both positive and negative (Hart *et al*., 2017).

The main ways in which agriculture is affected by climate change are through the increased pressures on crop and livestock production resulting from water availability, overall temperature variations, extreme meteorological events, presence and persistence of pests and diseases, as well as fire risks (Hart *et al*., 2017; IPCC, 2018).

In the EU, climate related impacts on agriculture have largely been negative, with moderate positive impacts limited to temperature increases in northern latitudes.

It is anticipated that crop productions will decline most severely, due to climate change, in tropical areas, where most of the undernourished and food insecure people live at present (FAO, 2014 and Brown *et al*., 2015).

[12] https://www.c40.org/other/the-future-we-don-t-want-staying-afloat-the-urban-response-to-sea-level-rise

A study cited published by the journal The Lancet (Springman *et al.*, 2016) and cited also by HLPE (2017) used a modelling approach based on the IMPACT mathematical model developed at IFPRI to evaluate risks associated with changes in fruit, vegetable and red meat consumption, and bodyweight for a number of deaths causes (coronary heart disease, stroke, cancer, etc.). The model developed scenarios based on combinations of emission pathways and socio-economic pathways.

The model projects that by 2050, climate change will reduce pro capita food availability by 3.2% and specifically by 4.0% in fruit and vegetables and 0.7% in red meat. This will be associated with a 28% reduction in the number of deaths that would be avoided because of changes in dietary and weight-related risk factors between 2010 and 2050. Twice as many deaths would be associated with reduced fruit and vegetable consumption than with undernourishment.

Agriculture as a driver of climate change

But agriculture is also a major cause of climate change. It is estimated that around 25% of all GHG emissions into the atmosphere are caused directly by crop and animal production (especially methane by ruminants) and forestry (mainly through deforestation). A further 2% is attributable to agriculture but is usually accounted in other sectors (industry, energy) and is due to the productions of fertilisers, herbicides and pesticides and to the energy employed for agricultural operations (FAO, 2014).

Similar figures are reported by Swinburn (2019) with a direct contribution of agriculture to GHG emissions of 15–23%, in the same range as transportation. However, if deforestation or conversion of pastures to crop lands and the whole food processing sector are taken into account, the GHG emissions represent almost 30% of the total, with livestock accounting for 12–19% of all GHG emissions.

Agriculture is a sizeable GHG source in the EU as well, with enteric fermentation by ruminants in the front line, although with variations according to type and intensity of livestock management. Grazing land management, however, is at present a net CO_2 sink and is likely to remain a sink in the future (EEA, 2017)

Alongside emissions of methane and nitrous oxide, cropland management overall is a net source of CO_2 emissions (although not in all countries) and is predicted to remain a source in the future.

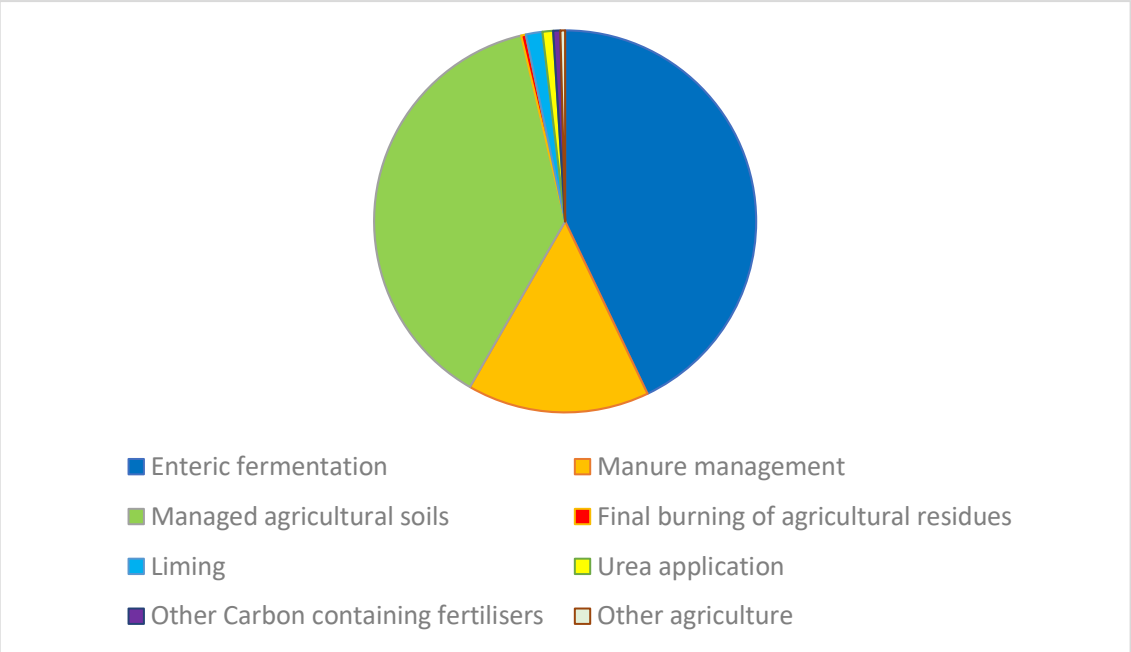


Figure 17 - Agriculture GHG emissions by source in Europe (reference year 2014) (Source: EEA, 2017)

However, navigating among statistics is not easy. AFOLU (agriculture, forestry and other land use) are treated with **two different components of the EU mitigation framework to 2020**.

Non-CO_2 emissions (e.g. CH_4 and N_2O) are treated under the **Effort Sharing Decision (ESD,** COM(2013)216) whereas CO_2 emissions and removals from the land using sectors are covered under the land use, land use change and forestry (**LULUCF**) Decision. In practice therefore different GHG impacts from the same sector are reported through separate frameworks. **At present the LULUCF sector remains formally outside EU climate policies** and EU emission-reduction targets. The EU's LULUCF Decision, introduced in 2013, does however require Member States to take certain actions, particularly in relation to improving monitoring and reporting for emissions and removals associated with cropland and grassland, in preparation for the sector's inclusion in the EU's emission reduction targets in the post-2020 accounting period. In addition to the ESD and LULUCF Decision, the EU-Emissions Trading System (ETS) (Directive 2003/87/EC) covers emissions from other GHG generating sectors and accounts for the majority of CO_2 emissions in the EU. **The EU-ETS does not cover agriculture as a sector**, yet there is an indirect link through its coverage of **biomass in energy** generating facilities and the **industrial production of ammonium nitrate** used in agricultural fertilisers (Hart *et al*., 2017)

According to EEA (2017) the level of non-CO_2 agriculture emissions (i.e. methane, nitrous oxide etc.) decreased by 113 $MtCO_2eq$ from 1990 to 2014 (-21%). This is largely due to a decrease in livestock numbers, but also to improvements in livestock and farm management practices encouraged by CAP. The speed of decline, however, was higher in the period from 1990 to 2000 (-16%) than in the period 2001 and 2012 (-8%) in parallel with the rate of reduction of livestock numbers.

Different climates, farming systems, management practices, relative importance of farming vis-à-vis other sectors in the economic system makes the relative contribution of agriculture GHG emissions to the national total to reach very different figures: the proportion is highest in Ireland (32.2%; 18.7MtCO_2eq) and lowest in Malta (3%; 0.088 MtCO_2eq).

In absolute rather than relative terms, the greatest contribution of GHG emissions from agriculture comes from France (18%; 79 MtCO_2eq), Germany (15%; 66.1 MtCO_2eq) and the United Kingdom (10%; 44.6 MtCO_2eq). These three MS account for little less than 44% of total EU-28 agriculture emissions.

As far as non-CO_2 GHG emissions are concerned ("Effort Sharing Decision" emissions), EU agriculture represents a significant share of national totals, as reported in Figure 18.

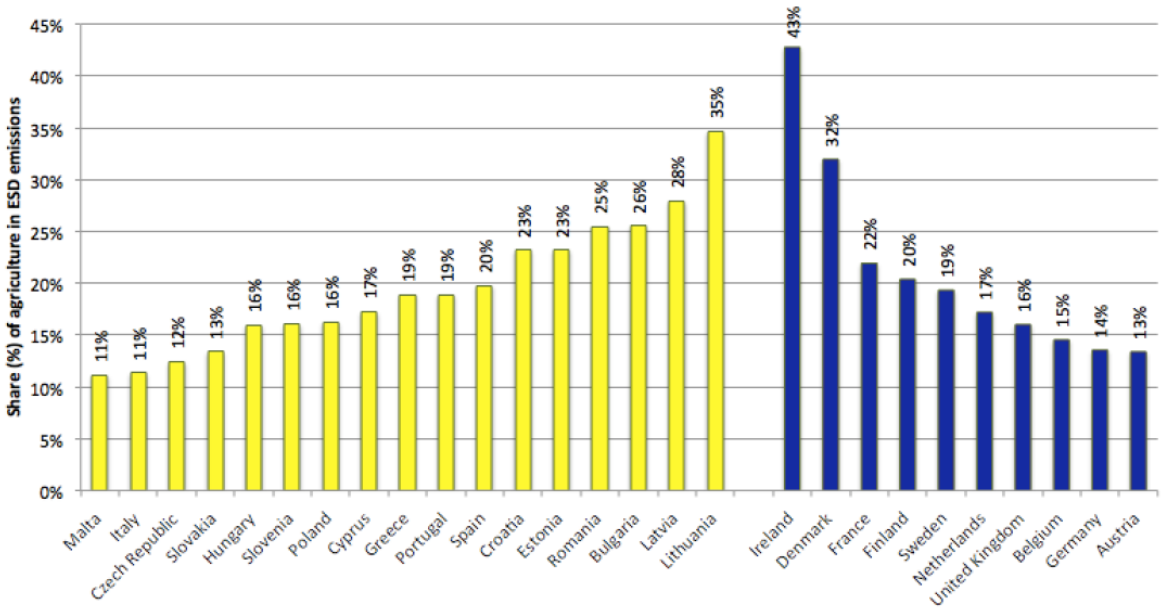


Figure 18 - Share (%) of agriculture in ESD emissions (i.e. non CO_2 GHG) in 2015. Yellow bars represent Member States with GDP lower than the EU Average. Blue bars represent Member States with GDP higher than the EU average (From: EEA, 2017

It is worth mentioning that France is also first in the EU-28 for carbon sequestration through its LULUCF sector (16.7%; 50.1 MtCO_2eq) whereas Germany and the UK rank 8th and 11th (EEA, 2017).

CAP environmental measures in the Rural Develoment Programme pillar have contributed to an improvement of the position of agriculture vis-à-vis climate change, albeit with considerable variations between MS and a "minimalist" approach in many countries and regions. A mere 1.8% of agricultural land is estimated to be included in contracts contributing to carbon sequestration and conservation by 2020 and 7.7% under management targeting the reduction of GHG or ammonia emissions (Hart *et al*., 2017).

The effort to effectively target agriculture in the context of climate change mitigation in the EU has not been really strong for a variety of reasons: an acknowledged more limited margin for improvement with respect to other sectors, the sensitivity of the argument regarding the need to ensure food security, and the reticence of many MS to engage with the farmers' organisation on a divisive subject. As a consequence, mitigation efforts

generally focus on activities that have the least impact on the productivity or growth of the sector, or those which are economically convenient, e.g. when they reduce expenses for inputs (Hart *et al*., 2017).

Efforts of the agricultural sector towards Climate Change mitigation is a sensitive issue also at the global scale, despite the general agreement on principles reached in Paris at COP21. A reason for the lack of agreement is the different attitude of developed and developing countries towards agriculture and its role on food security and rural livelihood. To put it bluntly, agriculture is a business in developed countries, a matter of survival in many developing countries.

The measures that are available to EU agriculture to reduce its negative impacts on climate change and increase its positive contribution to mitigation include improving the resource use efficiency of the sector (*in primis* fertilisers), soil management practices and livestock management (see Table 6) (Hart *et al*., 2017).

Table 6 - Climate mitigation actions with evidence of mitigation potential on agricultural land in the EU (From: Hart *et al*., 2017)

Land Use	• Conversion of arable land to grassland to sequester carbon in the soil • Agroforestry • Wetland/peatland conservation/ restoration • Woodland planting • Preventing deforestation and removal of farmland trees • Management of existing woodland, hedgerows, woody buffer strips and trees on agricultural land
Crop Production Systems	• Reduced tillage • Zero tillage • Leaving crop residues on the soil surface • Ceasing to burn crop residues and vegetation • Use cover/catch crops
Livestock Production Systems	• Livestock disease management • Use of sexed semen for breeding dairy replacements • Breeding lower methane emissions in ruminants • Feed additives for ruminant diets • Optimised feeding strategies for livestock
Manure, Fertiliser & Soil management	• Soil and nutrient management plans • Use of nitrification inhibitors • Improved nitrogen efficiency • Biological N fixation in rotations and in grass mixes
Energy	• Carbon auditing tools • Improved on-farm energy efficiency

The cost-effectiveness of different measures to reduce GHG emissions through changes in agricultural practices and food systems is of course relevant in order to compare with reduction measures in other sectors. The UNEP Emissions Gap Report 2017 (UNEP, 2017) provides a lists of actions that would not cost more than 100 US$ per ton of CO_2eq per year (see Table 7). The overall contribution is in the range of 5.5-7.7 $GtCO_2$eq/y, or 13 to 18% of emissions at current levels.

Table 7 - Overview of emission reduction potentials in 2030 that can be achieved at a cost of no more than US$100/t CO_2eq in the Agriculture sector (Gt CO_2eq per year) (UNEP, 2017).

Category	Emission reduction potential in 2030 ($GtCO_2eq/y$)
Cropland management	0.74
Rice management	0.18
Livestock management	0.23
Grazing land management	0.75
Restoration of degraded agricultural land	0.5 - 1.7
Peatland degradation and peat fires	1.6
Biochar	0.2
Shifting dietary patterns	0.37 - 1.37
Decreasing food loss and waste	0.97 – 2
Total	**5.54 – 7.42**

Other potential contributions of Agriculture to the reduction of GHGs are controversial and imply evident trade-offs, such as bioenergy crops (potential conflict with food/feed production and possible consequences on imports to meet demand) and the use of agricultural land for renewable energy installation, such as solar PHV and wind turbines.

Europe has not developed explicit target for the reduction of GHG from agriculture, nor have Member States. The focus on a generic reduction of non-CO_2 emissions (under the ESD) does not push the sector towards a decisive GHG emission limitation. Member States are postponing decisions that would face the opposition of farmers and the actions foreseen in the CAP are and will likely remain rather lukewarm (Hart *et al*., 2017)

Agriculture adaptation to climate change: building sustainable farming systems

Adaptation options for the agriculture sector include better management of soils and water resources, drought management plans, land use planning and behavioural change (Hart *et al*., 2017).

Agriculture is of course very susceptible to climate patterns, with place- and crop- specific impacts. The most obvious pressures come from water availability and temperature variations, but probably the highest risk comes from increasing pest dynamics due to the expansion of their range, higher winter survival, more generations per year. Less clear in their development, but also a source of concern are diseases that could take advantage of heat/drought stress of crops.

Adaptation can mean changing crops, changing animal breeds, but also *"building resilience into production systems and ensuring sufficient contingency planning and insurance, forecasting systems to enable early warning of extreme and detrimental weather events, and even physical changes, such as amendments to river pathways, floodplains or vegetation structure"* (Hart *et al*., 2017).

The protection of climate from change, the role of agriculture in its mitigation and the need to adapt agricultural systems did not appear in the definition of

"sustainable agricultural management" that appeared in the Report of the FAO Council of 1988 (FAO, 2014): "*the management and conservation of the natural resource base, and the orientation of technological change in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations. Sustainable agriculture conserves land, water, and plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable*".

However, it is obvious that the concept of sustainability includes the continuous adaptation to new challenges.

According to FAO (2014) five principles are fundamental in a sustainable agri-food system:

1. **Improving efficiency in the use of resources is crucial to sustainable agriculture**. Manty key resources, including water, fertilisers, soil, are often used with little regard to optimisation leading to their waste or even damage to the environment and the economy: the efficiency in the use of fertilisers is a good example: fertilisation is often applied in excess of needs or in a way that limits uptake; what is not used by crops ends up in water tables or water courses and becomes a source of pollution. Excess in nitrogen application contributes to GHG emissions both when applied in the fields and in the energy intensive industrial process of production. It is estimated that the production of the 110 million tons of nitrogen used as fertiliser in 2013, 96 billion m3 were used (i.e. over 870 m^3 of gas per ton produced).
2. **Sustainability requires direct action to conserve, protect and enhance natural resources.** A word of caution is needed when talking of increasing efficiency in the use of resources having a reduction in quantity used as the objective. It happens frequently that increased efficiency makes the use of the resource economically more convenient, which leads to an increase of use (the so called "Jevon's paradox"). Therefore, efforts at conservation of the ecosystems should be a clear priority. A long-term view must overcome short-term profit considerations.
3. **Agriculture that fails to protect and improve rural livelihoods, equity and social well-being is unsustainable.** Technical efficiency should not prevail over social considerations. Over 75% of the poor of the world live in rural areas and their ancestral, albeit in many circumstances undocumented, rights of land use, are often threatened by the introduction of "modern" agricultural models based on economies of scale that cause dispossession and dislocation of rural dwellers. The introduction of new crops or new production techniques should always involve local farmers and local communities in a participatory way.
4. **Enhanced resilience of people, communities and ecosystems is key to sustainable agriculture.** The rural communities, especially in poor countries, are vulnerable to threats that may be meteorological (droughts, floods, frost), biological (pests and diseases) or economic (price fluctuations). Devising methods, both physical (e.g. robust cropping systems) and socio-economic (risk sharing, relief subsidies) to mitigate risks increases resilience at the individual and community level.

5. **Sustainable food and agriculture require responsible and effective governance mechanisms**. Social justice, law enforcement, recognition of rights, a good balance between private and public initiatives, equity, recognition of women's rights and status, are all aspects of a good governance.

Mitigation and adaptation measures vs SDGs

The IPCC, in its 2018 report on the +1.5°C target (IPCC, 2018), points out that reaching the SDGs of the UN 2030 Agenda would be significantly easier if the more ambitious goal could be achieved instead of the +2°C goal: "*The avoided climate change impacts on sustainable development, eradication of poverty and reducing inequalities would be greater if global warming were limited to 1.5°C rather than 2°C, if mitigation and adaptation synergies are maximized while trade-offs are minimized"*.

Synergies in actions that characterise the 1.5°C pathways can be seen, for example between SDGs 3 (Good health and wellbeing), 7 (Affordable and clean energy), 11 (Sustainable cities and communities), 12 (Responsible consumption and production), and 14 (Life below water); in other cases a trade-off may emerge: SDGs 1 (No poverty), 2 (Zero hunger), 6 (Clean water and sanitation), and 7 (Affordable and clean energy).

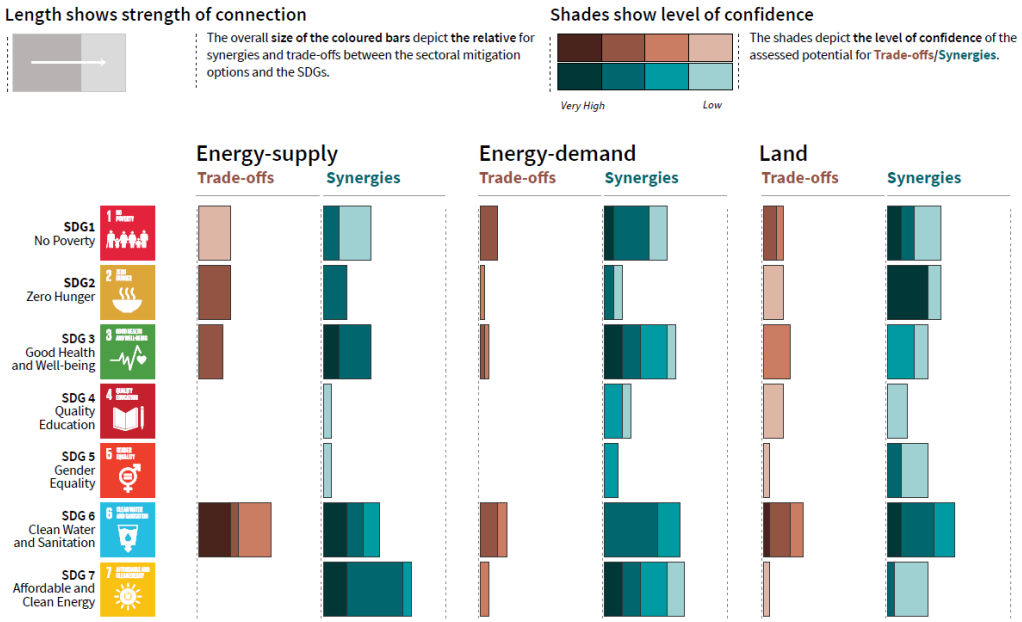


Figure 19 part a) - Potential synergies and trade-offs between the sectoral portfolio of climate change mitigation options and the Sustainable Development Goals (SDGs 1-7) (IPCC-2018)

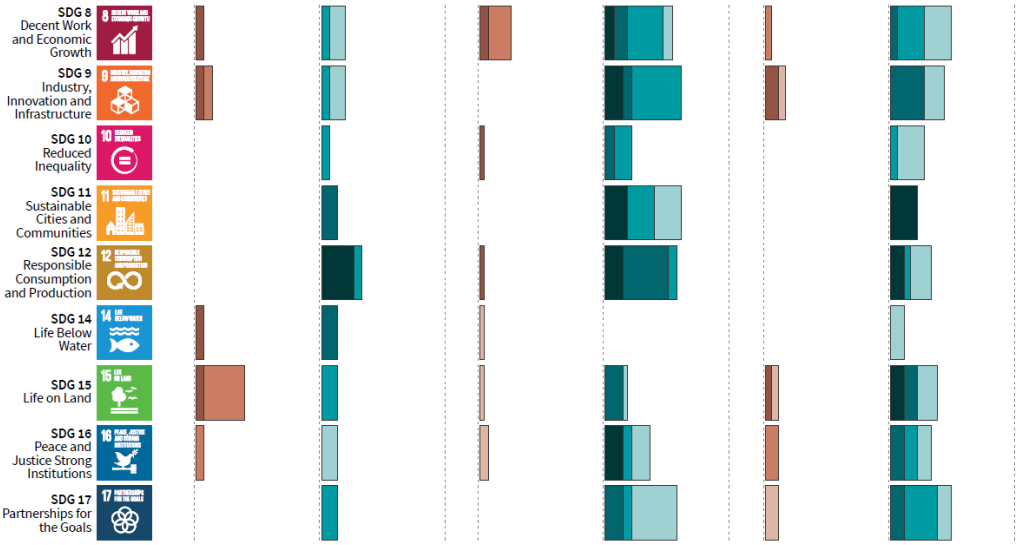


Figure 19 part b) - Potential synergies and trade-offs between the sectoral portfolio of climate change mitigation options and the Sustainable Development Goals (SDGs 8-17; legenda in Figure 19 part a) (IPCC, 2018)

However, technology alone cannot achieve significant results: "*strengthened multi-level governance, institutional capacity, policy instruments, technological innovation and transfer and mobilization of finance, and changes in human behaviour and lifestyles are enabling conditions that enhance the feasibility of mitigation and adaptation options for 1.5°C consistent systems transitions*" (IPCC, 2018).

The IPCC (2018) again: *"the large majority of modelling studies could not construct pathways characterized by lack of international cooperation, inequality and poverty that were able to limit global warming to 1.5°C"*.

Planetary boundaries

So far we have focused on climate change and on the relationships between climate change and agriculture. However, the impact of human activities on the biosphere is broader than the mere emission of GHGs.

The concept of Planetary Boundaries, introduced by Rockström *et al*. (2009) to identify levels of a range of anthropogenic perturbations below which the risk of destabilization of the Earth System is likely to remain low, a "safe operating space" for global societal development (Table 8 and Figure 20).

Table 8 - Planetary Boundaries (and control variables) according to Rockström *et al*. (2009).

Climate change	CO_2 concentration and Energy imbalance at top-of atmosphere
Change in biosphere integrity	Species Extinction rate and Biodiversity Intactness Index
Stratospheric ozone depletion	Stratospheric O_3 concentration
Ocean acidification	Carbonate ion concentration
Biogeochemical flows: P and N cycles	P flows and N intentional fixation
Land-system change	Area of forested land
Freshwater use	Blue water withdrawal
Atmospheric aerosol loading	Aerosol Optical Depth
Introduction of novel entities	(no control variables)

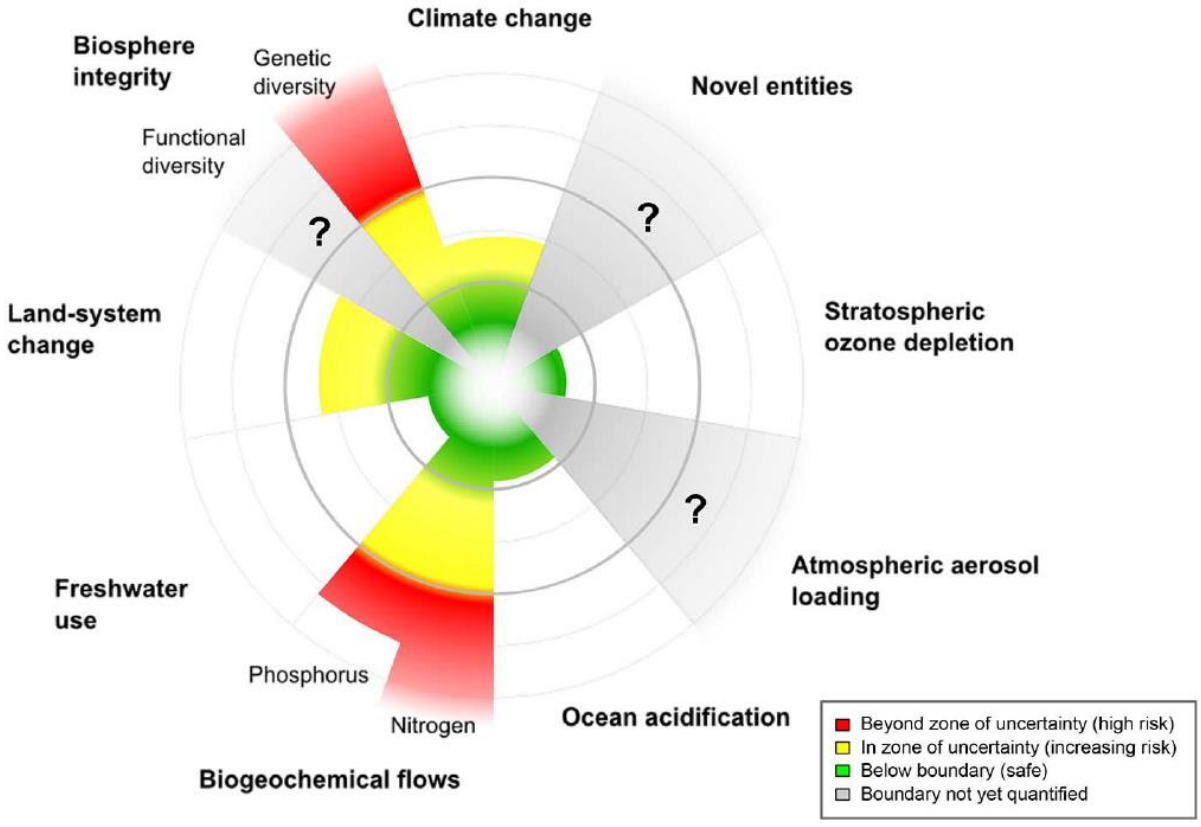


Figure 20 - The current status of the control variables for seven of the nine planetary boundaries. The green zone is the safe operating space (below the boundary), yellow represents the zone of uncertainty (increasing risk), and red is the high-risk zone (from: Rockström *et al*., 2009)

PBs are not irreversible tipping points, but rather delimiters of an area where such a risk may develop. Trespassing the safe operating space means entering an uncertain area, an area where early warning should move societies towards the adoption of corrective measures in order to avoid the worst (Steffen *et al.*, 2015a).

The list of PBs was updated in 2015 (Steffen *et al.*, 2015a) along with related control variables and specific levels for most boundaries (along with an uncertainty zone).

Campbell *et al*. (2017) explores the role of agriculture vs the nine planetary boundaries as described by Steffen *et al*. (2015a), as well as expected developments.

Land-system change. Cropland (12% of land surface) and pastures (28%) together represent the largest share of land use, except Antarctica and Greenland. Future expansion at least in the tropics/subtropics in response to increased food/feed demands is expected. Agriculture expansion is expected to exacerbate other impacts (CO_2, CH_4, NO_2), in particular if climate changes will reduce productivity of land under cultivation today. Forest surface is increasing in the North, decreasing in tropics/subtropics.

Freshwater use. Agriculture is responsible for 70% of all withdrawals (44% in OECD Countries) and withdrawals growing at a rate that is twice as high as that of population (FAO, 2014). Local variations are of paramount importance, due to climate (heat/rain) and limited transferability of water resources (OECD, 2017). Livestock acts as a water multiplier (as well as a land multiplier). Increasing efficiency (of conveyance, distribution and application) is a priority.

Biogeochemical flows - **nitrogen** and **phosphorous** cycles. Anthropogenic N sources now contribute more N to the Earth system than all natural terrestrial processes combined. The environmental costs of N losses in Europe have been estimated to outweigh the entire direct economic benefits of N in agriculture combined. The use of N fertilizer in agriculture increased by approximately 800% from 1960 to 2000 although estimates vary. Approximately half of the N applied to croplands is incorporated into plant biomass, while the rest is lost through leaching (16%), soil erosion (15%), and gaseous emission (14%). Phosphorus in Agriculture is responsible for >90% of P emissions. Mitigation strategies include waste treatment, buffer zones, reduced tillage.

Biosphere integrity. Species extinction, functional biodiversity loss, genetic uniformity, fragmented ecosystems are relevant components of Biosphere integrity. An estimated 75% of crop diversity has been already lost and up to 30% of domesticated animal breeds threatened of extinctions or already extinct (FAO, 2014). According to UNCCD (2017) global biodiversity loss, already estimated at 34% (in 2010, as expressed in Mean Species Abundance with respect to pre-industrial era) is expected to grow towards 2050 under all scenarios, even in the optimistic "Sustainability" SSP scenario.

Climate change. Food production involves mainly non CO_2 GHGs but high CO_2 is emitted in fertiliser production, processing and transport of goods. CO_2e emissions of agriculture ca. 11% (excluding LULUCF); 14-24 with LULUCF; 19-29 all inclusive (i.e. also N fertilisers).

Ocean acidification. Circa 25% of atmospheric anthropogenic emissions are absorbed by the Oceans. A 34% increase in seawater acidity has been recorded since 1800; unless CO_2 emissions are reduced, a +150% increase in surface ocean acidity is expected by 2100.

Stratospheric ozone depletion. N_2O is at present the most important cause of ozone depletion (after CFC was phased out); agriculture may reduce ozone depletion by more efficient fertiliser use.

Atmospheric aerosol loading. Black carbon from field burning is assumed to be the strongest contributor but measures are lacking.

Introduction of novel entities. New chemicals, pesticides, genetic entities.

Some variables have a high degree of uniformity worldwide due to the broad circulation of the atmosphere (CO_2 concentration) and ocean waters (water pH). Some, on the other hand, can have huge regional variations and can therefore reach dangerous levels on a local scale even in case world averages appear in the safe zone (e.g. freshwater use). Indeed Steffen *et al*. (2015a) make a laudable attempt at indicating also "regional boundaries" for a "safe operating space".

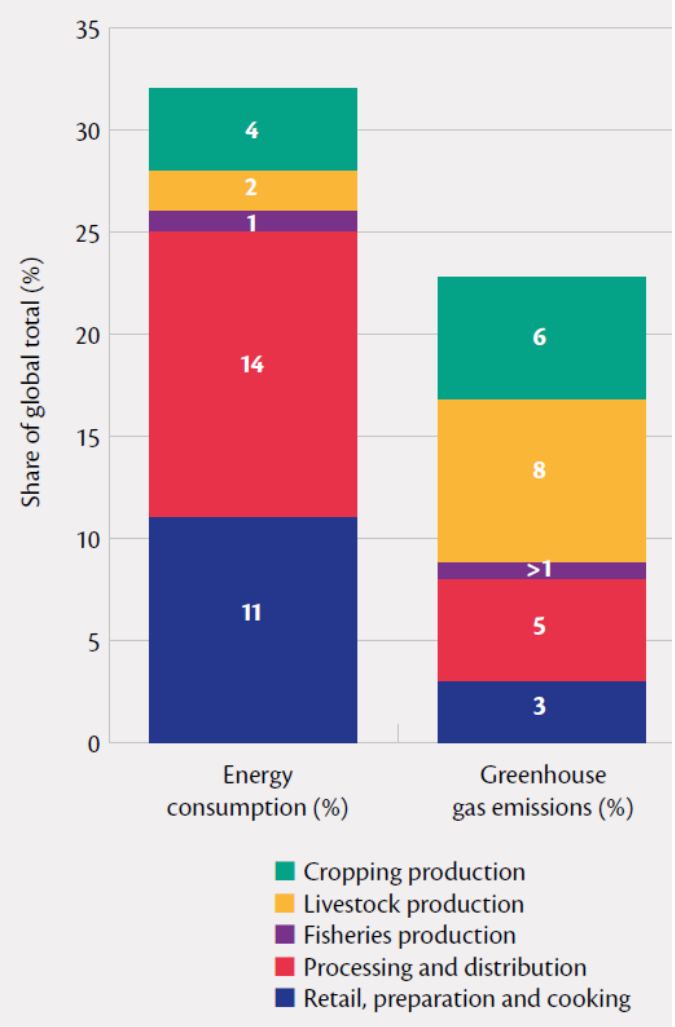


Figure 21 - Global food system contribution to energy consumption and GHG emissions (From Global Panel on Agriculture and Food Systems for Nutrition, 2016; source IFPRI. 2016. Global Food Policy Report)

Food systems

Food systems are not just agriculture. The High Level Panel of Expert on Food Security and Nutrition (HLPE)[13] defines a **Food System** a system that "*gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the output of these activities, including socio-economic and environmental outcomes*".

The HLPE, as well, defines a **Sustainable Food System** as "*a food system that ensures food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised*" (HLPE, 2017).

This is not dissimilar to the definition of FAO of a sustainable agriculture: *"To be sustainable, agriculture must meet the needs of present and future generations for its products and services, while ensuring profitability, environmental health, and social and economic equity. Sustainable agriculture would contribute to all four pillars of food security – availability, access, utilization and stability – in a manner that is environmentally, economically and socially responsible over time"* (FAO, 2014).

The concept of food system includes environmental, technical, social, economic and cultural components that should not be dealt with as separate issues. A conceptual framework describing the links between the components of food systems is reported in Figure 21.

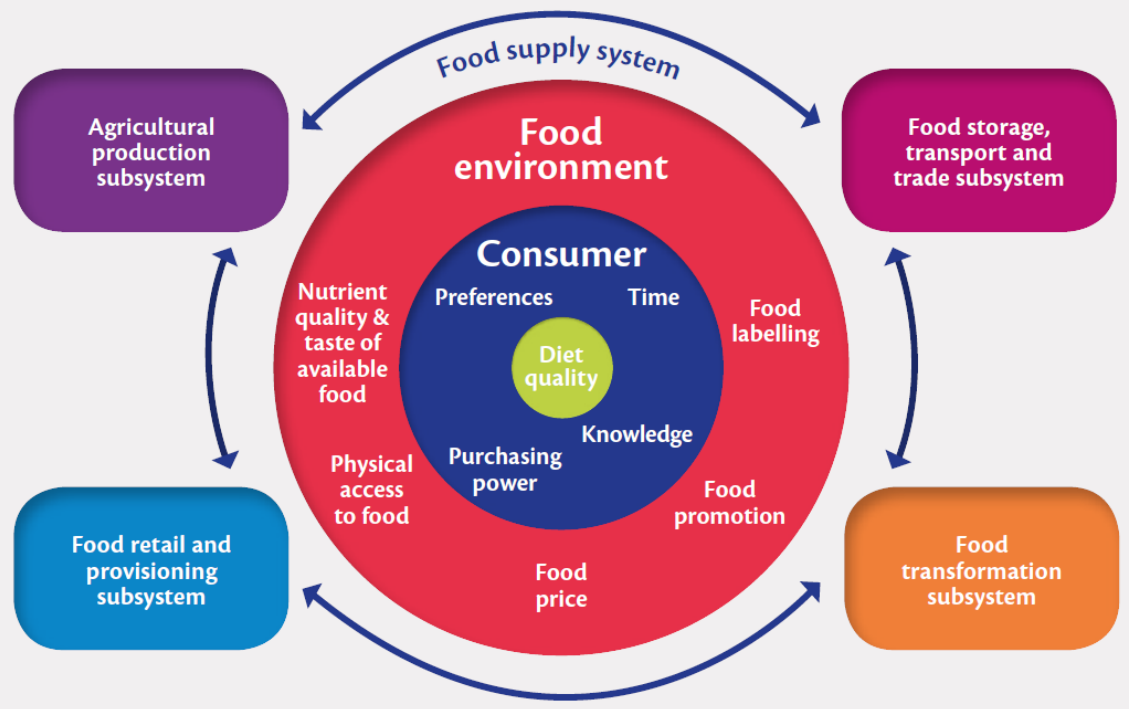


Figure 22 - Conceptual framework for the links between diet quality and food systems (From: Global Panel on Agriculture and Food Systems for Nutrition, 2016)

[13] The High Level Panel of Experts on Food Security and Nutrition (HLPE) is the science-policy interface of the UN Committee on World Food Security (CFS). It was created in October 2009 as an essential element of the CFS reform. The HLPE aims to facilitate policy debates and inform policy making by providing independent, comprehensive and evidence-based analysis and advice at the request of CFS.

The nature of the main drivers of food system changes, according to HLPE (2017) are:

- **biophysical and environmental** (natural resources, ecosystem services, climate change);
- **innovation, technology and infrastructure**;
- **political and economic** (leadership, globalization, foreign investment and trade, food policies, land tenure, food prices and volatility, conflicts and humanitarian crises)
- **socio-cultural** (culture, religion, rituals, social traditions and women's empowerment);
- **demographic** (population growth, changing age distribution, urbanization, migration and forced displacement).

The main trends are towards longer food chains, a vertical integration of production stages and an increasing economic weight of all that occurs beyond the farm gate. The Global Panel on Agriculture and Food Systems for Nutrition (2016) summarises the main trends as follows:

- Distancing between production and consumption
- From producing foods direct for the cooking pot to producing ingredients for food processing.
- From growing food to eat, to buying it.
- An increase in role and power of the private sector relative to the public sector.

A shift of value, labour and power to the middle of the food chain

According to HLPE (2017) "*The locus of power and decision-making is moving from farmers and producers to traders and retailers, and from governments to the private sector and multi-national corporations*".

There is a raising concern about the long term sustainability of the global food systems of today, for their excessive consumption and waste, their contribution to environmental degradation and pollution, and their damage to natural systems (HLPE, 2017).

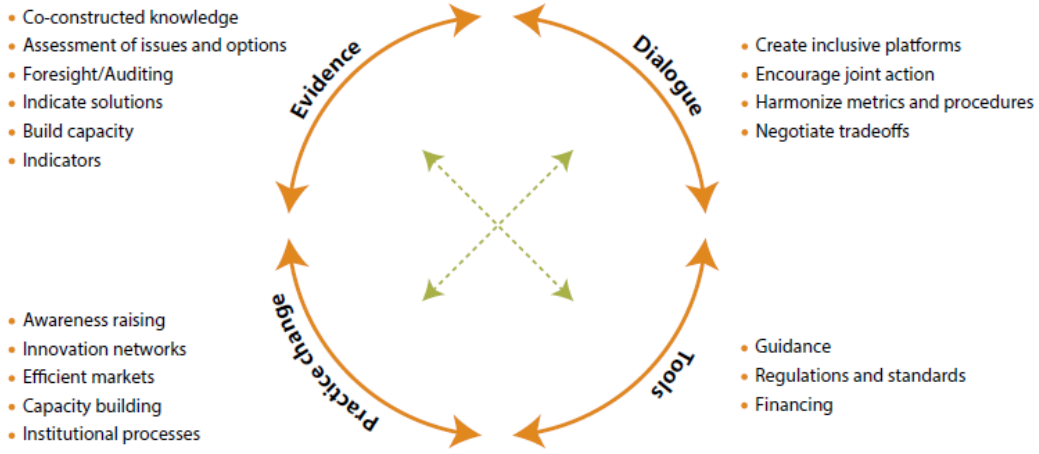


Figure 23 - Types of action to favour a transition to sustainable food systems (from FAO, 2014)

A transition towards sustainable agri-food systems implies four types of action (see Figure 22: FAO, 2014):

- Building relevant, co-constructed and accessible evidence.
- Engaging stakeholders in dialogue to build common understanding and joint action.
- Developing innovative approaches and solutions.
- Formulating tools and levers to enable and incentivize changes in food and agricultural systems

Food Security and Nutrition (FSN)

Food Security and Nutrition (FSN), sometimes referred to as Food and Nutrition Security (FNS) has four main dimensions (FAO, IFAD, UNICEF, WFP, WHO, 2017): **availability, access, utilisation** and **stability**.

Some split access into its physical and economic aspects, as in HLPE (2018); availability thus depends on food being produced; **accessibility** is meant as the physical access to where food is available (e.g. distance from markets); **affordability** is the economic possibility to access food; utilisation is the way food is prepared for eating; stability relates to possible fluctuations of supply.

Stability should also be considered in relation to price volatility. Price fluctuations obviously affect affordability of the most vulnerable groups (FAO, 2014).

Additional "nuances" are sometimes added to the list: **acceptability** (cultural aspects), **adequacy** (appropriate for the individual physical conditions), **awareness** (knowledge about food and nutrient content vs needs), **agency** (policy development and enactment).

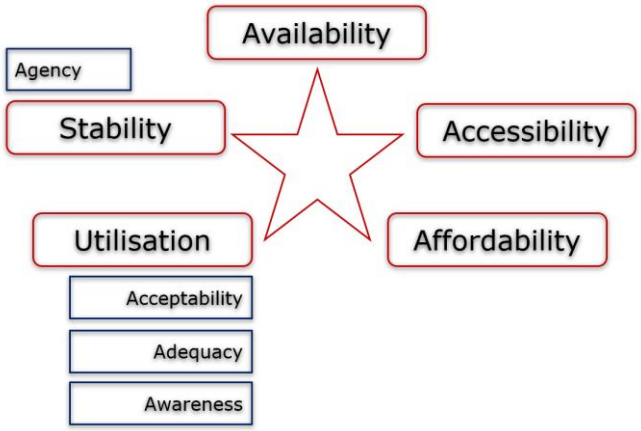


Figure 24 – The dimensions of FSN. Availability ("enough food to feed the world") is often the focus of debate, although accessibility and affordability are likely to be at least as important.

The main cause of hunger in the world is not insufficient availability but inability to buy food due to extreme poverty. And extreme poverty affected (in 2010) more than one third of rural people living in developing countries (FAO, 2014).

Food loss and waste

One essential component of food systems is Food Loss and Waste (FLW), estimated at 1/3 of production potential worldwide and pointed at as a main cause of undernourishment and malnutrition as well as of damages to the environment and climate. As the reasoning goes, one third more food would feed all the world or, conversely, if wasted production had not been produced in the first place, the impact on climate and the environment would have been considerably reduced.

It is commonly reported that if FLW were a country, it would be the third country responsible for GHG emissions after China and the US, due to the contribution to emissions of the primary and processing sectors involved in food that was lost or wasted.

FLW takes many forms along the whole food chain and has many different causes in different parts of the world.

The following table summarises some examples of FLW across the food chain.

Table 9 - Food loss and waste along the value chain (from Lipinski B *et al*. 2013. Reducing Food Loss and Waste. World Resources Institute. Washington USA; reported in Global Panel on Agriculture and Food Systems for Nutrition, 2016)

Production	Handling and storage	Processing and packaging	Distribution and market	Consumption
Definition				
During or immediately after harvesting on the farm	After produce leaves the farm for handling, storage,and transport	During industrial or domestic processing and/or packaging	During distribution to markets, including losses at wholesale and retail markets	Losses in the home or business of the consumer, including restaurants/caterers
Includes				
Fruits bruised during picking or threshing	Edible food eaten by pests	Milk spilled during pasteurization and processing (e.g., cheese)	Edible produce sorted out due to quality of vegetables	Edible products sorted out due to quality
Crops sorted out at post harvest for not meeting quality standards	Edible produce degraded by fungus or disease	Edible fruit or grains sorted out as not suitable for processing	Edible products expired before being purchased	Food purchased but not eaten
Crops left behind in fields due to poor mechanical harvesting or sharp drops in prices	Livestock death during transport to slaughter or not accepted for slaughter	Livestock trimming during slaughtering and industrial processing	Edible products spilled or damaged in market	Food cooked but not eaten
Fish discarded during fishing operations	Fish that are spilled or degraded after landing	Fish spilled or damaged during smoking		

Despite many possibilities to tackle the FLW problem in its multiple facets, a reduction but not elimination is to be expected. Some foods have a high seasonality that provokes production in excess of demand in peak season and/or do not tolerate extended storage. This the case of many fruits and vegetable, especially when compared with cereals.

Where storage is technically feasible, lack of costly infrastructures prevents their application (e.g. apples can be stored for a whole year in cold rooms with an atmosphere enriched with CO_2).

Food loss appears even higher in terms of lost calories if the controversial issue of low energy-efficiency of animals at producing food are factored in as in the Policy Brief by Lundqvist *et al*. (2008)[14].

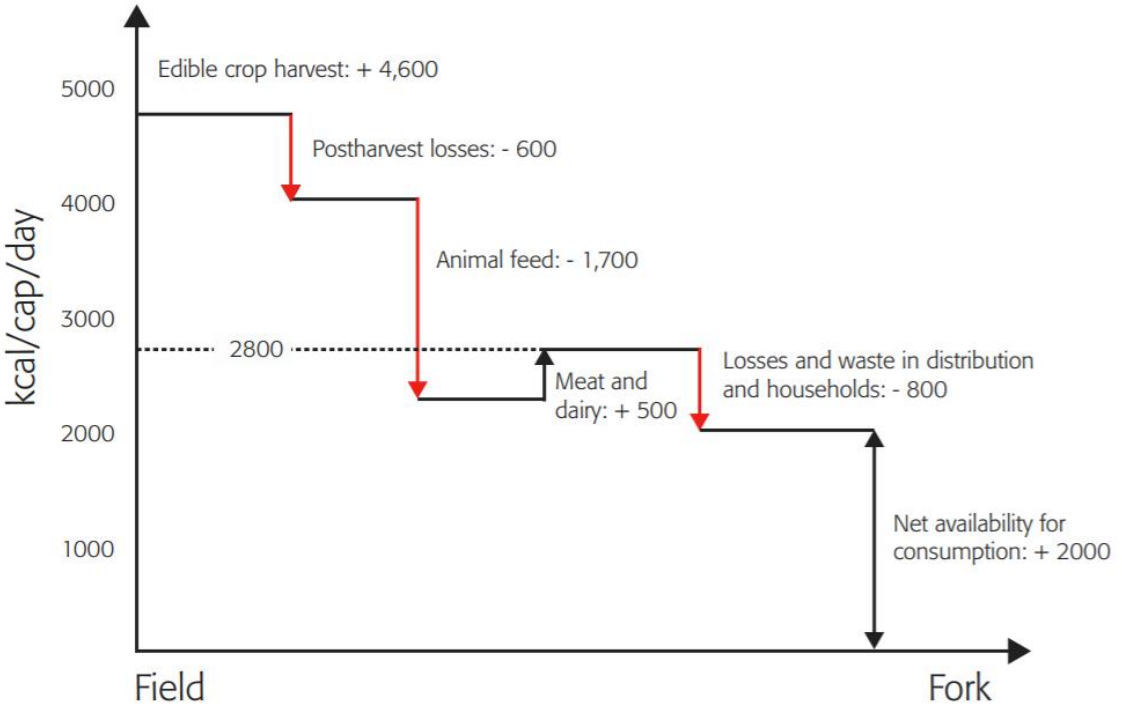


Figure 25 - From potential calories in crops to net availability for human consumption after losses in different stages of the food chain and the loss due to farm-animal metabolism are accounted for (Lundqvist *et al*. 2008).

International trade

Although international trade of food and feed still represents a relatively small share of total food and feed trade, it has grown three-fold in value and 60% in volume between 2000 and 2012 (Global Panel on Agriculture and Food Systems for Nutrition, 2016). Besides the obvious positive aspects, trade can have negative consequences on the development of poor countries where poor infrastructures (e.g. roads) or lack of machinery or subsidised production overseas makes internationally sourced commodities cheaper than locally produced equivalents, thus hampering the development of internal production systems.

[14] Lundqvist J, de Fraiture C, Molden D. 2008. **Saving Water: From Field to Fork – Curbing Losses and Wastage in the Food Chain**. SIWI Policy Brief. SIWI.

The issue of trade restrictions and tariffs on imports is a sensitive one, especially in the WTO context. However, it must be recognised that limitations to a complete freedom of trade can be an appropriate measure to safeguard internal markets from the disrupting effect of cheap commodities in developing countries, sometimes originating from subsidised agricultural systems of high-income countries.

Trade in commodities, dominated by cereals increasingly used as feed for livestock, stimulate local animal production with its both positive and negative consequences, depending on the level of consumption.

Trade in sugar is favouring the production of cheap sweet carbonated beverages in poor countries, thus contributing to the obesity emergency.

Trade has opened the international market to LMIC. Many of them have turned from traditional agriculture to commodities and other crops that are exported in exchange for cash, a significant source of revenue. However, cash crops may sometimes completely alter traditional food systems as is the case of the Sikasso region in Mali, where the widespread cultivation of cotton provoked a deterioration of food security (HLPE, 2017)

Opening internal productions, even of specialty crops, to the international market also exposes poor layers of the population to the higher purchasing power of HIC, potentially depriving the countries of origin of their traditional foods that are exported rather than offered on the internal market.

Dependence on imports also exposes countries to variations of international prices; and dependence on food imports is increasing exactly in those areas (Asia and Africa) where the highest demographic expansion is foreseen, thereby exacerbating food security issues and vulnerability to volatile prices (HLPE, 2017).

Diets and nutrition

The concept of undernourishment, as failure to reach a sufficient daily intake of calories, gave way to the broader concept of a nutrition for a healthy diet. Malnutrition includes lack of energy (calories) but also of micronutrients (minerals and vitamins), proteins, fibre, etc. in the amounts required by the individuals, depending on age, sex, physical activity. Malnutrition also includes excessive intakes leading to body weight over the optimal level.

There is no universally agreed definition of what indicators can be used to define the quality of diets. However it is generally recognised that diverse diets that reach a calorie intake matching but not exceeding the energy consumption and provides quality nutrients usually found in fruit, vegetables (most vitamins and minerals) and meat (iron, calcium, high quality proteins, B-group vitamins).

Table 10 - WHO guidelines on healthy diets (taken from Global Panel on Agriculture and Food Systems for Nutrition, 2016)

• A healthy diet helps protect against malnutrition in all its forms, as well as non-communicable diseases (NCDs), including diabetes, heart disease, stroke and cancer.
• Healthy dietary practices start early in life – **breastfeeding** fosters healthy growth and improves cognitive development. It may also have longer term health benefits, such as reducing the risk of becoming overweight or obese and developing NCDs later in life.
• **Energy intake** (calories) should be in balance with energy expenditure.
• A healthy diet includes fruits, vegetables, legumes (e.g. lentils, beans), nuts and wholegrains (e.g. unprocessed maize, millet, oats, wheat, brown rice).
• At least **400 g** (five portions) of **fruits and vegetables a day**. Potatoes, sweet potatoes, cassava and other starchy roots are not classified as fruits or vegetables.
• **Total fat should not exceed 30%** of total energy intake to avoid unhealthy weight gain, with a shift in fat consumption away from saturated fats to unsaturated fats and towards the elimination of industrial trans fats.
• **Limiting intake of free sugars to less than 10%** of total energy intake is part of a healthy diet. A further reduction to **less than 5%** of total energy intake is suggested for additional health benefits.
• Keeping **salt intake** to **less than 5 g per day** helps prevent hypertension and reduces the risk of heart disease and stroke in the adult population.

The Second International Conference on Nutrition (ICN2), held at FAO in 2014 declared: *"Nutrition improvement requires healthy, balanced, diversified diets, including traditional diets where appropriate, meeting nutrient requirements of all age groups and all groups with special nutrition needs, while avoiding the excessive intake of saturated fat, sugars and salt/sodium, and virtually eliminating trans fats, among others"* (ICN2 Rome Declaration on Nutrition, 14.j, 2014[15])

Although declared as the first Millennium Development Goal ("Eradicate extreme poverty and hunger") for the year 2015, hunger and malnutrition still affect all the countries of the world. The number of undernourished[16] in the world declined for several years in a row, albeit at a slower pace after 2010 than in the previous 5 years, but with a resurgence in 2016 and 2017 both in absolute and relative numbers (FAO, IFAD, UNICEF, WFP, WHO, 2017). Undernourished people are estimated at 820.8 million in 2017, or 10.9% of the world population.

Undernourishment affects in particular Africa (with a peak of one undernourished every three persons in Eastern Africa and one in four in Middle Africa) and southern Asia. Asia, due to its high population, has the highest absolute number of undernourished: 519.6 million, against 243.2 million in Africa.

[15] http://www.fao.org/3/a-ml542e.pdf, accessed 28 November 2018.

[16] Prevalence of undernourishment is the proportion of the population whose habitual food consumption is insufficient to provide the dietary energy levels that are required to maintain a normal active and healthy life (SDG Indicator 2.1.1)

Outside Asia and Africa live less than 50 million undernourished people, but pockets of undernourishment are found also in the advanced economies due to limited access to sufficient food by economically disadvantaged groups.

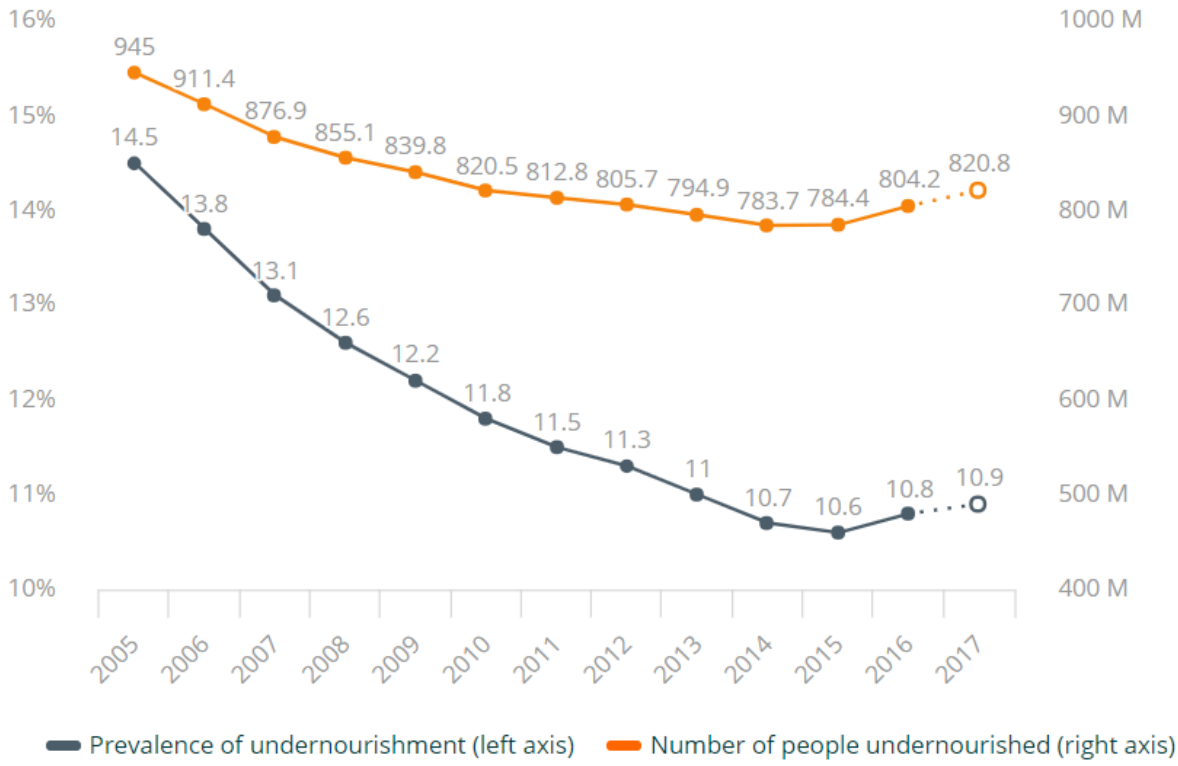


Figure 26 - Prevalence and number of undernourished people in the world, 2005–2017: data for 2017 are projections (from: http://www.fao.org/sustainable-development-goals/indicators/211/en/, accessed 16 November 2018).

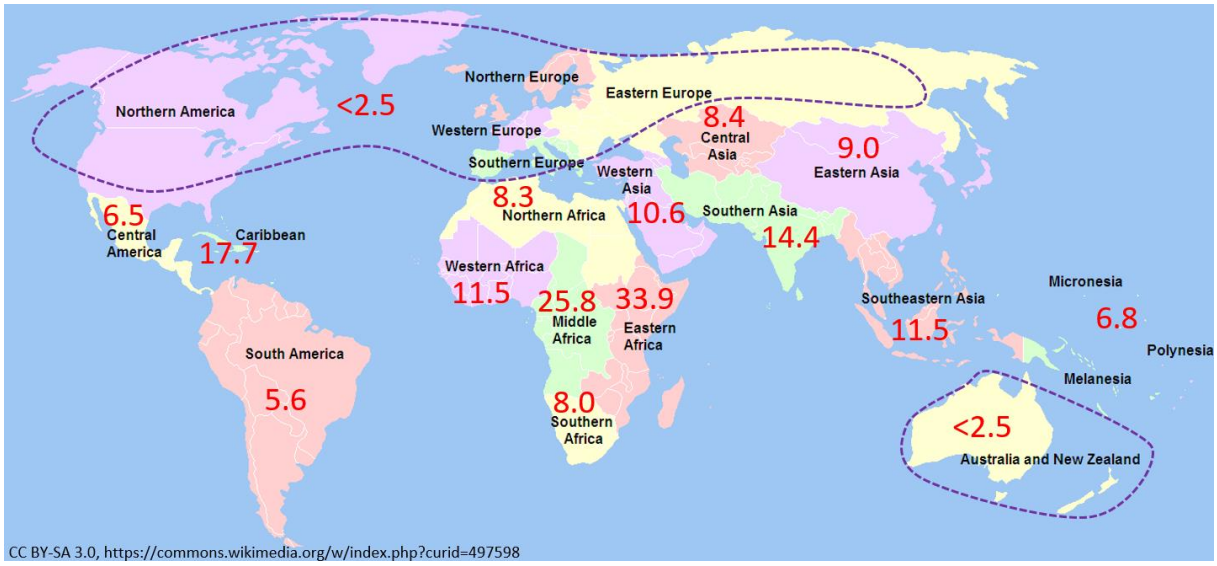


Figure 27 - Prevalence of undernourishment in the world by region 2000-2016 (Data from FAO, IFAD, UNICEF, WFP, WHO, 2017)

Prevalence of undernourishment in Europe (in 2016) are almost everywhere under 2.5%, except Bulgaria (3.6), Moldova (8.5), Slovakia (3.1, Albania (4.9), Serbia (5.6) and FYRoM (3.9) (FAO, IFAD, UNICEF, WFP, WHO, 2017).

The dominant cause of undernourishment is poverty, exacerbated in several parts of the world by conflicts and by floods and droughts (partly due to recurrent anomalies, such as those caused by El Niño and, more recently, for nations depending on commodities export, by the fall of international prices that reduced revenues.

Conflicts, and its consequences (damage to infrastructures, recession, inflation, unemployment, displacement, finance erosion) have been have been indicated as a main reason of food insecurity (FAO, IFAD, UNICEF, WFP, WHO, 2017), although it is difficult to extrapolate individual causes that are very often related with one another. South Sudan, Syria, Somalia, Yemen, Libya are just recent examples.

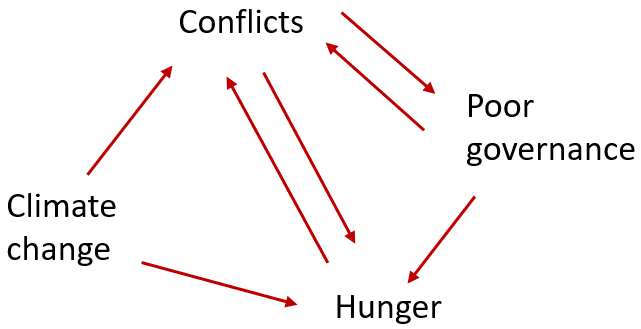


Figure 28 – The causes of food insecurity are many and with reciprocal cause-effect relationships.

Positive links between international aids supporting the development of agriculture and the resolution of conflicts have been observed. However, official direct assistance to developing countries is likely to be less focused on agriculture (with respect to food, health, infrastructures) in conflict areas than in otherwise comparable developing countries (FAO, IFAD, UNICEF, WFP, WHO, 2017)

Malnutrition, including both undernourishment and lack of micronutrients is responsible for the still high numbers of stunted and wasted children[17]. The

[17] Stunted children have a low height for their age: stunting is a consequence of chronic hunger; the weight of wasted children is too low for their age: wasting denotes acute undernourishment. The comparison is made with normal growth curves for the relevant populations: stunted and wasted children fall below two standard deviations under the WHO Child Growth Standards median.

prevalence of stunted children declined almost everywhere in the world in the last decade (except Oceania). Stunted and wasted children are likely to bear the consequences for the rest of their adult life, with reduced physical and mental capabilities.

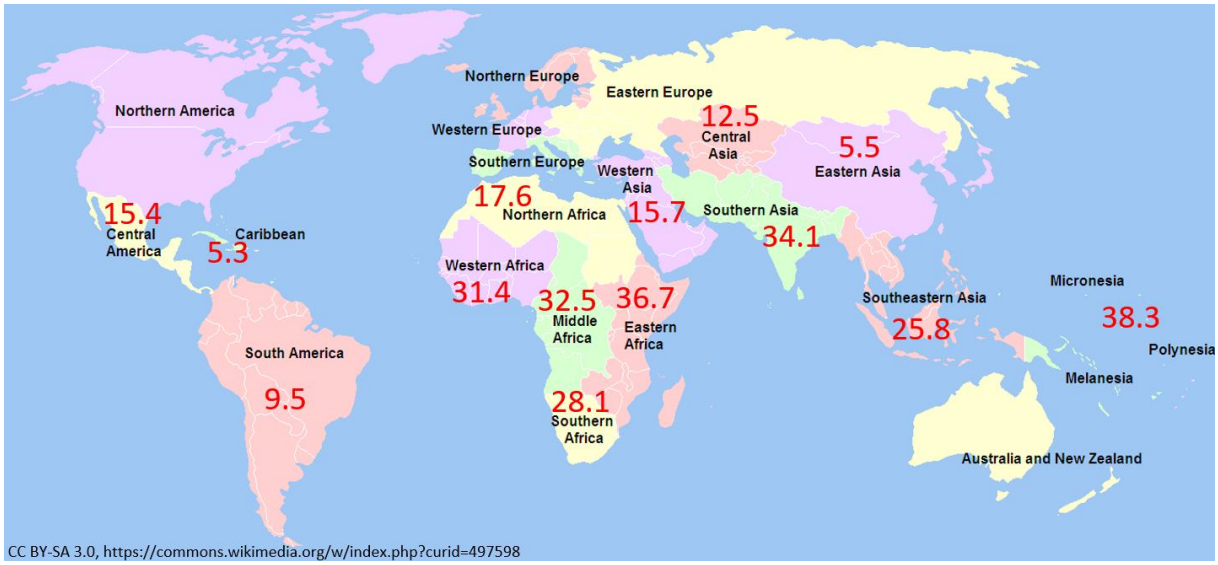
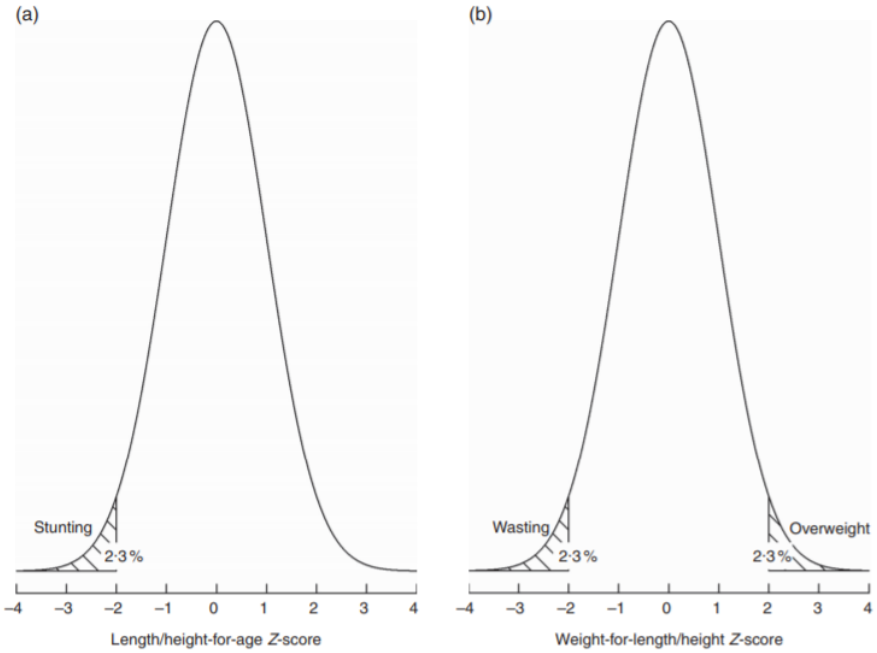


Figure 29 - Rates of stunting among children below 5 years of age in relevant regions of the world 2016 (Data from FAO, IFAD, UNICEF, WFP, WHO, 2017)

As for undernourishment, Asia comes first in absolute numbers of stunted children (87 million), followed by Africa (59 million), despite higher percent values in the African continent (Data from FAO, IFAD, UNICEF, WFP, WHO, 2017)



De Onis M, Borghi E, Arimond M, Webb P, Croft T, Saha K, De-Regil LM, Thuita F, Heidkamp R, Krasevec J, Hayashi C, Flores-Ayala R. 2018. **Prevalence thresholds for wasting, overweight and stunting in children under 5 years**. Public Health Nutr 21. doi:10.1017/S1368980018002434

Infant and child undernourishment (including maternal inadequate diets during pregnancy) has long lasting consequence in terms of retarded cognitive development, poor school performance, reduced strength and endurance, reduced resistance to diseases and, in general, limited labour capacity, diminished earnings and lower contribution to the economy in adult life, higher burden for health systems (HLPE, 2017)

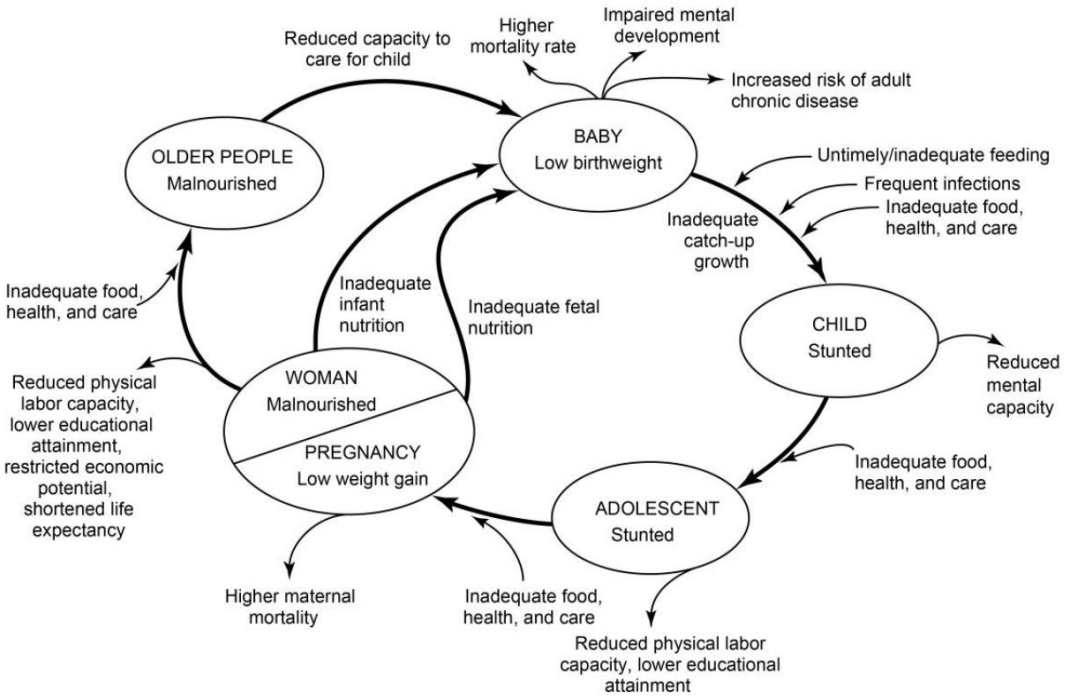


Figure 30 - Nutrition throughout the life cycle (Figure 6 of HLPE, 2017; adapted from ACC/SCN (2000) Fourth Report on the World Nutrition Situation. Geneva: ACC/SCN in collaboration with IFPRI)

However, other forms of malnutrition have gained increasing attention worldwide: micronutrient deficiencies (iron, zinc, vitamins), especially among children and women of fertile age, and excess weight.

Excess weight in children predisposes to obesity in adult life with all its burden of related non- communicable diseases (Type II diabetes, high blood pressure, cardiovascular diseases etc.) and shows an upward trend in the world. Prevalence was 5.3% in 2005; it raised to 6.0% in 2016.

Data for most European countries are not available except Moldova (4.9), Bosnia and Herzegovina (17.4), Montenegro (22.3) and Serbia (13.9).

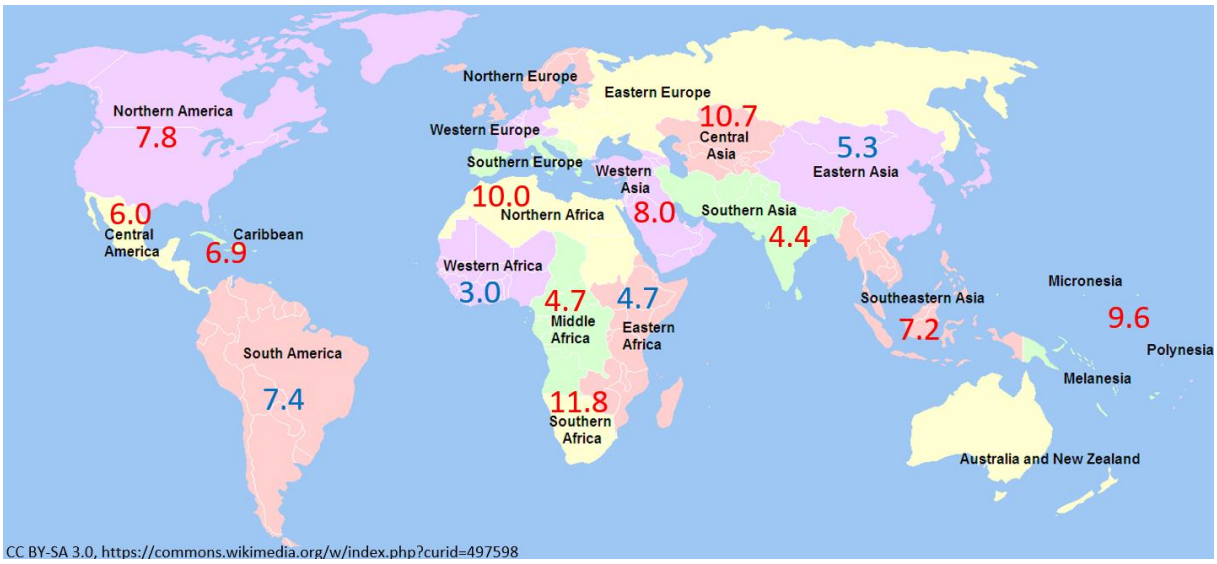


Figure 31 - Prevalence of overweight children below 5 years of age in selected regions of the world in 2016:red figures denote regions where rates increased from 2005; blue figures rates that declined or remained stable (Data from FAO, IFAD, UNICEF, WFP, WHO, 2017)

The share of overweight and obese[18] in the adult population is increasing in all the countries of the world. Global obesity rates among adults increased by 1% every three years between 2004 and 2014 (Data from FAO, IFAD, UNICEF, WFP, WHO, 2017). In the USA, over two-thirds of adults are overweight or obese; in the United Kingdom 67% of men and 57% of women are overweight or obese (HLPE, 2017).

Obesity is often referred to as a new "epidemics". No country in the world, so far, has succeeded in reducing its rates of obese people.

In many developing countries (but also in segments of high-income countries undernourishment and obesity coexist (HLPE, 2017). In upper-middle-income and high-income countries there is a positive correlation between adult obesity and the level of food insecurity. The most likely explanation is that food-insecure households are the most exposed to cheap low quality and calorie rich food (FAO, IFAD, UNICEF, WFP, WHO, 2017).

Excess weight is also an aspect of malnourishment as it impairs individual health and contributes to straining public health systems. The calories intake is higher than what is appropriate for the individual but often determined by a diet unbalanced towards sugars, fats (especially trans-fatty acids and saturated fatty acids), rich in salt and poor in quality nutrients.

[18] The definition of overweight and obese is based on the Body Mass Index (BMI), that is the ratio between weight (kg) and the square of height (m). Overweight is a person with a BMI>25, obese with a BMI>30. For example, a person of 1.75 m height is considered overweight if his weight is in excess of 76.6 kg, obese over 91.9 kg.

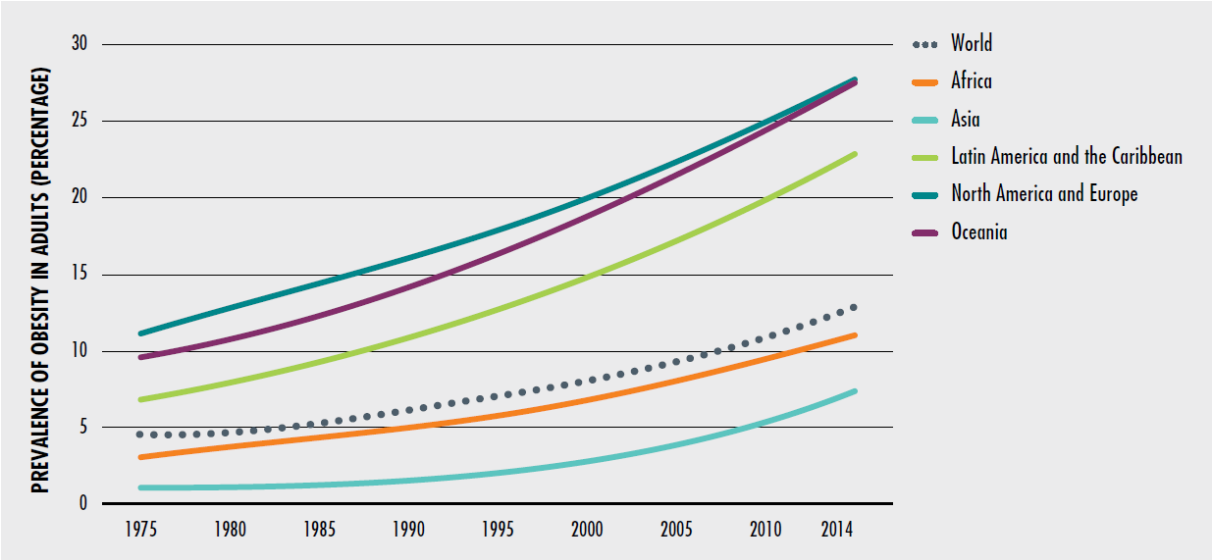


Figure 32 - Prevalence of obesity in adults over 18 years of age in the period 1975-2014 (FAO, IFAD, UNICEF, WFP, WHO, 2017)

Non-communicable diseases (type II diabetes, heart diseases, high blood pressures, high cholesterol, some cancers, …) that are associated with poor diets, collectively represent the highest disease-risk factor (Global Panel on Agriculture and Food Systems for Nutrition, 2016), although it must be acknowledged that this is largely due to the dramatic success in combating communicable, infectious, diseases.

According to HLPE (2017) the health consequences of overweight and obesity, according to a study that was carried out in 195 countries over 25 years, excess BMI contributed globally in 2015 to around 4 million deaths (7.1 percent of all deaths) and accounted for 120 million DALYs[19] (4.9 percent of all DALYs among adults).

Diet-related diseases that were once typical of the affluent countries are now increasing also in developing countries. It is estimated that the number of people affected by Type II diabetes in Nigeria will increase from 3.1 million in 2011 to 6.1 million in 2030; in Ethiopia it will increase from 1.4 to 2.7 million over the same time span (Global Panel on Agriculture and Food Systems for Nutrition, 2016)

The consumption of ultra-processed foods (usually rich in calories and poor in quality nutrients) is also linearly correlated with income. As ultra-processed foods are also often cheaper (on a per-calorie basis) than unprocessed food, the increase in consumption in developing countries is one of the factors contributing to an increase in overweight and obese worldwide.

Only in affluent countries has the consumption of processed an ultra-processed food declined slightly in the last decade, but the absolute level per capita is well over twice that of upper-middle-income countries and six times higher than lower-middle-income countries (see Figure 33)

[19] DALY (**disability-adjusted life year**) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. It was developed in the 1990s as a way of comparing the overall health and life expectancy of different countries (https://en.wikipedia.org/wiki/Disability-adjusted_life_year)

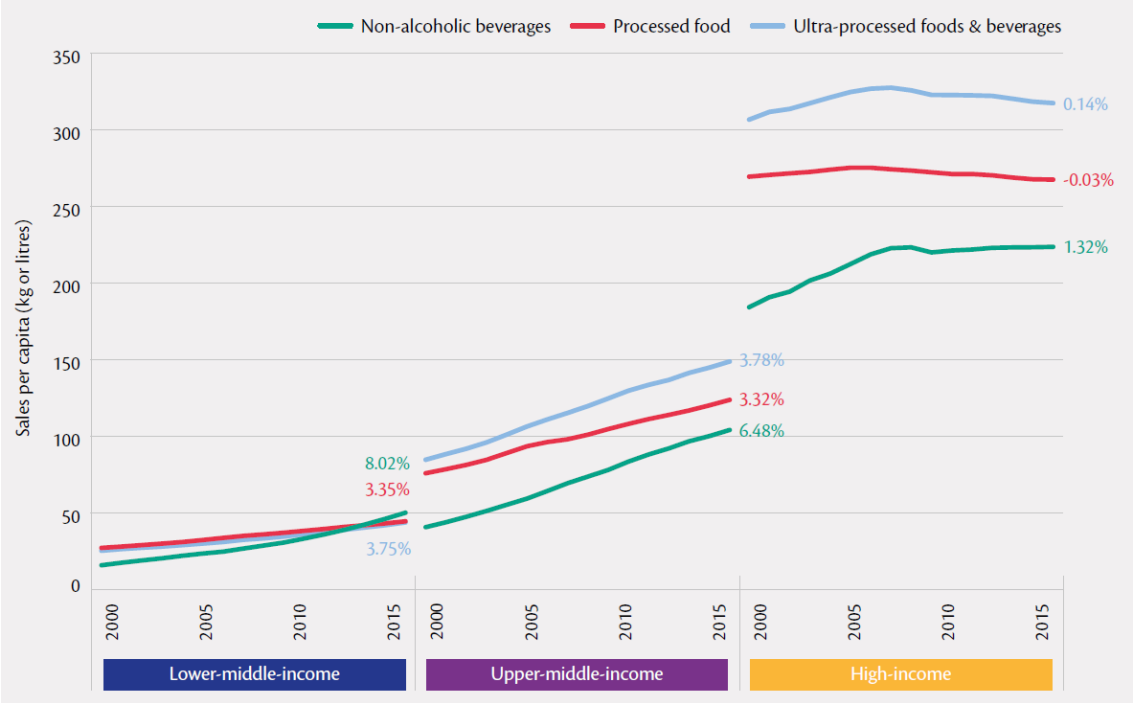


Figure 33 - Trends in per capita sales volumes of non-alcoholic beverages, processed foods and ultra-processed foods by country income group, 2000–15, with 15-year average growth rates shown (Data from Baker P. 2016. Working Paper n. 2. School of Regulation and Global Governance, Australian National University; cited in Global Panel on Agriculture and Food Systems for Nutrition, 2016)

Ultra-processed food and carbonated beverages rich in sugar is expected to rise in developing countries, continuing the current trends

Given the above considerations, the current exponential trend in overweight and obese people (Figure 34) is expected to continue, with negative individual and public health consequences.

Fruit and vegetables consumption stays below recommended WHO levels (400 g/day) in all the world, irrespective of income level. The only exception is East Asia that slightly exceeds the threshold.

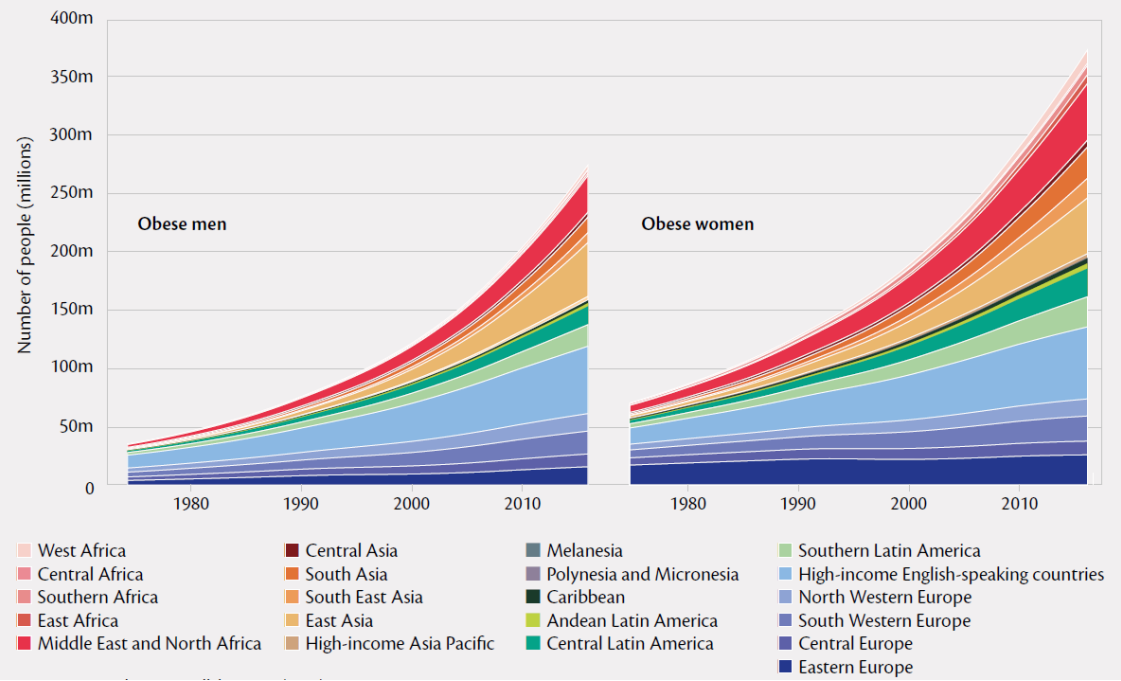


Figure 34 - Trends in the numbers of men and women affected by obesity: 1980–2010 (from NCD-RisC. 2016. The Lancet 387, 1377-1396; cited in Global Panel on Agriculture and Food Systems for Nutrition, 2016)

Future prospects for food and nutrition

Food availability forecasts based on current trends depict a future that is quite different from SDG #2. The Global Panel on Agriculture and Food Systems for Nutrition (2016) predicts the existence of 653 million people undernourished in 2030 under a BaU scenario, with no reduction in Africa (actually a slight increase in absolute numbers with respect to the 2005-2007 base years) and a significant reduction in South and East Asia, but still insufficient to eradicate hunger in that part of the world.

This forecast, however, is based on the undernourishment statistics of the year 2015 and does not take into account the increases occurred in 2016 and 2017. Therefore, the situation could be even worse.

As for diet quality, current trends do not justify optimism.

Whereas meat consumption should grow in the poorest parts of the world to reach WHO recommended levels, there is a significant risk of overshooting by middle-income countries (such as China), with negative consequences for health and the environment. At the same time, consumption of meat and other animal source foods in high-income countries stays well above recommended levels; a shift from red to white meat (especially poultry) is occurring and it is expected to continue, but with very limited reduction of total animal source products consumption.

Urbanisation may affect food availability and diets both in positive and negative ways. Higher average income, access to markets for fresh fruits and vegetables and availability of a broader range of products to choose from are positive aspects. However urbanisation usually goes along with more sedentary lifestyles and increased consumption of ultra-processed food rich

in calories and poor in nutrients, leading to nutrient deficiencies and excess weight (Global Panel on Agriculture and Food Systems for Nutrition, 2016).

Also the globalisation of markets is playing positive and negative roles. On the positive side: increased availability of a broader range of foods, not produced locally; lower food prices; internationally accepted safety standards. On the negative side the fact that the overwhelming share of food trade is in commodities (cereals in particular) rich in calories and poor in nutrients and that sweet carbonated beverages, exported or locally produced by international companies are contributing to the obesity epidemics.

More subtle and less predictable are the effects of climate change. In general terms, the areas that will likely be the most severely affected in their production capacities are those where food is most needed.

Policies and measures to improve diet quality and the efficiency and equity of the food systems have been proposed in several documents.

This is the list of policies suggested by the Global Panel on Agriculture and Food Systems for Nutrition (2016):

1. Invest in nutrition-enhancing agricultural productivity growth, markets and trade systems
2. Increase research to ensure a greater presence of healthy foods in markets globally, including through public-private partnerships
3. Facilitate markets and trade in ways that moderate food price volatility
4. Improve infrastructure in agriculture and market systems to increase year-round availability of nutrient-dense foods to all consumers
5. Develop national policy and regulatory framework for food safety and quality
6. Improve the nutritional quality of and consumer choice regarding processed foods
7. Integrate nutrition education into all available national services reaching consumers
8. Expand agriculture-supportive targeted social protection programmes
9. Expand agriculture-supportive school meal programmes
10. Improve the quality and specificity of metrics and data needed to support evidence-based policy actions

Table 11 is more specific on concrete actions that might help in stimulating healthier food environments and higher quality diets

Table 11 - Aligning actions across food supply subsystems to create healthier food environments for higher-quality diets Global Panel on Agriculture and Food Systems for Nutrition (2016)

Diet goal	Agricultural production	Transformation	Storage, transport and trade	Retail and provisioning
Increase fruit and vegetable intake	Invest in mixed and integrated cropping systems to produce production diversity in areas where markets are poorly developed; where markets are developed invest in fruits and vegetable production using global funding mechanisms	Develop micro-enterprises for local processing to reduce waste	Leverage the World Trade Organization (WTO) Aid-for-Trade initiative or Enhanced Integrated Framework (EIF) Aid-for-Trade partnership to invest in production in low-income countries	Invest in "wet market" infrastructure to enable maintenance for low income groups; increase capacity for food safety among traders
Increase intake of legumes/ pulses	Agricultural research into new varieties to boost yield	Develop fast-cooking bean flours	Train farmers in management practices to reduce loss to insect damage; safeguards to prevent distortions that discourage local production and regional trade in legumes	Food price subsidies for legumes where consumption is low
Increase intake of grains high in protein, micronutrients and fibre	Incentivize the production of underutilized grains	Develop more efficient threshing and milling technologies for underutilized grains; develop novel foods with underutilized species	Ensure policies support open regional trade where neighbouring countries produce underutilized grains	Set standards and marketing incentives for use of wholegrains in processed food products
Encourage balanced consumption of safe milk	Improve availability of animal health services and ensure women have access to animals	Train milk processors in food safety and quality assurance	Invest in infrastructure to ensure safe transport of milk from farm to retail	Establish milk retail hubs are open for trading at times and locations convenient for women; provide meals containing milk in workplaces where women work

Replace trans fats with unsaturated fats	Encourage cooperatives between trans fat-free oil producers to lower prices	Prohibit public investment and disincentivize private investment in facilities producing hydrogenated oils	Lower tariffs on trans fat-free oils relative to oils containing trans fats	Create an incentive for street vendors to use trans fat-free oils through use of a "healthier oil" sign
Reduce intake of sugary drinks	Horticulture producers donate fruits that do not meet quality standards for the production of fruit juices, thus potentially lowering costs	Reformulation to reduce sugar and salt content; creating incentives for sugary drinks companies to meet sales reduction targets of sugary drinks and increase sales of pure fruit juices	Codex Alimentarius Commission sets international guidelines for consumer-friendly nutrition labels including sugar warnings on sugary drinks	Sugary drink taxes

The following recommendations for actions that are applicable worldwide to improve food systems and diets have also been proposed by the Global Panel on Agriculture and Food Systems for Nutrition (2016)

1. **Focus food and agriculture policies on securing diet quality for infants and young children.** These are woefully inadequate in many countries. Improved policy choices are needed which recognize the centrality of high-quality diets for the youngest.
2. **Improve adolescent girl and adult women's diet quality as a priority in all policy making that shapes food systems**. Women are particularly vulnerable to the health impacts of low-quality diets because of their higher nutrition requirements and because of their disempowerment in some cultures.
3. **Ensure that food-based dietary guidelines (FBDGs) guide policy decisions to reshape food systems**. FBDGs are largely absent in low-income countries (present only in 2 out of 31) and limited in lower-middle-income countries (12 out of 51). They are needed to inform and to influence food policies around the world.
4. **Animal source foods (e.g. dairy, eggs, fish and meat) provide important nutrients. Policy support for these foods should be pragmatically evidence-based rather than driven by ideology**. Infants, children, adolescents and women of reproductive age living in low-income contexts will find it extremely hard to meet nutrient requirements in the absence of these foods. At the same time some groups in low-income contexts are consuming levels of these foods in excess of recommended levels.
5. **Make fruits, vegetables, pulses, nuts and seeds much more available, more affordable and safe for all consumers**. They offer considerable benefits in terms of diet quality. There are opportunities throughout the food system to overcome supply-side barriers to make them available, affordable and appealing. Public policy can also

incentivize greater investment in the infrastructure required to produce, store and transport these foods.

6. **Make policies which regulate product formulation, labelling, advertising, promotion and taxes a high priority**. These are needed to create disincentives for companies to allocate resources to forms of processing that undermine diet quality. Policies to educate consumers of the adverse health effects of consuming these products more than occasionally are also needed.
7. **Improve accountability at all levels**. Governments committed to reshaping food systems toward healthy diets need to set targets and publish transparent scorecards of their results. Private sector actors should acknowledge their far-reaching roles in defining food environments – and the nutritional quality of foods and other products that they promote to consumers. Civil society organizations need to monitor the performance of others.
8. **Break down barriers associated with the longstanding division of jurisdictional responsibilities within many governments – between agriculture, health, social protection and commerce**. These can fundamentally impede integrated action across food systems, inhibit the effective allocation of resources and create barriers that inhibit access to data.
9. **Institutionalize high-quality diets through public sector purchasing power**. Food provided in schools, hospitals, across the armed forces and in the prison system should be of the highest dietary benefit to the consumer. This approach has the potential to shape the norms around foods that contribute to high-quality diets and incentivize suppliers and contractors to align their value chains accordingly.
10. **Refocus agriculture research investments globally to support healthy diets and good nutrition**. Global and national public research organizations (and their funders) must rebalance their priorities to reflect a priority focus on high-quality diets. **Much more investment in research on fruits and vegetables, animal source foods, legumes, nuts and seeds is urgently required**. Better national-level and subnational data are needed on diet, consumer food prices, food safety, food loss and waste. The Access to Nutrition Index that assesses the conduct and performance of companies should be strengthened at the country level.

According to HLPE (2017) of the around seven thousand edible plant species that have been used and cultivated at some point in time, only six crops dominate today's agriculture: maize, rice, wheat, sugar cane, soybeans and oil palm with a progressive standardisation of food supplies worldwide. Of those six, maize, wheat and rice represent over half of the global food and feed supply from vegetal products.

Alternative approaches to FSN include "food fortification" and "personalised nutrition" that are gaining popularity in high-income countries. Fortification of staple food (wheat, rice, potatoes, …) with high value nutrients (zinc, iodine, iron, vitamins) may help in some circumstances but should not be perceived as an alternative to diverse and balanced diets, especially in

developing countries where the trend of the major crops to replace traditional nutrient-rich crops is already real.

Fresh foods, fruits and vegetables in particular, have broad spectra of nutrients that display their full beneficial effect in combination and not as isolated chemicals.

Insects are already an important protein source for many communities. It is estimated that more than 2000 insect species are already eaten in 130 countries and in many of them they represent a significant share of all the protein intake (HLPE, 2017). Therefore, it is mainly cultural barriers that prevent them from becoming a common food in western countries, where they are considered for animal feed (as a substitute of soy cake) or in aquaculture.

The path towards sustainable diets

The concept of sustainable diets is evidently overlapping with that of sustainable food systems and sustainable agriculture.

According to *FAO's report "Sustainable Diets and Biodiversity*[20]*, s*ustainable diets are those "diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources".

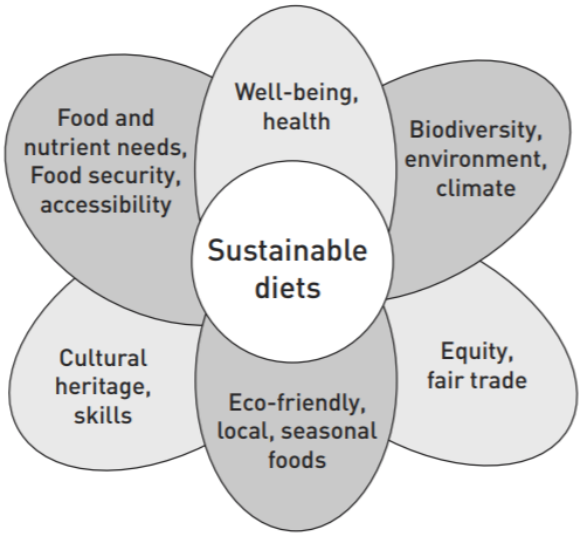


Figure 35 - Schematic representation of key components of sustainable diets (from: Lairon D. 2012. **Biodiversity and sustainable nutrition with a food-based approach**. In: Burlingame B, Dernini S, Ed. 2012. Proceedings of the International Scientific Symposium "Biodiversity and Sustainable Diets United Against Hunger. 3-5 November 2010, Rome. FAO and Bioversity International)

When the whole chain of food from "farm to fork" (primary productions, transports, transformation, preservation, retail, consumption) is considered, it appears that it is responsible for one third of total energy consumption and

[20] http://www.fao.org/docrep/016/i3004e/i3004e.pdf

for almost 30% of global GHG emissions. Whereas production (up to the farm gate) takes a relatively small share of the total energy absorbed by food systems (22%), it is responsible for the lion's share of GHG emissions (65%) of the whole sector (see Figure 21).

This difference is mainly due to the different types of emissions of production and post-production phases. Agricultural emissions (in particular CH_4 from ruminants and NO_2 from nitrogen applications) have a much higher screening effect on infra-red radiation than CO_2, which represents the main GHG emitted in the production of energy from non-renewable resources.

These figures make it clear why diets, amounts and types of food consumed, have are a major driver of climate changes.

The relationship between human health and planet health was the object of a report published by the EAT-Lancet Commission (Willett *et al*., 2019).

According to the report, current eating patterns are responsible for both poor health (lack of nutrients and or excess of animal source food) and contribution to climate change. At the global scale there is an excess of meat, eggs and starchy sugars (Figure 36). All the other food categories are consumed well below recommended amounts.

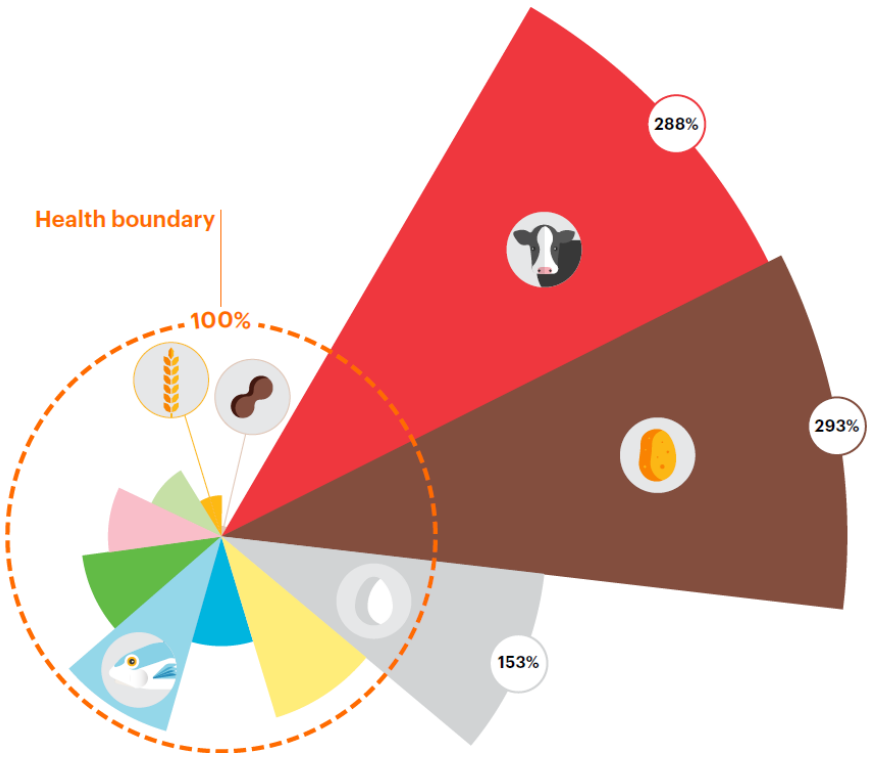


Figure 36 – Deviations of food components form a healthy diet on a global scale. At the regional scale the picture displays significant differences (Willett *et al*., 2019)

The common feature of diets in all continents is a lack of intake of fruit and vegetables and in particular of plant sources of proteins (legumes and nuts).

A healthy diet would mean doubling (at least) the intake of plant sourced food and halving (or reducing to one third) animal source food, with particular regard to red meat. Such a shift in diets would be sufficient to bring GHG emissions into the acceptable limits, compatible with the relative "planetary

boundary". This is fixed at 5.0 Gt CO_2 eq./year (range 4.7–5.4) and is represented only by non-CO_2 emissions (mainly CH_4 and N_2O), as agriculture is expected to become a net absorber of CO_2 (about 10 Gt CO_2eq/year).

EU-15 had, in 2013, the highest per-capita consumption of fruit and the lowest of vegetables. The different behaviour of Europeans towards fruits and vegetables, both associated with a balanced and nutritious diet, is not easily explained, as both food classes share, more or less, the same problems as far as price, seasonality and shelf life are concerned. Both are at the same time nutritious (vitamins, fibres and microelements) and frequent vectors of agents of food-borne diseases, requiring a healthy and controlled chain from the field to the household (HLPE, 2017)

This is also seen at a global level. Whereas fruit consumption increases with income, vegetables decrease; but all foods of animal source increase (in particular milk, red meat and processed meat)(Global Panel on Agriculture and Food Systems for Nutrition, 2016; HLPE, 2017).

The apparently higher than advisable rate of meat consumption in large part of the world (affluent countries) suggests that there is room for improvement in parallel towards more healthy diets and less negative impact on climate.

However, on a global scale, the correlations between income level and different components of diets are pointing at an evolution towards a higher environmental impact of food systems if income levels keep growing in most countries as was the case in the last couple of decades.

A bundle of different approaches to long-term food security is needed: less resource-intensive production, less carbon-intensive processing and transport, less land-intensive diets (*in primis* animal products and processed foods), and a significantly lower levels of food waste "from farm to fridge" (UNCCD, 2017).

"Action to reduce EU demand for GHG-intensive agricultural production, through measures to address excess meat and dairy consumption in diets or measures to tackle food waste has not yet been adopted at EU level" (Hart *et al*., 2017). The high political power of farmers, as well as the lobbying capacity of their organisations and a certain incoherence between environmental and agricultural policies in the European Union and the European Commission are probably the main reason for this lack of clarity.

There are contrasting views on meat-less diets, namely vegetarianism (that admits non-meat animal source food (eggs, milk, cheese) and veganism (no animal source food) vis-à-vis impact of diet on climate change.

In HLPE (2017) a number of studies are cited according to which "*dietary patterns that replace ASF with plant-based alternatives confer the greatest environmental benefits; vegan diets were associated with the greatest reductions in GHG emissions and in land use, and vegetarian diets with the greatest reductions in water use. Diets that replaced ruminant meat with other alternatives, such as fish, poultry and pork, also show reduced environmental impacts, although less than plant-based alternatives*".

In a study carried out by IDDRI[21] livestock is considered in the framework of a hypothetical wholly agroecological Europe (Poux and Aubert, 2018). A

[21] Institut du développement durable et des relations internationals; https://www.iddri.org/fr.

totally vegan population would imply the loss of all pasture (at least in their present function of feeding herbivores) and would create an imbalance in the nitrogen cycles: the plant crops cultivated to feed humans would extract more nitrogen than could be fixed by rotations with leguminous crops and the fields would evidently not receive manure applications. The recourse to synthetic Nitrogen would be inevitable. Not only would the elimination of all livestock be undesirable, but also ruminants would be referable to non-ruminants, despite methane emissions, because they can feed on grass from pasturelands that do not compete with food production and at the same time serve as effective carbon sinks.

According to the EAT-Lancet Commission (Willett *et al*., 2019), however, a dietary transition is not only measure to qualify food systems contribution to a healthy planet. The satisfaction of other conditions is necessary to stay within the "planetary boundaries":

1. no expansion of crop land, or expansion towards already modified environments, such as abandoned farmland;
2. rational use of freshwater resources (although with limits due to the strong regional character of this factor);
3. a catch-up of productivity in under-performing areas filling at least 75% of the gap vis-à-vis the most productive areas of the same crops.

The achievement of the last objective, however, implies a re-distribution of fertiliser inputs (especially nitrogen and phosphorus) from areas of excessive use to areas of insufficient application that has obvious technical and economic obstacles.

A fourth condition, probably one on which it is easier to reach a general consensus, is halving the loss or waste of food, in line with SDG Goal 12.3.

The EAT-Lancet Commission envisages a set of five strategies to achieve the goal of healthy diets for a healthy environment:

- Seek international and national commitment to shift toward healthy diets
- Reorient agricultural priorities from producing high quantities of food to producing healthy foods
- Sustainably intensify food production to increase high-quality output
- Strong and coordinated governance of land and oceans
- At least halve food losses and waste, in line with UN Sustainable Development Goals

However problems arise when moving from the identification of possible strategies to their implementation. Swinburn (2019) clearly identifies the root causes of this failure to take concrete actions: the main context is the fight on obesity, but the same considerations apply to climate and environmental issues as well: "*patchy progress is due to what the Commission*[22] *calls policy inertia, a collective term for the combined effects of inadequate political leadership and governance to enact policies to respond to The Global Syndemic, strong opposition to those policies by powerful commercial interests, and a lack of demand for policy action by the public*".

[22] The Lancet Obesity Commission: https://www.thelancet.com/commissions/global-syndemic

In the same text, with even more explicit wording, the Commission describes the type of influence vested interest exert on policy makers: "*Industries with vested interests, such as transnational food and beverage manufacturers, are powerful and highly resourced lobbying forces that have opposed governments' attempts to regulate commercial activities or modify them through fiscal policies, such as imposing a tax on sugary drinks or changing agricultural subsidies. Politicians are either intimidated by industry opposition or they might hold beliefs that education and market-based solutions that are grounded in neoliberal economic and governance models are sufficient to reverse the obesity epidemic*".

The Commission calls for "*a Framework Convention on Food Systems (FCFS) would strengthen the ability of nations to act, reduce the power asymmetries created by Big Food* (the dominant multinational companies)*, and ensure comprehensive action in line with the double-duty or triple-duty actions needed to address "The Global Syndemic*[23] *of Obesity, Undernutrition, and Climate Change"…..*"an international agreement to address conflicts of interest must be instigated. The agreement could be based on Article 5.3 of the FCTC (Framework Convention on Tobacco Control), which explicitly excluded the tobacco industry from policy development and implementation*".

Land management

Land is the ultimate resource for food production (apart from seas, oceans and inland waters) and therefore the status of land surfaces is of paramount importance in FSN and degradation of productivity a major source of concern. Agriculture is the largest human use of land, covering roughly 38 per cent of land surface, not including Greenland and Antarctica (UNCCD, 2017)

An extensive report, "The Global **Land Outlook"** was produced in 2017 by the United Nations Convention to Combat Desertification (UNCCD, 2017).

In the face of increasing demand for land-intensive crops and livestock around 20% of the Earth's vegetated land surface showed **persistent declining trends in productivity** from 1998 to 2013 (20% of cropland, 16% of forests, 19% of grassland, 27% of rangeland). This is particularly worrying as further intensification (albeit under the "sustainability" label) is advocated to meet increasing food and feed demands.

A very common phenomenon worldwide is soil degradation that can be:

Physical degradation or the structural breakdown of the soil due to the disruption of aggregates and compaction that provoke a reduction in water retention capacity, more runoff and erosion, decreased drainage.

Chemical degradation, with salinization, acidification, nutrient loss and the accumulation of noxious minerals

Biological degradation through the perturbation of soil biota, increased oxidation and consequent loss of organic matter; loss of nutrients.

The loss of fertility is often addressed by more aggressive tilling, increased input of fertilisers, often with a further exacerbation of damages while

[23] The concept of "syndemic", used by The Lancet Obesity Commission, denotes a combination of two or more diseases that occur together both in time and place, display a reciprocal interaction at the biological, as well as psychological and societal levels and are subject to the same set of driving forces.

contributing to climate change instead of favouring the function of soils as carbon sinks. According to UNCCD (2017) agricultural soil has a significant potential to act as a carbon sink: about 100 Gt. One should not be misled, however, but the potential, as there is a concrete risk, under different scenarios, that further conversion of forests and rangelands to croplands will occur, thus acting in the opposite direction of more carbon flows towards the atmosphere.

At the same time, even in case the potential was fully achieved, it would represent less than one third of the carbon stock present in the atmosphere. It has been estimated that, due to human interference, soil carbon contained in organic matter was reduced by 176 Gt compared to pristine state. At the current trend, instead of acting as carbon sink, soils would be a further source of atmospheric carbon adding another 80 Gt of carbon to the atmosphere by 2050. The global potential to store carbon in soils is therefore considerable but it requires fundamentally different agricultural models with respect to today's practices (UNCCD, 2017).

According to Campbell *et al.* (2017) sustainable agriculture of the future implies:

1. increasing agricultural production per unit land area, per unit fertilizer input, and per unit water consumed (resource efficiency);
2. maintaining and increasing soil organic matter in croplands, which is a key to water holding capacity, nutrient availability, and carbon sequestration;
3. employing agroforestry practices that provide food and fibre yet maintain habitats for threatened species; and
4. maintaining local biodiversity and associated ecosystem services such as pollination and pest control.

According to the UNCCD "Global Land Outlook" (UNCCD, 2017) a combined effort of governments, farmers, industries, consumers is needed to reduce the pressure and limit the damage to land resources:

1. Multifunctional landscape approach: *prioritizing and balancing different stakeholder needs at a landscape scale while incorporating site-level specificity on land use, demand, and condition so that a full range of goods and services are produced. Land use planning helps identify those land uses that best meet the demands of people while safeguarding soil, water, and biodiversity for future generations.*

2. Resilience building: *enhancing the adaptive capacity of communities and ecosystems through a mix of conservation, sustainable management, and restoration of land resources. There are many tools and practices to safeguard healthy, well-functioning, and diverse natural and managed lands that can help to mitigate and adapt to climate change and other natural resource pressures.*

3. Farming for multiple benefits: *optimizing the most desirable suite of ecosystem services from food production activities. This requires a fundamental shift in agriculture practices to support a wider array of social, environmental, and economic benefits[24] from managing land-based natural capital.*

[24] According to UNCCD (2017) "*In some cases, the approach has been transformed into one which seeks payments for ecosystem services on the assumption that such remuneration will ensure their provision.*" However, the concept of "payment" for ecosystem services is a double-edged sword: on the one hand it aims at rewarding individual (onerous) efforts to act towards the environment in a way that benefits humanity; in a way, it is a way for Society to share the economic burden of a virtuous behaviour. But on the other hand, giving a "price" to a service may spread the idea that it can be traded much in the same

4. Managing the rural-urban interface: *framing a new approach to spatial planning to minimize the impacts of urban sprawl and infrastructure development. Cities designed for sustainability in the wider landscape can reduce environmental costs of transport, food, water, and energy, and offer new opportunities for resource efficiency.*

5. No net loss: *providing incentives for the sustainable consumption and production of natural resources. Land degradation neutrality or no net loss of healthy and productive land means more services onsite and less negative environmental or social impacts offsite. For consumption, it means significantly reducing the current levels of food waste and loss.*

6. Creating an enabling environment: *providing the conditions necessary to scale local successes into large-scale, transformative initiatives. This includes fostering the underlying social and economic conditions and institutions, particularly those relating to stakeholder engagement, land tenure, gender equality, and the availability of sustained investment and infrastructure".*

Land grabbing

One of the fundamental issues affecting FSN is land tenure rights; for most people in the developed countries, where private property of land is well established and common areas (such as some forests and pastures) are regulated by consolidated legislation or soft law, it is even hard to imagine the number of situations that characterise many development countries in which access to land is often regulated by unwritten traditions and rights overlap in time, space, type of use and even gender.

Land-poor but cash-rich countries and big companies are investing huge amounts of money in land acquisitions in many parts of the world but especially, at present, in Africa.

According to the Tirana Declaration[25], large-scale land acquisitions or concessions are defined as "land grabs" if they are characterized by one or more of the following:

- Violations of human rights, particularly the equal rights of women;
- Not based on free, prior, and informed consent of the affected land users;
- Not based on a thorough assessment or are in disregard of social, economic, and environmental impacts, including the way that they are gendered
- Not based on transparent contracts that specify clear and binding commitments about activities, employment, and benefits sharing;
- Not based on effective democratic planning, independent oversight, or meaningful participation.

It is estimated (UNCCD, 2017) that more than 42 million hectares of land have been purchased by foreign investors since the year 2000 out of a total of around 200 million hectares that changed hands; the acquisitions average size being around forty thousand hectares. This phenomenon is particularly evident in Sub-Saharan Africa but is not limited to this continent. Nor is "land grabbing" limited to the initiative of foreign investors; the majority of large

way as material goods and that its value coincides with its "market price". For goods that should be available to all and property of no one (clean air, favourable climate, pure water) a rather dangerous idea.

[25] ILC. 2011. **Securing Land Access for the Poor in Times of Intensified Natural Resources Competition**. Report of the ILC Int.l Conf. and Assembly of Members Tirana, Albania 24-27 May 2011. https://www.landcoalition.org/sites/default/files/documents/resources/aom_2011_report_web_en.pdf

scale land acquisition is carried out by economically powerful nationals as presumably safe investments for an anticipated widespread food scarcity[26]. According to UNCCD (2017) "*almost 10% of the total area under cultivation, and 35% per cent of the remaining potentially-available cropland in Africa has been acquired by large entities, with over 70 million hectares allotted for biofuels*".

Quite often these areas are of prime quality and either come with water rights or end up in appropriating, thanks to high technological capacities, a large share of surface or underground water reserves.

According to investors, land acquisitions bring technological progress in agricultural practices that are increasing the productivity of land and that former users (i.e. evicted peasants) are offered paid jobs and services. The opponents argue that the rural poor that find occupation in the new large farms find themselves trapped in low paying jobs; and those who do not find jobs, also due to the less labour-intensive technologies introduced, are just evicted and have no choice but to emigrate or increase the numbers of urban populations.

Critics of "land grabbing" also argue that this phenomenon is also spreading the idea that large scale intensive, largely monocultural (industrial) agriculture is the only acceptable standard, blocking the way to alternative models that could be more appropriate from both a social and environmental point of view, with diverse agroecosystems and diverse, especially traditional, crops that are essential for an appropriate nutrition (UNCCD, 2017).

The main "financial" purpose of these investments often creates situations in which cash crops or even biofuel crops for export are produced, instead of food crops, in areas where undernourishment is common among rural populations.

[26] According to the UNCCD (2017) "*In South Africa 80 per cent of farmland was still owned by the white minority in 2013. Overall in Africa only about 10 per cent of rural land is registered, leaving 90 per cent informally administered. Similar land tenure issues extend around the world; India has the largest population of landless people on the planet*".

Agroecology as a paradigm of conceivable transitions

Agroecology is a complex concept that addresses multiple goals with emphasis on the social aspects (smallholders, local markets, traditional agriculture) on the one end or on the bio-ecological aspects (exploitation of positive interactions between ecosystem components). The FAO Agroecology Knowledge Hub provides a list of 19 definitions[27]. We here report one of them appearing on the website of the French Ministry for agriculture and food[28]:

"L'agro-écologie est l'utilisation intégrée des ressources et des mécanismes de la nature dans l'objectif de production agricole. Elle allie les dimensions écologique, économique et sociale et vise à mieux tirer parti des interactions entre végétaux, animaux, humains et environnement. [Agro-ecology is the integrated utilisation of natural resources and mechanisms within the objective of agricultural production. It combines the ecological, economic and social dimensions and aims at a better exploitation of the interactions between plants, animals, human beings and the environment.]

We here take agroecology not only as a conceivable agricultural system that could meet the environmental and social objectives of sustainable transitions, but also because the likely obstacles such a transformation would meet are paradigmatic of the difficult road of any deviation from the mainstream agricultural and agrifood systems.

The report "From Uniformity to Diversity" (IPES-Food, 2016) published by the International Panel of Experts on Sustainable Food Systems[29] in 2016 compares "industrial agriculture", the dominant paradigm for agriculture in most of the advanced economies and, increasingly, in developing countries entering the world markets, with "agroecology". It explores the positive achievements and the negative consequences of the former with the various situations where the agroecological concepts (technical and social) have been adopted for food security, diet quality, health and wealth.

The main differences of the two paradigms are synthesised in Table 12.

Table 12 – Main differences between "industrial" agriculture and agroecology (IPES-Food, 2016)

Specialised Industrial Agriculture	Diversified Agroecological Farming
Monocultures, Concentrated Animal Feeding Operations	Temporal and spatial diversification at plot, farm and landscape levels
Genetically uniform varieties and breeds selected for productivity and response to inputs	Wide range of less uniform, locally-adapted varieties/breeds based on multiple uses
Vertical and horizontal segregation of product chains	Natural synergies. Production types integrated
Highly mechanized, labour-saving	Labour-intensive
Maximization of returns from a single product	Maximization of multiple outputs

[27] http://www.fao.org/agroecology/knowledge/definitions/en/; accessed 7 November, 2018).

[28] http://agriculture.gouv.fr/infographie-les-fondamentaux-de-lagro-ecologie; accessed 7 November, 2018.

[29] IPES-Food, http://www.ipes-food.org

Intensive use of external inputs	Low external inputs. Recycling of waste within full nutrient cycling
Long value chains.	Short value chains

The remarkable results obtained by "industrial agriculture" and especially during the "green revolution" are acknowledged, but so are the negative consequences of the factors that fuelled it (cheap energy, neglect of the environment, large investments, privatisation of genetic resources):

- Loss of natural biodiversity (including pollinators) and of genetic diversity of crops
- Pollution of air and waters (from widespread use of fertilisers, herbicides, pesticides)
- Land quality degradation, loss of organic matter, soil erosion
- GHG emissions
- Excessive water withdrawals from rivers, lakes and aquifers; salinization (salinization is estimated to affect 20% of irrigated lands worldwide: FAO, 2014)
- Expulsion of small farmers and rural workers
- Loss of traditional food systems contributing to diverse diets
- Antimicrobial resistance

Industrial agriculture, according to IPES-Food (2016), has entered a vicious circle, in which the damages provoked by intensive farming technologies push farmers towards a further intensification of farming: larger farms[30] and herds, more mechanisation, more uniformity, greater use of chemical inputs.

Agroecological farming is supposed to be inferior in productivity vis-à-vis industrial agriculture. This can well be the case when productivity is calculated on yield of a single crop, but the comparison is biased by the intrinsic multiplicity of crops that alternate in space and time in agroecological farming, the on-farm reuse of residues the integration with livestock, on the nutritional value of productions. IPES-Food (2016) reports al number of studies that shift the balance towards agroecology once total productivity per unit area are considered instead of single crops.

Agroecology is credited with a "built-in" resilience given by its multiple crops structure and combination with livestock rearing (not all the eggs in the same basket), by diverse ecosystems that are less prone to external stresses, by practices that limit erosion and thus the damages caused by heavy rains or floods.

Other advantages derive from the reduced dependence on inputs. Not only less GHG are produced, less toxic chemicals are spread, less excess fertiliser enters the surface waters and the aquifers; also from the economic point of view, farmers reduce expenses and are less dependent on expensive credit.

[30] It is estimated that there are 570 million farms worldwide, of which the large majority are small; for example 410 million are less than a hectare in size and 475 million less than 2 hectares. Despite the numbers, smallholders farming less than 2 hectares only occupy 12 per cent of total agricultural land, with the remainder held by significantly larger farms (UNCCD, 2017).

Agroecological farming systems are certainly more labour-intensive and therefore outperformed by industrial agriculture if labour efficiency is considered. However, if the displacement of farmers made redundant by highly mechanised industrial farming systems is included in the picture, agroecology may often appear as the winning option.

IPES-Food (2016) then explores the factors that act against a wider diffusion of agroecology and lock the current farming systems in the "industrial agriculture" paradigm.

These "lock-ins", analysed with regard to an agroecological transition, are however likely to be relevant for any hypothetical deviation from the current dominant "industrial" model that has shown its weaknesses.

Eight "lock-ins" are identified:

1. **Path dependency**. Costly investments already made by farmers in machinery and infrastructures devised for specialised monocultures would not be recovered.
2. **Export orientation**. Large scale monocultures of the major commodities to be offered on the international markets have been enforced also on developing countries as the only pathway to economic development. International commodity trade has become vital for big processed food producers that require large quantities of standard materials. The influence of international markets is evident also in the increased use of edible crops (wheat, maize, soybean) for the production of biofuels[31].
3. **The expectation of cheap food**. Standard, highly processed, calorie-rich and nutrient-poor requires standard foodstuffs of large scale commodities; mainly cereals and vegetable oil crops. This food is produced and sold by big economic conglomerates (commodity traders, food industry, retailers) at low prices in urban centres, thus reinforcing expectations of cheap food by the urban masses.
4. **Compartmentalised thinking**. Silo structure of scientific disciplines, sectoral approaches to policies, fragmented administrations have contributed to reinforcing a piecemeal approach towards the development of agriculture; focus being placed on individual areas (fertilisation, irrigation, mechanisation, breeding, pest control, etc.) without due consideration for interactions and side effects, technical, environmental and social. Compartmentalised thinking is being exacerbated by widespread privatisation of research (indoor research and private funding to public institutions) that directs efforts towards the most rewarding sectors for large companies.
5. **Short term thinking**. The problem is certainly not unique to agricultural policies. The short-term objectives of politics, generally focused on the next electoral round, do not encourage strategic choices that might produce visible results in a longer time frame. A widespread transition to agroecology falls certainly in this category.
6. **Feed the world narratives**. The idea behind the "feed the world narrative" is the classical "comparative advantage" of David Ricardo and

[31] The global area under biofuel crops was estimated at 45 million hectares in 2010 and is expected to double, to roughly 3–4.5 per cent of all cultivated land by 2030 (UNCCD,2017).

Adam Smith: that all would be advantaged when each produces what one is best at and exchanges it with other goods through trade. The international commodity trade was built and still operates under this principle. The "feed the world" narrative assumes that the main problem be global availability of food (mainly treated as source of calories) and not accessibility or affordability.

7. **Measures of success**. The comparison of industrial agriculture with agroecology is vitiated by the widespread use of total yields of specific crops, productivity per worker, and total factor productivity as indicator of success. These are intrinsically inadequate for the evaluation of systems that combine a diversity of crops on the same farm or plot, either spatially or temporally, that have positive environmental spill-overs in terms of soil quality, lower GHG emissions, natural biodiversity, that re-uses internally (instead of selling on the market) part of its production.
8. **Concentration of power**. Both ends of the food chain (farmers and consumers) are made by a myriad of subjects. Producers of agricultural inputs (agrochemicals, seed, machinery), traders of commodities, retailers are dominated by few multinational conglomerates often extending their business on multiple areas (e.g. seed and herbicides). Their business model is based on large scale production and worldwide trade of standard products. Their public messages, through advertisements, lobbying and commercial policies are preventing any alternative model from developing.

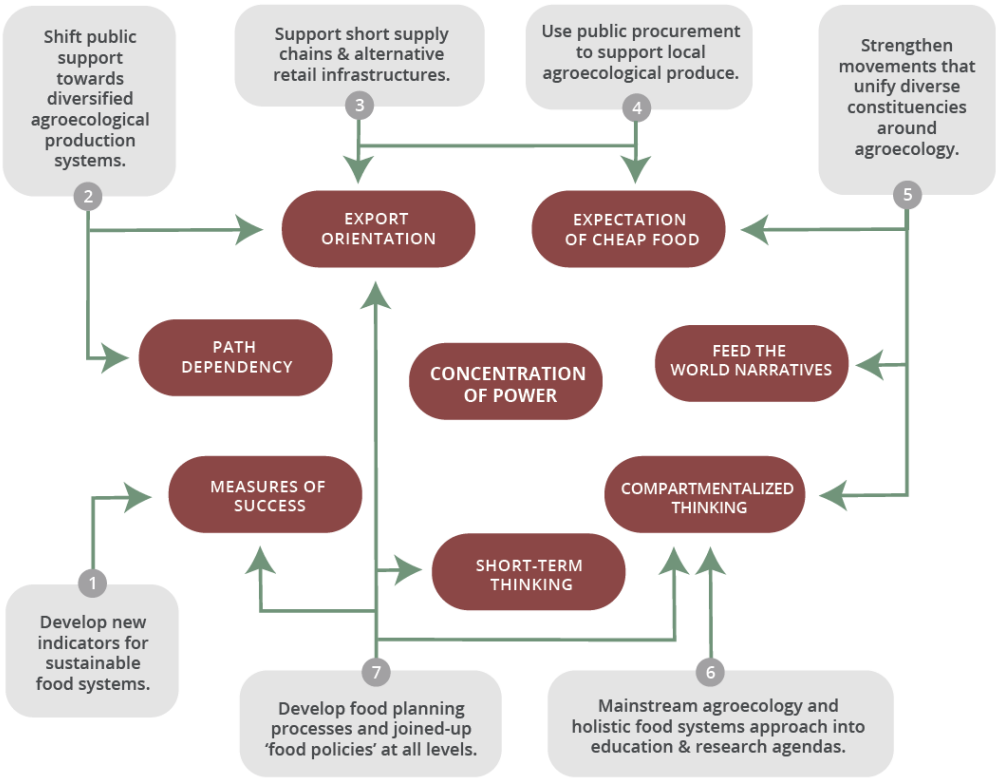


Figure 37 - IPES-Food key recommendations for supporting the shift towards diversified agroecological systems. Recommendations make reference to the eight major "lock-in" factors identified. "Lock-in" factor "Concentration of power" stands at the base and reinforces all the rest (IPES-Food, 2016: reproduction of Figure 14 at page 67)

The seven "key recommendations" proposed by IPES-Food (2016) to address the "lock-ins" that stand in the way of a transition are represented in the Figure 37.

Concentration of power in the Agri-food sector ("lock-in" n. 8, above) has been the object of a report by IPES-Food (2017). Mergers and acquisitions that have become more frequent in recent years and have involved some of the biggest players are generally justified by the desire of companies to increase shareholder value and market share, to conquer new markets, appropriate key resources, control the supply chains.

The sectors involved are those of seeds and agrochemicals, fertilizers, livestock genetics, animal pharmaceuticals, farm machinery, agriculture commodity trade, food and beverage processing and food retail (Figure 38).

One of the consequences of the concentration of the economic power in a limited number of big transnational players is negatively affecting the power of policy makers, often the target of massive lobbying actions and "blackmailing" (threat to move operations to other areas of the world in case of unfavourable policies), in their duty to protect the rights of citizens to adequate nutrition (IPES-Food, 2017).

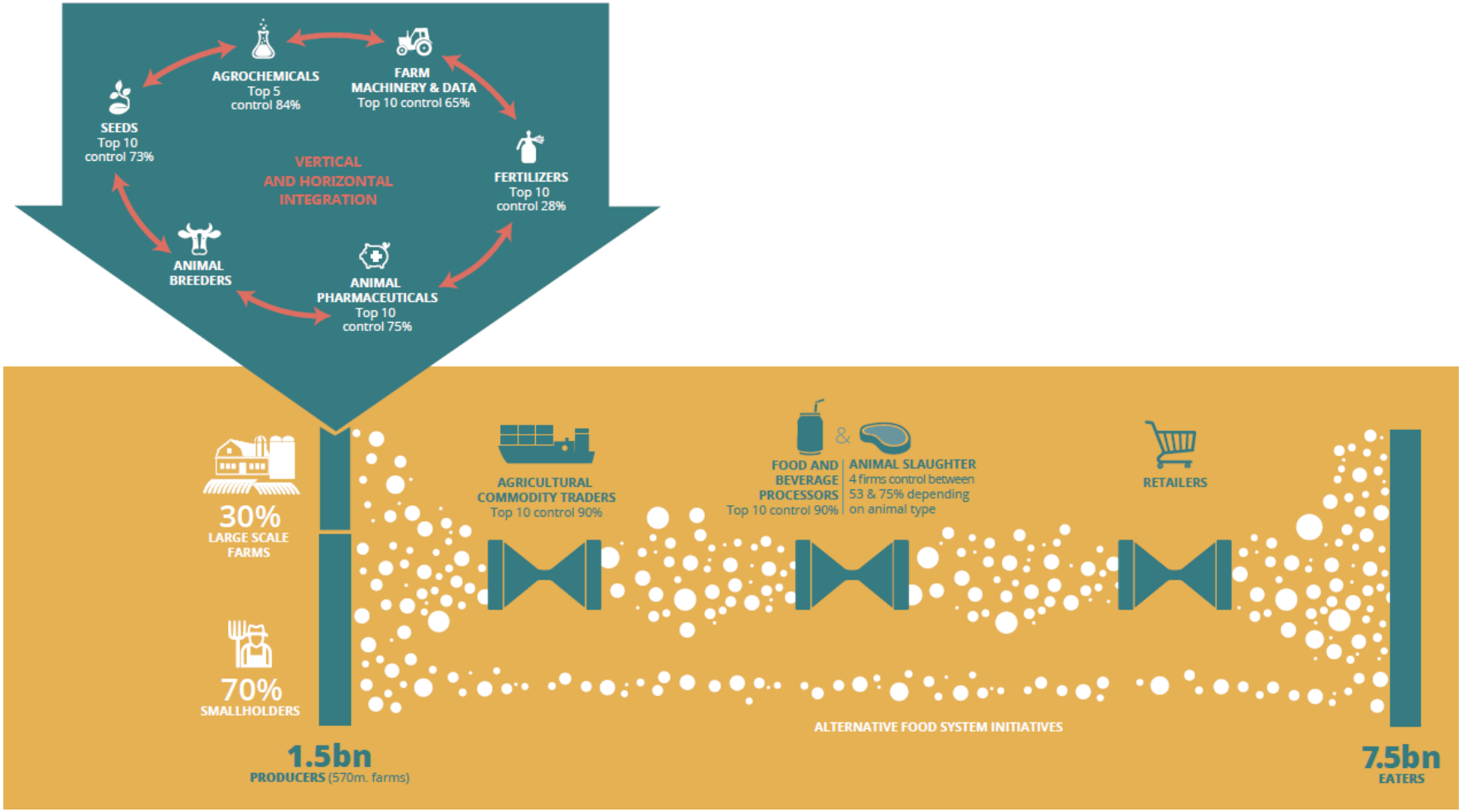


Figure 38 - Concentration of power deriving from mergers and acquisitions in the food chain creates a series of bottlenecks that limit the choice of farmers and, ultimately, of consumers (from IPES, 2017)

According to IPES-Food (2017) concentration of industrial and economic power creates a series of negative impacts:

1. *Redistributing costs and benefits along the chain, and squeezing farm income*; farmers are forced to bear the costs of farming inputs when their price increases more than the price of commodities as well as market risks, with higher and higher shares of value are appropriated by the commodity trade, processing and retail sectors.
2. *Reducing farmer autonomy in a context of 'mutually-reinforcing consolidation'*; farmers increase their dependence from input suppliers (seed, agrochemicals, …) and commodity traders that, locally, act in a regime of quasi-monopoly.
3. *Narrowing the scope of innovation through defensive and derivative R&D*; according to IPES-Food (2017) mergers and acquisitions tend to optimise research infrastructures but fail to produce real innovation; research is mainly directed at protecting past investments ("milking the cow").
4. *Hollowing out corporate commitments to sustainability*; return on investments being the main objective of companies that have financial actors in the driving seat has the loss of interest in values as a consequence; "green" brands are often acquired in order to improve image at the expense of production standards.
5. *Controlling information through a data-driven revolution*; the real value of the digital revolution are data; especially digital agriculture that appears the most revolutionary sector in the food system today is at risk of data being appropriated by the big companies (e.g. farm machinery manufacturers) at the expense of the farmers who buy and operate machinery: farmers de facto are the sources of data but have no direct access to them.
6. *Escalating environmental and public health risks*; traceability becomes a nightmare when ingredients are sourced worldwide and when the food chain involves a long line of actors.
7. *Allowing labour abuses and fraud to slip through the cracks*; loss of direct relationships between food industries and suppliers makes it impossible to check the absence of labour exploitation or fraud along the chain.
8. *Setting the terms of debate and shaping policies and practices*; the sheer economic power of the big conglomerates and their lobbying capacity affects sectoral policies and can even shape research agendas of public institutions, thus adding publicly funded research capacity to their own.

Power imbalances also feed the myth of the consumer being "in the driving seat" in food markets, determining what and how the food industry produces with his behaviour as a buyer. Powerful and subtle advertisement campaigns and other less obvious actions by the industry (the big multinationals *in primis*) can influence individual behaviours and public policies.

Conflict of interests are sometimes apparent, but sometimes "flow under the surface", via lobbying groups when regulations and policies are developed or by private financing of research. Scientists too can experience conflict of interest. The nutrition scientific community has been increasingly scrutinized for where it sources its funding (HLPE, 2017). Scientific results may not be

altered, especially when research is carried out by public institutions, but decisions on what research to fund and whether or not to publish the results or the way results are presented to the non-scientific public, are the domain of the industry and can affect the quality of the messages.

At the European level an interesting forward-looking study was carried out by IDDRI[32], an independent policy research institute on sustainable development, based in France, financed by research institutions (e.g. INRA and CIRAD), companies and Ministries. The "Ten Years For Agroecology" (TYFA) project[33] started in 2014. A report was published in 2018 (Poux and Aubert, 2018).

The TYFA project makes use of an original quantitative model (TYFA*m*) to design scenarios for an agroecology-based European agriculture (including livestock) in 2050 meeting the quantitative and qualitative demands of a healthy nutrition, reducing the global environmental footprint of Europe (e.g. by avoiding the import of vegetable proteins for feed from other continents) increasing biodiversity and, at the same time, achieving a 45% reduction of GHG emissions from the agricultural sector. The TYFA project explores the feasibility of a Europe-wide adoption of Agroecology as the dominant model of agriculture.

The model adopted by the TYFA project is reported in Figure 37.

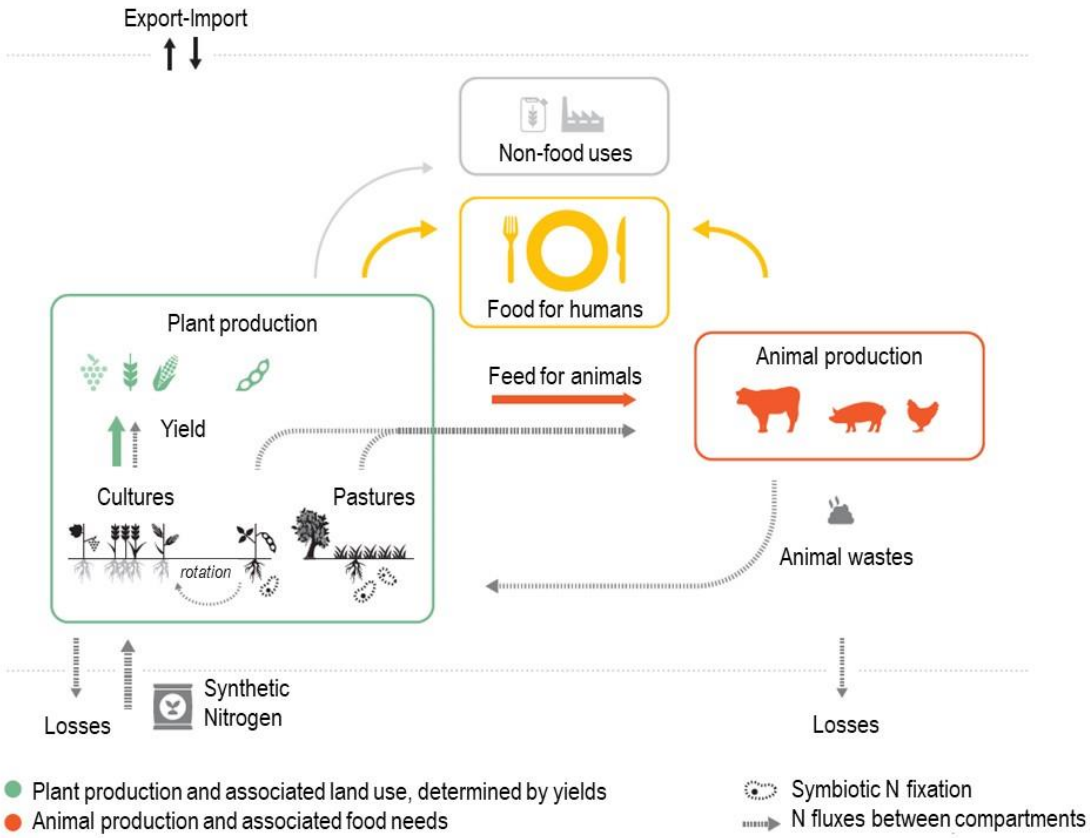


Figure 37 - Logical structure of the TYFA*m* model: a simplified representation of the European food system (From Poux and Aubert, 2018)

[32] Institut du développement durable et des relations internationales (www.iddri.org)

[33] https://www.iddri.org/en/project/tyfa

The agroecological perspective does not necessarily have mitigation of climate change as its ultimate goal, as the emphasis is on avoiding external inputs (synthetic fertilisers and biocides) by the exploitation of ecosystem regulatory services provided by a biodiverse context at the plot, farm and landscape levels. However, the production models it envisages have potentially a beneficial influence also on the limitation of GHG emissions from agriculture and in enhancing the sink function of soils and vegetation.

The agroecological concept is opposed to the other common paradigm for a sustainable agricultural model, that of "sustainable intensification". Sustainable intensification means making a more efficient use of currently available resources, in order to "produce more with less"; the concept is criticised by the agroecological movement as it does not fundamentally change the production systems but merely aims at reducing some of its negative effects (e.g. less chemicals) while potentially increasing others (e.g. loss of biodiversity).

The main effects of an agroecological transition for Europe would lead to:

1. **Healthy diets**: reduced consumption of animal products and increased consumption of fruit, vegetables and vegetable protein; adherence to current nutritional guidelines.
2. **Stop importation of soybean and palm oil**: end deforestation caused by imports; protein and oil-protein crops are essential components for maintaining the fertility of agroecological systems.
3. **Abandonment of pesticides**: consideration of human and environmental health issues according to the precautionary principle, given the impossibility of defining a safe dosage and to monitor the systemic effects of active ingredients and adjuvants.
4. **Abandonment of synthetic fertilizers**: difficult to use without pesticides (see 3) and absence of references on systems without pesticides but with fertilizers.
5. **Maintenance of permanent grassland areas, all farmed extensively**: unfertilized permanent grasslands support biodiversity and provide nitrogen from spontaneous legumes; grass-fed meat and milk production is richer in Ω3, essential for a balanced diet.
6. **Extensification of ruminant farms**: derives from points 1, 4 and 5; ruminants are essential for maintaining permanent grasslands and managing fertility; animal welfare issue.

The IDDRI "Ten Years For Agroecology" report (Poux and Aubert, 2018) is critical of several common "narratives" on the role of European agriculture that are "locking-in" the currently dominant "industrial" model (Table 13).

Table 13 - Critical analysis of current dominant narratives on the role of agriculture in Europe by the "Ten Years For Agriculture" project (Translated from: Poux and Aubert, 2018; original in French)

The dominant narrative	**Our analysis**	**The TYFA position**
"Europe must increase production in order to (contribute to) feed the world"	EU cereal exports represent less than 1% of the world production. EU devotes the majority of its cereals to feed its livestock (over 50% of its production) The EU is a net importer of agricultural land (almost equivalent to 30% of UAA): at present it is the world that feeds Europe and especially its livestock	The EU has no vocation to feed the world and is not in a position to be a big player in this area. The best possible EU contribution is to reduce its "food footprint". Basically, its up to the world to feed itself. However, a certain export capacity should be preserved in order to intervene in case of a food crisis.
"Europe must produce to provide cheap food to Europeans"	The low production costs are linked to environmental, sanitary and social costs that are borne by farmers, the public in general and the disadvantaged groups in particular. The diet of Europeans is too rich in animal source foods that are even wasted due to their affordable cost.	The overall European production is too high (in Kcal) and unbalanced: too many ASF produced with cereals and soy; not enough vegetables. The nutritional quality on fundamental aspects (Ω3, pesticides) needs to be improved. Access to food for the disadvantaged populations should be considered within a global approach to the reduction of poverty and not by a downwards spiral of production costs.
"Agriculture and the agri-food industry are part of a movement towards the liberalisation of trade; to argue for an agricultural exception is irrealistic"	The EU holds at present food and environmental preferences that provide a meaning to its political project. There is a growing awareness of environmental issues in international trade.	It is legitimate to defend, in and outside Europe, food and environmental models in the framework of international trade. This is a major expectation of the European society.

The TYFA model envisages an agricultural production in 2050 reduced by 30% with respect to current levels in the plant products sector and a reduction of 40% in the animal products. The former figure is deduced by a comparison with the organic farming system of today that applies the same principle of no external inputs (apart from energy!). The second is derived in part from the lower demands of animal products in a healthy diet context for Europe and in part from the perspective of positive interactions with agriculture (crop and pasture lands).

The reasons for an elimination of biocides and of synthetic N fertilisers is not only motivated by the desirability of those cations per se (as noxious for human health and the environment). Biocides, insecticides in particular, act against the ecosystem services provided by a useful fauna: pollinators,

hyperparasites, predators. Nitrogen fertilisers are an obstacle to the actions of Rhizobia, the Nitrogen-fixing symbionts of *Leguminosae* (or *Fabaceae*).

The major changes foreseen in the crop sectors are a reduction of cereals, an expansion of oil and protein crops, and, most notably, an expansion of pastures and forage crops (mainly N-fixing species) as the main sources of feed for animals in substitution of imports.

In coherence with this scenario, it is anticipated that the livestock will more or less remain stable or slightly decreasing for beef and dairy cows, drastically reduced for monogastrics, unable to process grass as the ruminants do.

The adoption of agroecological practices and of the envisaged shifts in agricultural productions (crops and livestock) is expected to reduce emissions of GHG by almost 40% with respect to 2010. The main contributions to the reduction would come from the stop to feed imports (effect on land use change in the countries of origin), from the stop to the synthesis of N fertilisers, and from the reduced N_20 and NH_3 emissions from soils. Methane from enteric fermentation would remain more or less stable because the numeric reduction of livestock would affect the monogastrics and not the ruminants.

The impact on biodiversity is difficult to estimate quantitatively. An increase is of course expected for those areas that are converted from croplands to pastures and indeed for the deliberate creation of seminatural communities in the form of hedges and tree lines across landscapes and to the adoption of agroforestry or other mixed crop models.

Opportunities for change could be suggested by a wide range of successful examples in different parts of the world, but the first essential step is to build a consciousness among the public at large, especially consumers and especially in urban settings.

Policy incentives (e.g. through the CAP in Europe), citizens-led policy councils, widespread environmental consciousness, education on healthy diets, integration of agroecology into academic curricula, collaborative research with farmers and citizens are among the initiatives that would support a transition from industrial agriculture to agroecology.

Other less drastic changes towards sustainable food systems are proposed by UNCCD (2017), with a combination of goals, from human health, to the preservation of ecosystem services, to an efficient use of resources with a long term view.

1. **Close the gap between actual and potential yield in all environments**

Closing gaps, sometimes significant, between current and potential productivity with already available technologies offers more possibilities of increasing food production than insisting on focusing research and extension on the already very productive agricultural contexts. The real challenge is to close the gap in productivity without increasing the environmental toll.

2. Use land, water, nutrients, and pesticides more efficiently

The use of fertilisers, water and particularly pesticides is far from optimal in many parts of the world, with vicious circles that push to ever increasing inputs to compensate for loss of fertility due to land degradation or to the disruption of viable agro-ecosystems. Not unfrequently, increased input application is pushed by the industry.

3. Reduce offsite impacts of food and non-food production

A rational use of the agricultural means of production includes the minimisation (possibly elimination) of negative impacts downstream, such as surface water eutrophication, water table pollution, damages to non-pest animals and, ultimately, climate change. Several pathways have been proposed going from precision agriculture to "regenerative" agricultural models.

4. Stop expanding the agricultural frontier

Expansion of agriculture, where necessary, should not occur at the expense of forests and pastures, but directed at the recovery of degraded lands.

5. Shift to more plant-based and whole food diets

A diet shift towards more plant based food and less animal source food, especially in affluent countries, is indicated as the main avenue both towards a reduction of agricultural negative impact on climate and the environment and, frequently, to better health. Quite clear in this line is the message carried by the EAT Lancet Commission (Willett *et al*., 2019).

6. Raise awareness about health, sustainability, and responsibility

Consumer information through labelling, certification schemes, awareness raising campaigns on the effects of food and food systems on health, climate and the environment is essential in order to encourage sustainable consumption.

7. Reward sustainable land management practices

In many instances, environment and climate-friendly production systems are advantageous for the farmers themselves (e.g. protection of pollinators, reduced expenses on inputs, increasing soil fertility). Where they are not, or where benefits are delayed, public support in the form of incentives should encourage beneficial practices.

8. Reduce food waste and post-harvest losses

Food loss and waste takes a high toll both on food security and nutrition and on the environment. As it is characterised by a wide range of causes and forms in different parts of the world, a broad range of measures are needed to tackle the problem, from fields to homes.

9. Improve land tenure security, access to nutritional food, and gender equity

Land tenure security is deemed necessary for ensuring attention to long-term preservation of agricultural land, both at the farm and the landscape level. Although land tenure is taken for granted in western cultures, the situation is often quite different in areas where traditions or institutions are not strong enough to protect collective or individual rights. Where institutions are weak

or corrupt, land grabbing, in its various forms, can displace traditional farmers, undermine diverse food production systems, leading to food and nutrition insecurity.

10. Implement integrated landscape management approaches.

Comprehensive land management is becoming more and more complex due to increasingly different perspectives and interests; farmers vs industry, urban vs rural dwellers, production vs amenity. Strong institutions are needed to keep the dialogue constructive, with mutual recognition of stakeholders' expectations.

Scenarios and foresights

This analysis is based on reports and foresights published in or after 2015, the year when the fourth SCAR Foresight[34] was published. However a number of the previous documents analysed by Le Mouël *et al*. (2018) should be mentioned here, as they constituted a reference also for the most recent analytical studies and foresights and, as visions of possible futures, might still guide new foresight exercises.

Millennium Ecosystem Assessment

The **Millennium Ecosystem Assessment** (Carpenter *et al*., 2005) explores four scenarios based on the combination of opposite directions along **two axes**:

- international cooperation and trade (**global vs regional**) and
- attitudes towards ecosystem management (**pro-active vs reactive**):

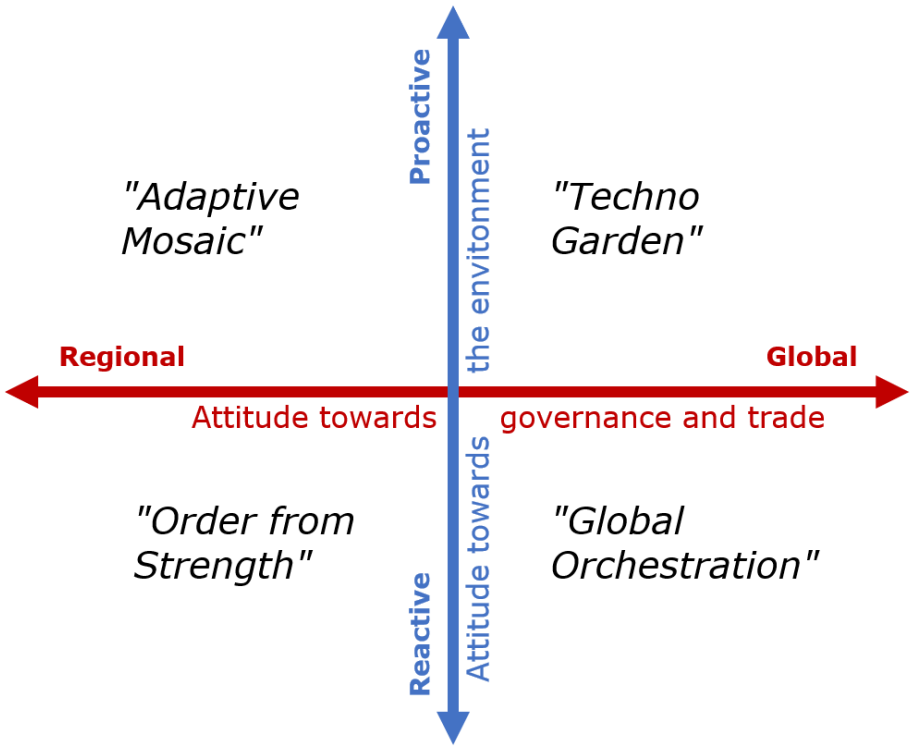


Figure 38 – The two dimensions leading to four main scenarios of the Millennium Ecosystem Assessment.

The MEA is partly qualitative (storytelling) and partly quantitative; a number of simulation models were applied to variables that lent themselves to numerical analysis.

[34] Mathijs E, Brunori G, Carus M, Griffon M, Last L, Gill M, Koljonen T, Lehoczky E, Olesen I, Potthast A. 2015. **Sustainable Agriculture, Forestry and Fisheries in the Bioeconomy – A Challenge for Europe**. SCAR, EC/RTD/F.3. Brussels

The two dimensions of MEA scenarios, namely the weight of global governance mechanisms in high level decision making and the dominant attitude towards the environment (including climate and natural resources) are recurrent features of several subsequent studies.

Future of Food and Farming

The **Future of Food and Farming**[35] is a foresight exercise carried out in 2011 by the UK Government to explore the possible evolution of food systems towards the year 2050, with nine billion or more people to feed.

The possible futures are analysed under the lens of **five global challenges** and various hypotheses on **population growth**, **income** and **climate** evolution. Scenarios, developed in part with quantitative models, consider pessimistic, neutral and optimistic outlooks on the future.

The five challenges are the following:

a) Balancing future demands and supply sustainably

b) Addressing the threat of future volatility in the food system

c) Ending hunger

d) Meeting the challenges of a low emissions world

e) Maintaining biodiversity and ecosystem services while feeding the world

While most of the above challenges are recurrent in several subsequent studies, the volatility issue is specific to the "Future of Food and Farming", likely due o the recent episodes of the food price spikes of 2007-2008.

Agrimonde

Agrimonde (Paillard S *et al*. (Eds.), 2014: produced by CIRAD and INRA) takes the "Global Orchestration" scenario of the MEA (see above) as a reference: "*a globally connected society that focuses on global trade and economic liberalization and takes a reactive approach to ecosystem problems but that also takes strong steps to reduce poverty and inequality and to invest in public goods such as infrastructure and education*". Different hypotheses are made according to population growth, change in food diets, climate change, demand in non-food products, incomes and their distribution, trust in international trade and environmental regulations. Sustainability implies radical changes in agricultural models and diets and a reduction of income inequalities.

Shared Socio-economic Pathways (SSP)

SSPs were developed (Riahia K *et al*., 2017) to provide a set of contrasting possible distant futures in the evolution of society (a century perspective) as a framework to analyse the conditions (demographic, environmental,

[35] Foresight. **The Future of Food and Farming**. 2011. Final Project Report. The Government Office for Science, London.

economic and social) leading to such conceptual descriptions. The SSPs were taken as reference in a number of scenario-based foresights to explore the effect of different societal choices on climate.

There is no a priori quantification of climate-related variables (e.g. GHG emissions) but only the relative weight of adaptation to and mitigation of climate change.

SSPs are based on a series of five "narratives": (see also Figure 39)

SSP1 Sustainability – Taking the Green Road (Low challenges to mitigation and adaptation)

The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity.

SSP2 Middle of the Road (Medium challenges to mitigation and adaptation)

The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations. Global and national institutions work toward but make slow progress in achieving sustainable development goals. Environmental systems experience degradation, although there are some improvements and overall the intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain.

SSP3 Regional Rivalry – A Rocky Road (High challenges to mitigation and adaptation)

A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Policies shift over time to become increasingly oriented toward national and regional security issues. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialized and high in developing countries. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions.

SSP4 Inequality – A Road Divided (Low challenges to mitigation, high challenges to adaptation)

Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries. Over time, a gap widens between an internationally-connected society that contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labour intensive, low-tech economy. Social cohesion degrades and conflict and unrest become increasingly common. Technology development is high in the high-tech economy and sectors. The globally connected energy sector diversifies, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources. Environmental policies focus on local issues around middle and high income areas.

SSP5 Fossil-fueled Development – Taking the Highway (High challenges to mitigation, low challenges to adaptation)

This world places increasing faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated. There are also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 21st century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary.

Various scenario studies then combined all or a subset of the SSP with Representative Concentration Pathways (RCP)[36], hypothetical developments of GHG emissions for climate modelling that extend to the year 2100.

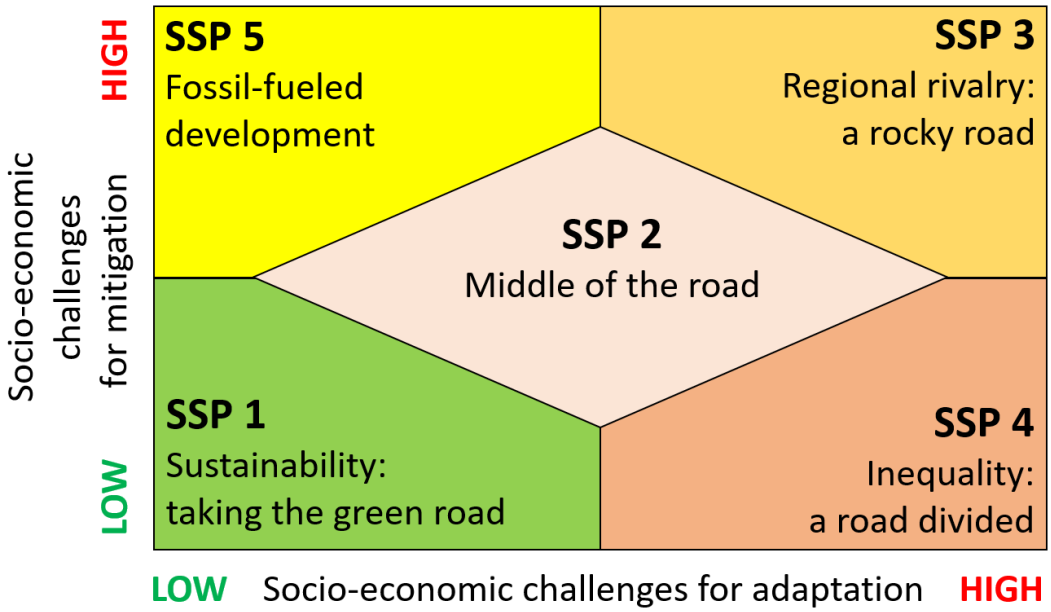


Figure 39 – Scenarios devised to analyse the consequences of climate change and the measures to mitigate or to adapt to it are being based on a group of five "Shared Socio-economic Pathways" (SSP)[37] that might develop if no explicit mitigation and/or adaptation policies are adopted.

World agriculture towards 2030/2050

Another well known and often cited pre-2015 scenario is the 2012 update of FAO's publication of 2006 by Alexandratos and Bruinsma (2012) "*World agriculture towards 2030/2050"*. It is a typical "projection" scenario based on the best predictions available on GDP (World Bank), demography (UN), agriculture (OECD/FAO) assuming different levels of change in crop

[36] Van Vuuren D, Edmonds J, Kainuma M, Riahi K, Thomson A, Hibbard K, Hurtt G, Kram T, Krey V, Lamarque J-F, Masui T, Meinshausen M, Nakicenovic N, Smith S, Rose S. 2011. **The representative concentration pathways: an overview**. Climatic Change. **109**, 5-31.

[37] Kriegler E, O'Neill BC, Hallegatte S, Kram T, Lempert R, Moss R, Wilbanks T. 2012. **The need for and use of socio-economic scenarios for climate change analysis: a new approach based on shared socio-economic pathways**. Global Environmental Change **22**, 807–822.

productivity, cropping intensity and land use. They derive the universally cited figures of a 60% agricultural production increase over the 2005-7 levels to satisfy world food demand in 2050.

International Assessment of Agricultural Knowledge, Science and Technology for Development

A different approach had been undertaken for the IAASTD, the International Assessment of Agricultural Knowledge, Science and Technology for Development[38], initiated by the World Bank and FAO; it came in a series of assessments developed in the previous couple of decades: the Global Biodiversity Assessment, the Ozone Assessment, the IPCC reports, the Millennium Ecosystem Assessment, the Comprehensive Assessment of Water Management in Agriculture and the Global Environment Outlook (GEO). IAASTD focuses on the role of AKST (Agricultural Knowledge, Science and Technology) to reduce hunger and poverty, improve rural livelihoods, and facilitate equitable, environmentally, socially and economically sustainable development.

Around a common baseline scenario, IAASTD develops a number of model-based projections based on different hypothetical variants of climate policies, trade policies, and investments in Research and Technological Development and in infrastructures.

Recent Foresights

We here focus on a series of recent Foresight studies (published since 2015) carried out with different methods and for different purposes. They are clustered in this analysis in two groups based on their scope. One group consists of scenarios that explore the evolution of societies in response to the main drivers of change; the second group is more focused on issues that directly or indirectly affect food systems.

Whereas the second group appears more closely related to the objectives of the fifth SCAR Foresight, the complexity of transitions towards a "safe and just operating space" requires a broad view, fully justified by the interconnections among the Sustainable Development Goals and between physical "planetary boundaries" and social systems.

OECD Science, Technology and Innovation Outlook 2016

The OECD STI Outlook of 2016 (OECD, 2016a) provides a list of megatrend areas that are taken as reference also in other Foresight exercises:

1. demography;
2. natural resources and energy;
3. climate change and environment;

[38] McIntyre B, Herren HR, Wakhungu J, Watson RT. 2009. **International assessment of agricultural knowledge, science and technology for development (IAASTD): global report**. Island Press, 606 pp.

4. globalisation;
5. the role of government;
6. economy, jobs and productivity;
7. society;
8. health, inequality and well-being.

As already remarked, we should however distinguish trends that are unlikely to change trajectories in the coming decades (unless some totally unforeseeable dramatic events take place) and trends that, however powerful, could display sudden changes of direction or uncertainties on their development. Of the eight areas of OECD (2016a), climate change and environment, demography and natural resources and energy belong to the first group; the rest to the second.

A characteristic of megatrends is a long lag time between causes and effects, an inertia that raises uncertainties about the right measures to take in order to push the trends on a desirable track and fuels honest as well as interested doubts on the appropriate policies.

BOHEMIA Report (New Horizons: Future Scenarios for Research & Innovation Policies in Europe)

The "BOHEMIA" foresight (Ricci *et al.*, 2017) develops scenarios as narratives around groups of SDGs under the influence of megatrends (Figure 40).

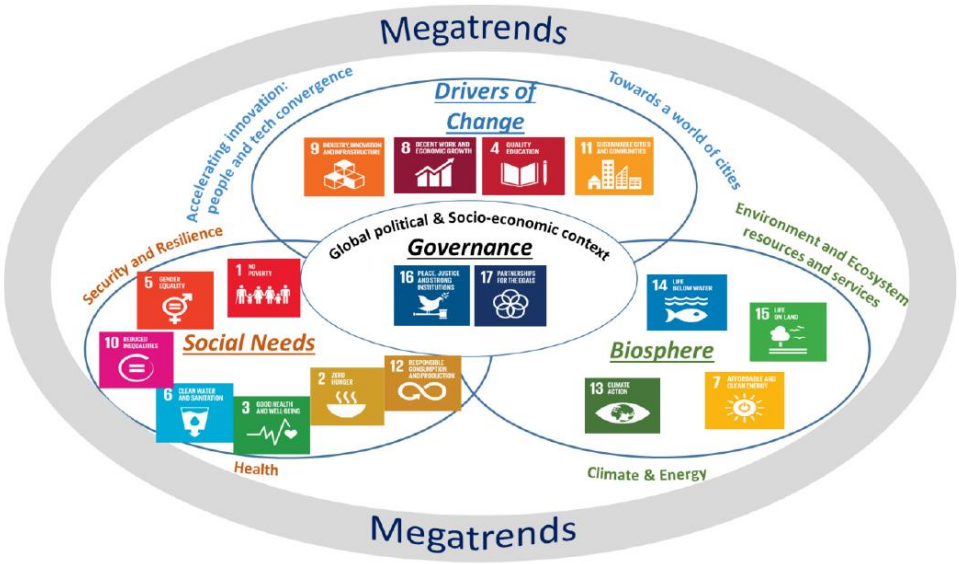


Figure 40 - The BOHEMIA scenarios' space and the SDGs (Ricci *et al.*, 2017)

Megatrends are drawn mainly from EEA (2017) and OECD (2016a), but "accelerated innovation" and "urbanization" are regarded as megatrends in their own right

Seven scenarios are grouped in four areas:

Governance

1. Global political and socio-economic context

Biosphere

2. Climate and Energy
3. Environment and ecosystems resources and services

Social needs

4. Health
5. Security and resilience

Accelerating innovation

6. People and tech-convergence
7. Towards a world of cities

Each of the seven scenarios are seen through a "pessimistic" and an "optimistic" lens. Actually, these definitions are rather imprecise, as the BOHEMIA report uses the terms "perseverance scenarios" for a future driven by megatrends without significant changes in the social and economic foundations of our society; and "change scenarios", that indeed move towards a "future we want" under a strong EU leadership.

A weak Europe or a global renunciation to achieve the SDGs or both conditions simultaneously determine the pessimistic "perseverance" view in which the future is largely determined by the unaltered development of the current megatrends.

The following table summarizes the conditions leading to positive and negative scenarios:

Table 14 - Conditions leading to negative ("perseverance" under the influence of current megatrends) and positive ("change") scenarios (Ricci *et al.*, 2017).

Perseverance scenarios	**Change scenarios**
International fragmentation; ineffective institutions and instruments of global governance	Effective supranational institutions; countries willing to partly renounce to sovereignty in exchange for global governance
Rising inequality within social groups at the national level	Policies directed at reducing inequalities; effective equality of opportunities
Protectionism; restrictions to trade	Liberalisation of exchanges
Sustained demographic growth in developing countries; ageing populations in developed countries; migrations; collapse of health and social security systems	Natality drops significantly in developing countries; immigration successfully managed; social cohesion
Digitalisation divides the workforce; structural unemployment	Digitalisation as an empowering revolution for all
Financialisation of economy; global economic powers and weak regulatory instruments (national or international)	
	Individual behaviours towards healthy lifestyles and responsible use of natural resources; circular economy
Disaffection vs politics and participation in the civil society	Public participation in decisions
Overexploitation of the commons	Stewardship for the commons

Fossil energy still too cheap to invest in renewables; persistent economic stagnation discourages climate friendly policies	Renewable energy cheap; development of convenient off-grid solutions; technological breakthroughs in energy storage
Inability to decouple growth from the consumption of resources; the myth of the GDP as a measure of development	
Short-termism, localism (out of sight, out of mind), tribalism	Strategic view; willingness to invest on the future; universalism
Paralysis; positive developments blocked by losers	
Price dominates (food, energy, water, land)	Values dominate
Cure (ultimate treatments for the rich)	Prevention (and cost/benefit analysis in health systems)
Search for scapegoats	Positive leadership
Negative public attitude towards science and innovation	Co-creation of innovation; informed acceptance of new technologies

The World in 2050

"The World in 2050" was developed by the International Institute for Applied Systems Analysis (IIASA) (TWI2050, 2018) to analyse the forces that either favour or hamper the achievement of the SDGs.

According to TWI2050 (2018) points at the weaknesses of a market based economy in making the achievements of social inclusion and environmental quality preservation as priorities. Markets are devised to attract economic value to capital investors, not at increasing or even protecting the common goods.

Politics should correct market failures in this area and impose, through the expression of the democratic will of citizens, essential transformations that the market is unable to produce if left on its own. These are the areas suggested by TWI2050 (2018):

1. Human capacity and demography;
2. Consumption and production;
3. Decarbonization and energy;
4. Food, biosphere and water;
5. Smart cities; and
6. Digital revolution.

Action in these areas would provide a perspective necessary for building societies and economies characterised by equity, inclusiveness, healthy environment, clean development. The will power and courage of Governments required to achieve these goals are not underestimated, as deep changes in cultures, societal values, economic and normative dynamics would be necessary.

Capable institutions, a lively and engaged civil society, research and innovation, investment in infrastructures, public-private alliances are all necessary ingredients.

Obstacles to transitions/transformations include (TWI2050, 2018):

1. Vested interests, specifically enterprises and individuals who are benefiting in the short-term from unsustainable practices;

2. Major wealth owners resistant to the taxation needed to fund public services and public investments;
3. Limited capacity of governments to plan and implement policies with time scales of decades (short political business cycle and lack of technical capacity);
4. Difficulty of a suitable balance in public-private partnerships
5. Lack of public understanding and a resistance to change

However, the perspectives are far from encouraging, as tendencies towards inward-looking populist and nationalistic policies and a progressive weakening of global governance mechanisms are driving in the opposite direction.

Shaping the Future of Global Food Systems

The World Economic Forum (with Deloitte Consulting LLP) produced a scenario analysis on the future of global food systems (WEF, 2017). Two dimensions have been considered as the main "space" for future development of food systems: the first one regards the attitude towards resources: either intensive (somehow a BaU hypothesis) or efficient; the second one relates to the degree of connectivity (as opposed to fragmentation) of states, markets, economies, cultures. This description of the "playing field is remarkably similar to that proposed by Duckworth *et al*. Ed.s (2016) (see page 87).

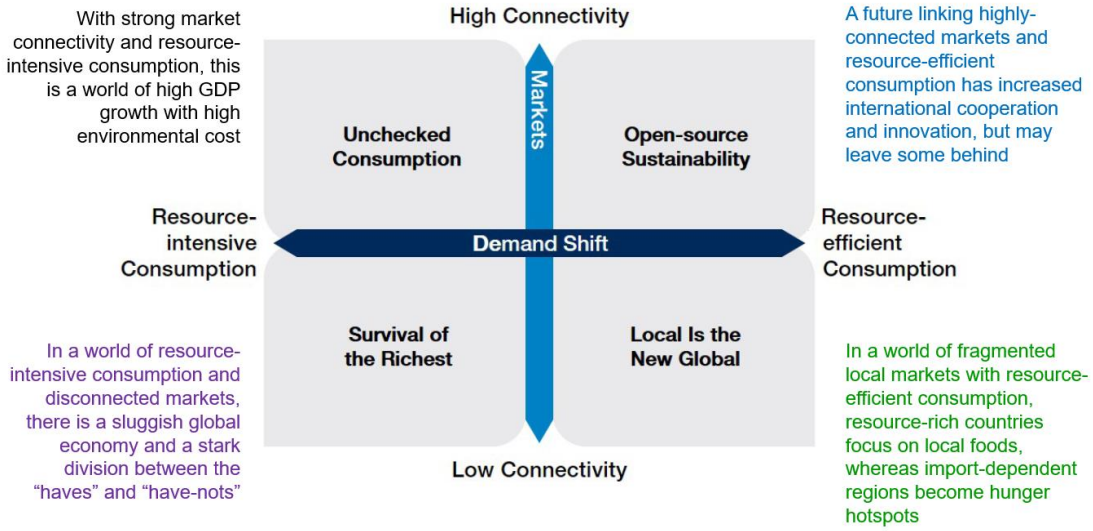


Figure 42 –Scenarios of the World Economic Forum (with Deloitte Consulting LLP) produced a scenario analysis on the future of global food systems (WEF, 2017)

The main insights of WEF (2017) are:

a) Consumption will make or break global health and sustainability.
b) Putting nutritious and sustainable food on every plate requires a fundamental redesign of food production systems.
c) Climate change will affect all future scenarios and poses a significant threat. Food system dynamics are likely to exacerbate inequality within and between nations.

d) Industry 4.0 technologies and other innovations can revolutionize food systems but will introduce new challenges.

WEF (2017) also lists a number of opportunities for the development of food systems:

a) A new era of business could capture market opportunities

b) New and bold "smart policies" are needed to redesign food systems

c) **Social and ecological priorities** should be at the centre of redesigned food systems.

Towards the 3rd Strategic Programme of Horizon 2020

The "Strategic Foresight: Towards the 3rd Strategic Programme of Horizon 2020" (Duckworth M *et al*. Ed.s., 2016) was produced under the leadership of SAMI Consulting for the EC as input to the 2018-2020 H2020 programming period. It combines 4 **perspectives** by 2 drivers by 2 *factors* (alternative directions) into 15 scenarios (instead of 16: one did not make sense):

Innovation and competitiveness

Energy: *abundant and environmentally benign vs expensive and polluting*

Values: *economic values vs new sources of value*

Sustainability

Economic growth model: *linear material vs circular ecological*

Governance cultures: *elitist/exclusive vs participative/inclusive*

Social change and societal challenges

Data ownership: *private vs open*

Values: *consumerist/materialistic vs non-materialistic*

Radical opportunity spaces

Global governance: *effective global governance vs fragmented world*

Individual attitudes: *engaged vs opting-out*

Out of these combinations (Duckworth M *et al*. Ed.s., 2016) derive four contrasting scenarios, as described in Figure 42.

Figure 42 – Four contrasting scenarios of the "Strategic Foresight: Towards the 3rd Strategic Programme of Horizon 2020" (Duckworth M *et al*. Ed.s., 2016)

The Knowledge Future: Intelligent policy choices for Europe 2050

The document (Hudson *et al.*, 2015) is the outcome of a Foresight exercise carried out by a panel of experts with diverse expertise in order to advise on fundamental policy orientation in the area of knowledge management and exploitation, with Europe in 2050 as a target.

Two scenarios for Europe in 2050 and for its position in the global context are proposed, one positive and one negative. The chances of either to become reality depend much on the way Europe and its Member States react to the megatrends that are driving change: **globalisation, demography and technological progress**.

Globalisation boosts development but at the risk of depletion of resources, environmental destruction, fierce competition and the risk of rising inequalities between and within states. The areas in which globalisation will be most readily realised are finance and trade, with multinationals in a position to navigate across States towards the most favourable business zones. However, globalisation might trigger the reactions of States responding with nationalistic policies, barriers to the free movements of goods and people, fragmentation.

Demographic changes are multi-faceted: the mere increase in world population, accompanied by a steady and ageing European population will put pressures on welfare systems while encouraging immigration. Urbanisation may give rise to vibrant poles of innovation due to the concentration of people, wealth, knowledge, business opportunities; but also the risk of creating unmanageable agglomerations where food and water provision, sanitation, basic services become scarce and degrade any existing social fabric is real.

New technologies (3- 4-D printing, Artificial Intelligence, augmented reality, nanotechnologies, genome manipulation, robotics) provide opportunities if their introduction will keep pace with the evolution of society and contributes to the development of socially responsible businesses but imply threats of unemployment or underemployment also for the educated ones if their introduction will outpace the adaptation potential of people. Unemployment and rising inequalities would trigger discomfort, loss of hope, anger and social tensions (city vs rural, employed vs unemployed, natives vs immigrants) in a downward spiral.

The **favourable scenario**, called ***"A European success"***, depicts a Europe where social tensions were relaxed by a widespread positive fallout of technological advances. The situation is the result of a renewed confidence on the European ideals and institutions and a stronger cooperation among Member States on education, regional development and fiscal policies (especially towards multinationals). The driving forces are openness (especially in the exchange of knowledge and in pushing for innovative solutions), the leadership of cities in the development of eco-smart solutions, a broader participation of citizens (citizens' science, crowd-funding, crowd-sourcing) and an inclusive attitude towards usually neglected segments of society, namely the elder and the immigrants that are viewed as a resource rather than a burden or a threat. The scenario includes a more responsible attitude of business, that would include social responsibility as a priority and a clear distinction between private and public goods; competition may be mitigated by cooperation

The **negative scenario** is characterised by a reversal of all these conditions. Rich Regions in Europe increase their distance from Regions that move forward at a slower pace or are moving backward, being unable to fight successfully in the global economy. Multinationals exploit fragmentation to skew attempts at imposing taxes on their business. Some European companies stay afloat in the global market but the majority are unable to compete with competitors from emerging economies. Knowledge generated by public Institutions is appropriated by the industry and the very priorities of public research are either directly or indirectly set by private interests; dwindling public resources for research and education put public institutions under the thumb of private funds targeted at private goals. Economic imbalances and inward-looking policies invigorate a widespread sentiment that blames European Institutions and the very concept of a European Union for any negative situation; a growing nationalism characterises the political debate and fundamental European values, such as individual freedom, equality, openness, social security lose credit.

The recipe of (Hudson *et al.*, 2015) for achieving the positive scenario is "Openness", "Experimentation and Flexibility" and "European-level Cooperation".

Openness is a pervasive concept, involving citizens participation, removing barriers to entrance for new enterprises, circulation of knowledge (also between businesses), data management and ownership, a rethinking of intellectual property protection, shared infrastructures.

Experimentation and flexibility involve the relationships between universities and industry, social models and lifestyles, rethinking development (wellbeing vs wealth).

European-level cooperation depends on the conviction that Europe is the space where big challenges (economic, social, scientific) are best tackled. In science that means focusing on ambitious goals that can be reached only by pooling intellectual and material resources but will benefit humanity. This concept anticipates, somehow, the "mission oriented" research advocated by Mariana Mazzucato beginning of 2018 (Mazzucato, 2018).

What the future will look like thus seems to depend less on technology, demography and institutions and more on how these will be considered by volatile public opinions. Public opinion decides on the acceptance or rejection of technologies, on inclusion vs segregation of segments of society, on the future of a shared governance of fundamental social and economic issues. The risk of technological advancements that destroy more jobs than can be created is considered real; long-term unemployment or underemployment could create the preconditions for a disintegration of the social fabric and push Europe on the road towards the negative scenario.

Technological evolution is also a source of concern for possible misuse by accident or criminal design. Advances in synthetic biology might lead to artificially created or modified disease strains with consequent risk of pandemics. Quantum computing is likely to provide instruments to crack most of the current encrypting techniques on which the protection of private data and financial transactions are based. Artificial intelligence could be used to selectively target individuals with biased or totally false information with a view to affecting political choices and therefore disrupting democratic systems. Technologies (already controversial and not yet in use) for induced cooling of the atmosphere, officially aimed at mitigating climate change, could be used to maliciously alter weather patterns (Collins *et al.*, 2019).

Inequality (World Inequality Report 2018)

Inequality was identified by several Foresight studies as a challenge, as a driver in the evolution of economic systems and a risk to social cohesion.. According to **WEF**'s **Global Risks Report 2019,** "*Rising income and wealth disparity" ranked fourth in GRPS respondents' list of underlying trends. Although global inequality has dipped this millennium, within-country inequality has continued to rise*" (Collins *et al.*, 2019)

The **World Inequality Report 2018** (Alvaredo *et al.*, 2018) shows that whereas between-countries inequality has been reduced in the last decades[39], thanks mainly to the faster development of some emerging economies with respect t the rest of the world, within-country inequality is rising everywhere, although with different rates across the world.

[39] With remarkable exceptions, however; several sub-Saharan African countries and South-American countries falling behind and increasing their distance from the rest of the world (Alvaredo *et al.*, 2018)

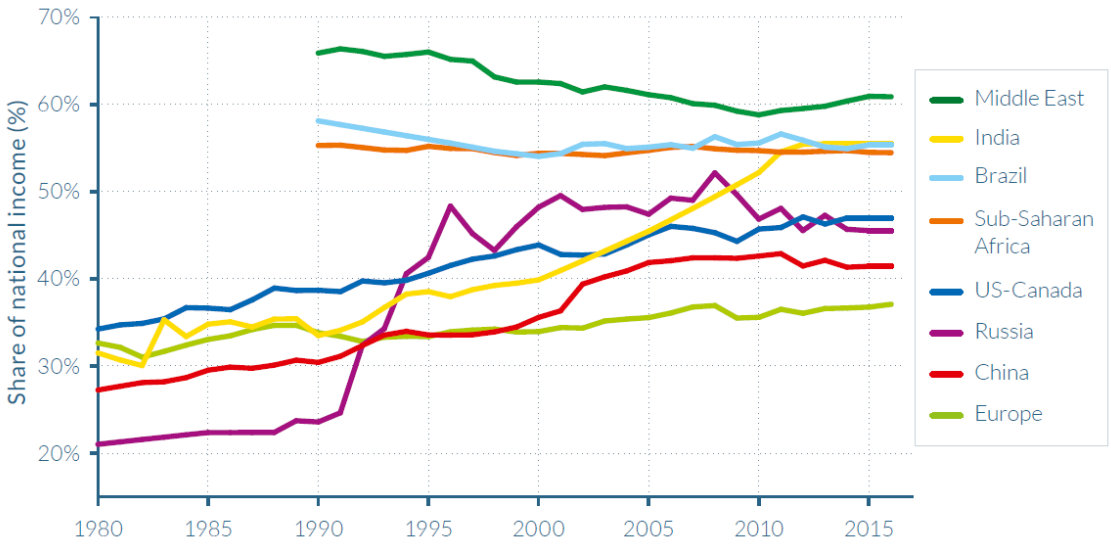


Figure 43 - Top 10% income shares across the world, 1980–2016
(From: Alvaredo *et al.*, 2018)

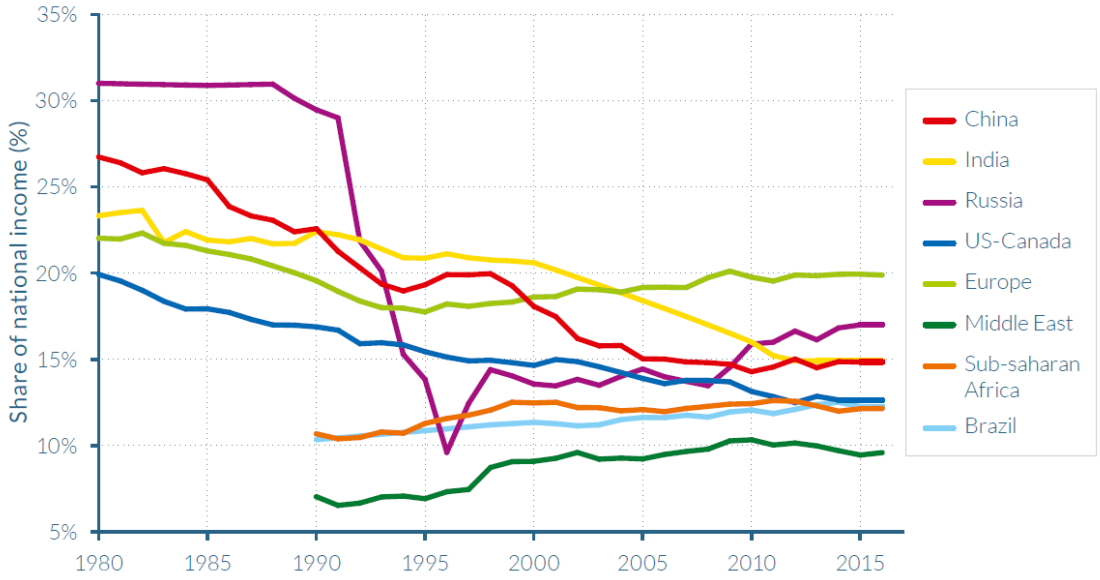


Figure 44 - Bottom 50% income shares across the world, 1980–2016
(From: Alvaredo *et al.*, 2018)

The share of global wealth increases, however, was highest at the bottom and at the very top of income distributions, with limited increases for the middle classes (the mid 40%), originating what was called the "elephant curve" of income.

The World Inequality Report 2018 (Alvaredo *et al.*, 2018) produced three scenarios for global inequality towards 2050 (see Figure 45): the first assumes that every country follows the current trend of income distribution of the US; the second that every country follows its own current trend; and the third that all countries follow the current trend of Europe that remains, at present, the most egalitarian region of the world.

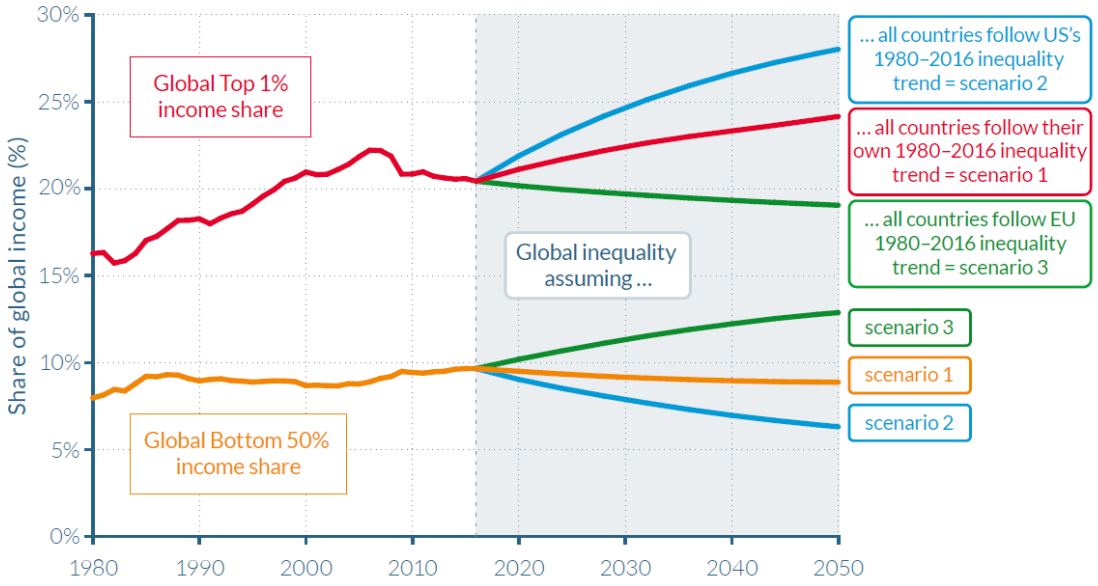


Figure 45 - Three scenarios for future global inequality (From: Alvaredo *et al.*, 2018).

The average income of the bottom 50% of the world population is expected to increase, by 2050, in all the above scenarios, but by less than 50% under scenario 1 and by almost 300% under scenario 3 (Figure 46).

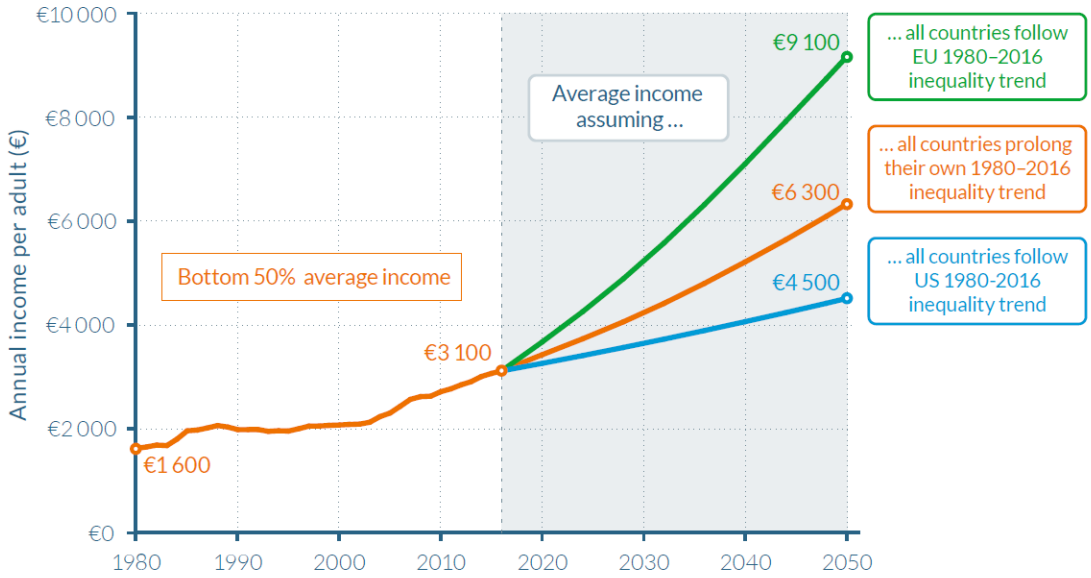


Figure 46 - Trajectories of bottom 50% average income towards 2050, under three scenarios of future global inequality (From: Alvaredo *et al.*, 2018).

Inequality is not only a matter of uneven distribution of economic wealth but also of appropriation of natural resources, emissions of GHG, etc. The wealthiest of the world are the strongest contributors to the degradation of the environment and to climate change due to their lavish lifestyles; the poorest do not enjoy the benefit their share of resources and are the most likely to suffer from the consequences of a deteriorating environment (Steffen *et al.*, 2015a).

Agrimonde-Terra

Agrimonde-Terra (Le Mouël *et al.* Ed., 2018) builds a set of five scenarios with a 2050 perspective by combining three classes of "drivers" …

- Global context
- Climate change
- Diets

… and four classes of "uncertainties" …

- Urban-rural relationships
- Farm types and sizes
- Livestock systems
- Cropping systems

… each coming with a set of alternative assumptions. The whole list of drivers and uncertainties and their assumptions are reported in Figure 47.

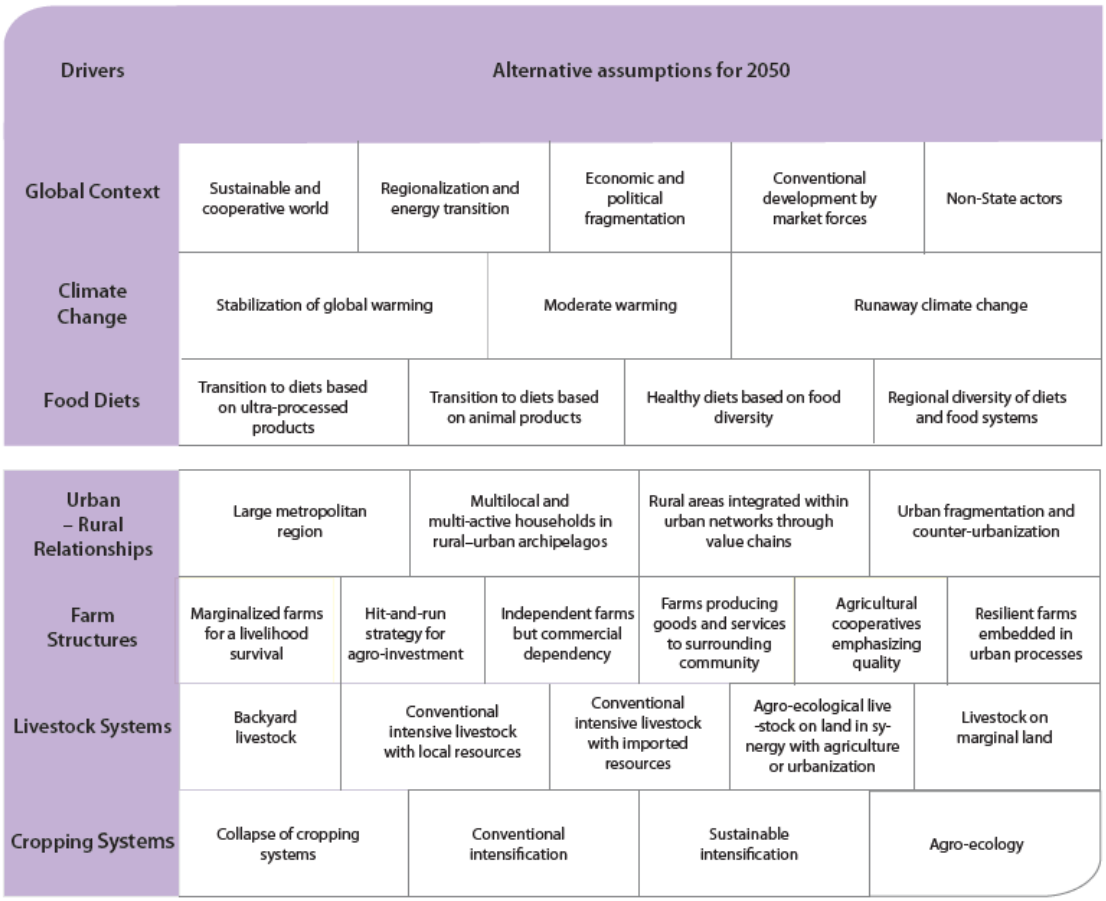


Figure 47 - Drivers and uncertainties and alternative assumptions according to Agrimonde Terra (From Le Mouël *et al.* Ed., 2018)

Each scenario starts from a different "Global context" assumption and combines compatible assumptions of the other drivers and uncertainties to produce "plausible"[40] pictures for the year 2050.

[40] Mora O. 2106. **Agrimonde-Terra foresight: Land use and food security in 2050. Scenarios of land use and food security in 2050.** Working Paper. INRA, DEPE, Paris)

1. **"Land use driven by metropolization"** links the development of megacities at global level with a nutrition transition led by global agri-food companies selling ultra-processed foods, in a global context of development through market forces and rapid climate change, leading to the marginalizing small farmers.
2. **"Land use for regional food systems"** relates the increase of medium-size cities and their networking with rural areas to the emergence of regional food systems based on family farming and traditional foods, and a set of regional agreements.
3. **"Land use for multi-active and mobile households"** links strong individual mobility between rural and urban areas and a development of non-farm employment to the emergence of hybrid diets based on traditional and modern value chains, in a globalized world where family farms and cooperatives are major actors in land use.
4. **"Land use for food quality and healthy nutrition"** assumes that due to the increasing cost of malnutrition, a radical move towards healthy diets occurs fuelled by global cooperation and public policies in a context of climate change stabilization, implying a re-configuration of agricultural system backed by new alliances between stakeholders.
5. **"Land as commons for rural communities in a fragmented world"** assumes that in a context of repeated multiple crises, development based on small towns and rural communities occurs focusing on managing common property in agriculture in order to ensure food security.

The first three scenarios are considered a possible extrapolation of trends already occurring in different parts of the world. The fourth and fifth scenarios represent possible deviations from the present landscape stemming from two contrasting global contexts: a cooperative world with health and sustainability as priorities (Scenario 4) and an ultra-fragmented world based on local communities (Scenario 5). Agroecology and sustainable intensification are components of all scenarios (only Agroecology in Scenario 5), except Scenario 1.

Scenario 1, in which the evolution of food systems is driven by urbanisation is a Business as Usual scenario, assuming trends in diets (increasing ultra-processed food and animal source products), industrialisation of agriculture and livestock systems, etc. to continue. The scenario leads to a collapse of agricultural systems (for climatic, environmental or social reasons) or, at best, to an exacerbation of present problems (pollution, loss of biodiversity, rural zone marginalisation)

Scenario 5 (stemming from a fragmented world) proposes two alternatives: community based agroecological systems or a collapse of cropping systems in a new enactment of the "tragedy of the commons" where a balanced management of community lands fails to develop.

Almost all scenarios foresee an increase in agricultural land and a diminishment of forest land, especially so where animal productions are expected to increase or when the "tragedy of the commons" pushes farmers to expand agricultural and pasture lands to compensate for diminished productivity.

Most scenarios indicate that significant parts of the world (e.g. MENA, India) would become more dependent on food imports than they are at present and exposed to food price fluctuations and other trade disruption factors.

The conclusion of Agrimonde-Terra is that **only Scenario 4** (Land use for food quality and healthy nutrition) is **likely to succeed in feeding the world sustainably by the year 2050**. It is worth recalling that this scenario

assumes a cooperative world, success in containing temperature increase within 1°C (that is, 0,5°C less than the most optimistic COP 21 target), healthy diets and a limitation of livestock (agroecological management of stocks and use of marginal lands), conditions that represent a significant break from current trends and imply drastic transformations of the food systems.

The Global Land Outlook

United Nations Convention to Combat Desertification published the first edition of the Global Land Outlook in 2017 (UNCCD, 2017).

The report explores three of the five Shared Socio-economic Pathways (see page 81) up to the year 2050 plus a variant of the middle scenario (SSP 2) under the additional hypothesis of a decline in productivity. It draws from a study (Van der Esch *et al.*, 2017) that was carried out by the Dutch research institution PBL (*Planbureau voor de Leefomgeving* = Environmental Assessment Agency).

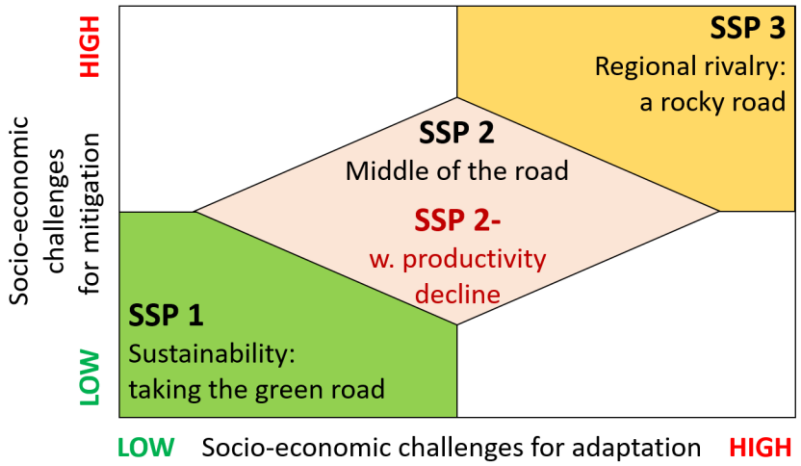


Figure 48 - The three (plus one variant) scenarios of the Global Land Outlook (UNCCD, 2017)

Table 15 - Assumptions embedded in the three Global Land Outlook (UNCCD, 2017) SSP scenarios.

	SSP 1 Sustainability	**SSP 2 Middle of the Road**	**SSP 3 Fragmentation**
Globalization of trade	High	Medium	Low
Meat consumption	Low	Medium	High
Land-use change regulation	Strict	Moderate	Little
Crop yield improvement	High	Medium	Low
Livestock system efficiency	High	Medium	Low

It is interesting to note that under the "rosy" SSP 1 scenario (development within environmental boundaries, low population increase, emphasis shifting from growth to human well-being, reduced inequality) the average per person GDP would be twice as high as in the SSP 3 scenario (political fragmentation, resurgent nationalism, declining investments in education and technology, high population increase in developing countries, environmental degradation). SSP 2 (the Middle of the road scenario) is halfway in between.

The three scenarios show a clear advantage of undertaking a sustainability pathway also from the individual affluence point of view. The situation is similar for land use change: more areas converted to crop and pastures under SSP 3; stable or declining under SSP1. SSP 2 again in the middle (Figure 49).

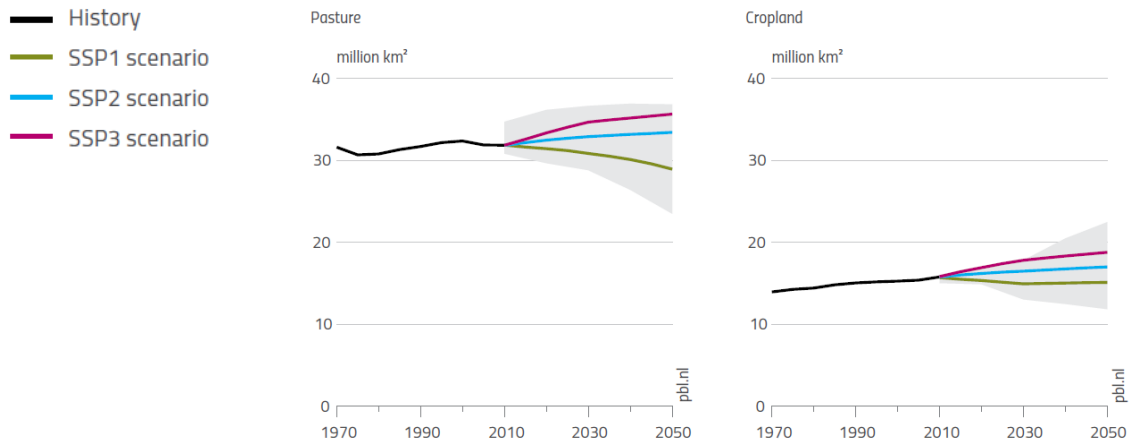


Figure 49 – Evolution of land surface dedicated to crops and pastures under the three main SSPs of the Global Land Outlook (UNCCD, 2017)

The increase in food production, however, would be less than proportional to the increase of agricultural land because the best land is already in use and expansion would take place on less productive or degraded soils.

Coming to regional differences, all SSP scenarios predict and increase of land dedicated to agriculture in the tropics where the risk of organic matter loss, erosion and degradation is very high. Organic matter and nutrients are mainly stored in living plants and in rapidly decomposing matter rather than in soils; once the vegetation is cleared, fertility vanishes and replacement with synthetic fertilisers rather ineffective and/or cause of pollution due to low absorption capacity.

Climate change will also impose a further burden to agricultural production, with Sub-Saharan Africa the most hardly hit (-20%); in most other areas of the world the decline would be between 5 and 10%. An expansion of cropland to compensate for the loss of productivity is to be expected.

Under all scenarios, Sub-Saharan Africa would see the most remarkable changes of land use; as the most fertile lands are already cultivated, crop

production will expand on less fertile soil with a consequent reduction in productivity.

In other regions (this is the case of South Asia) there is little room for agricultural expansion, as most of the land is already used.

The Future of the Food Economy (ScMI AG, 2017)

The Future of the Food Economy (Die Zukunft der Ernährungswirtschaft. Wie essen wir 2030?: is particularly interesting in that it captures the point of view of the Food Industry. It is a Foresight study carried out for the Bavarian Food Cluster (Cluster Ernährung am Kompetenzzentrum für Ernährung) to explore possible scenarios in which the food industry would operate in a relatively near future. The target year is 2030.

Scenarios are positioned on a two-way chart (Figure 50) according to two core questions:

1. How much will politics interfere with the food environment? Regulations in agriculture, environment, food safety and trade are considered.
2. What is the degree of innovation in the food economy? Innovation is primarily digitisation, but also the development of novel foods and personalised nutrition.

   In a strongly regulated environment two more questions are raised:

3. How much will the free trade and digitisation shape the food economy?
4. What will be the importance of values, regionality and quality in the food economy?

   The driving forces of innovation are the object of two more questions:

5. To what extent will the consumers drive innovation?
6. To what extent can the food companies push innovation?

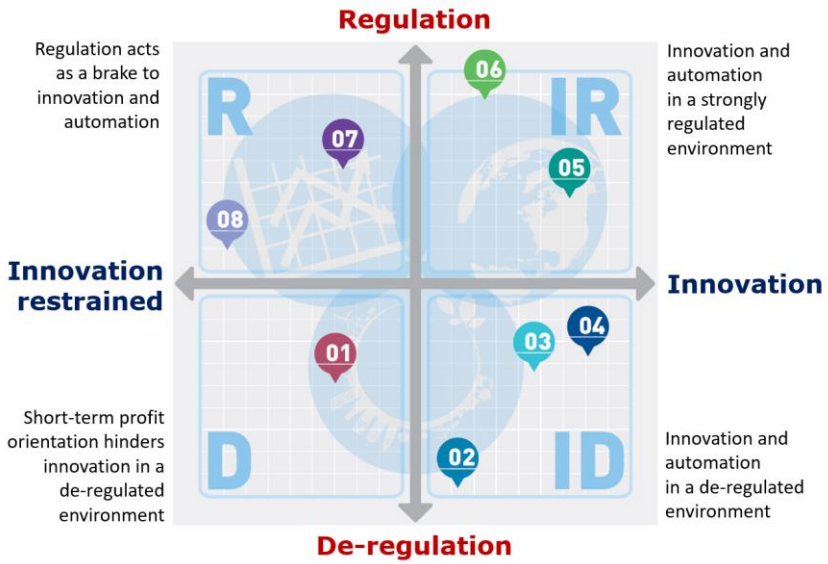


Figure 50 - "The map for the future". Eight scenarios for the German (Bavarian) food industry in 2030 (from ScMI AG, 2017: picture at page 7, modified).

Different combinations of the six questions give origin to eight scenarios:

1. Efficiency scenario

Short-term profit promotes global standardisation; long-term innovation is discouraged. "Milking the cash-cow" becomes imperative.

2. Disruption scenario

Global industry innovations for food and nutrition. Artificial food widely established. Rationality before emotions among consumers.

3. Digitization scenario

Global transformation in the markets leads to a broader choice. Global food companies continue to introduce "innovations" into the market. Consumers are open to novelties, including personalised nutrition

4. Export Scenario

Regional innovation champions (often SMEs) make good use of their flexibility and often stand in the global market against big companies in a networked world.

5. Global & Fair Scenario

Global flows of goods behind regional and valuable products. The consumer moves towards a world in which regionality and values are important, but that is anyway driven by global logistics

6. Regional diversity scenario

Rediscovery of traditional values and foods leads to new choices, against globalization. The demands of value-conscious consumers push a regionalized offer

7. Renunciation scenario

Critical consumers push for direct marketing and self-sufficiency. Variety of choices and global innovations lose importance. Consumer refusal leads to simplification. Strong moral reasons.

8. Supply scenario

Security of supply becomes the central theme (due to conflicts and protectionism disrupting trade). Experience and values lose importance.

Alternative Futures for Global Food and Agriculture

The OECD published a scenario analysis of possible agriculture futures in 2016: Alternative Futures for Global Food and Agriculture (OECD, 2016b), although based on two expert workshops of 2013 and 2014.

Key current **trends and uncertainties** that are likely to affect future options are:

a) a growing demand for food (meat *in primis* but also fruit and vegetables) due to the improving wealth of emerging economies;

b) dwindling natural resources: water, land, biodiversity;

c) the effects of climate change on agricultural productivity.

Other resources are taken into consideration, albeit mainly from an "availability" and "affordability" point of view, rather than in a perspective of environmental protection, namely fertilisers and fossil energy.

The **"soft" dimensions** that will shape the future, given the current trends, are:

a) scope and depth of international cooperation; the weight of multilateralism and global governance vs bilateral relationships and ad hoc agreements;

b) the diffusion of technological innovation; will the technological divide between the rich and the poor countries get wider and deeper or will it be somehow closed;

c) the feelings about sustainability within and across societies; will individual awareness of the value of public goods grow or recede into individualism and short-term opportunism?

The interaction of trends and uncertainties with the "soft" dimensions produced three scenarios that combine the degree of international policy concertation with the level of societal concern for the environment (see Figure 51).

Figure 51 - Three global scenarios of the OECD (2016b) study "Alternative Futures for Global Food and Agriculture". Quite interestingly, a scenario of increasing international concertation on climate- and environment-friendly policies is not envisaged.

The **first scenario** is more or less a "business-as-usual" one, with no effort to replace fossil energy and a high input agricultural model; increasing food

production is made possible by production systems that further deteriorate natural resources and climate. It is clearly a short-sighted perspective.

In the **second scenario** concern for the environment derives from a grassroots movement, from consumers and citizens, rather than by politics. Agricultural production may be under stress by the need to observe strict standards; food prices may consequently increase. Quite curiously, it is estimated that average temperature increase will be limited to 2-3°C (anyway higher than the COP 21 less optimistic target of +2°C) but that the change will be beneficial to agricultural productivity in the North (plausible) but compatible with adequate production also at southern latitudes (not as plausible).

The global orchestration envisaged in the **third scenario** is entirely dominated by the economic interests; trade is free, big international corporations dominate the markets and exert a powerful action on governments to their advantage. The big global problems (energy, climate, genetic resources, are addressed with technology, rather than with changes of social and economic models and of lifestyles. The strong reliance on technology increases the divide between developed and developing economies. Inequality grows.

BioEconomy 2030

"Drivers of the European Bioeconomy in Transition. (BioEconomy2030) - an exploratory, model-based assessment" (Philippidis *et al.*, 2016) is a modelling study carried out by JRC-Sevilla that delineates three possible scenarios in which the Bioeconomy might develop in the coming years and analyses the expected evolution with regard to growth, employment, energy market, land value, food prices, etc.

The "Reference Scenario" (RS) is a typical Business as Usual scenario, mainly consisting of the present CAP structure and the current mandatory blending levels of fuels.

RS is compared with two contrasting scenarios: one of increased EU engagement and leadership in climate friendly policies, including a revised, greener CAP, and sustained effort towards the substitution of fossil feedstock with biomass in the production of plastics, lubricants and other chemicals; this scenario is called "Outward Looking" (OL), as it implies an assumption of responsibilities towards the solution of global problems.

On the other front, an "Inward Looking" (IL) scenario envisages an abandonment of current efforts towards biofuels and a return to basically fossil feedstock both for energy and for the materials industry. In this vision it is the market that determines fundamental policy choices.

In the RS, the fuel blending mandate creates unfavourable conditions for the other industrial biobased sectors due to competition for biomass that pushes feedstock prices up and make the traditional fossil based sectors more competitive. There is also a negative repercussion on EU agricultural output.

The IL scenario, negative in terms of environmental friendliness, is positive in merely economic terms, with growth and incomes rising; the opposite is true for the OL scenario. The main cause of growth in IL is the repeal of the

mandatory blending, making the cost of energy decline. The effect of IL policies would restrict the economic perspectives of the bioenergy sector; however, this would trigger a reduction of biomass productions that would reflect negatively also on the biomaterials industry. As a result, employment would shrink both in the bioenergy and in the biomaterials industries.

Agriculture itself would be negatively affected by an OL policy as a revised, greener CAP would impose new environmental compliance burdens on production.

Quite interestingly, land devoted to biofuels would decrease both under IL (which is obvious) and under OL because, despite higher blending commitments, reduced demands of fuels caused by more ambitious GHG reduction policies would reduce demand of blended fues anyway.

A decrease in both scenarios (IL and OL) is also expected in aricultural production and food production with respect to RS, higher for OL than IL, although with limited effect on prices and on farmers' incomes. Farmers, however, would be better off under IL than OL.

The **perspectives of the Bioeconomy**, and in particular of the bioindustry, **do not appear as bright as a climate and environment concerned policy would deserve**. A strong political will, possibly shared globally, would increase its chances of success.

Delivering on EU Food safety and Nutrition in 2050

"Delivering on EU Food safety and Nutrition in 2050" is a scoping study carried out for DG SANCO by the Food Chain Evaluation Consortium (FCEC, 2013) in order to identify the main challenges that the European food system is likely to face in the coming decades in the area of food safety and nutrition, their likely impacts and the actions necessary to stick to the current high standards. The study is mainly based on the consultation of a broad panel of experts and stakeholders, extensive literature review and expert interviews.

One of the main aspects that makes this report particularly interesting is the comprehensive list of drivers of change identified and the related trends and uncertainties (Table 16).

Table 16 – Main drivers of change affecting food safety and nutrition in a 2050 perspective (from: FCEC, 2013)

Main driver	Trends and uncertainties identified
Global economy and trade	Globalisation of trade in food and feed Increasing number of countries covered by free trade agreements Emerging economies exporting more high added-value products & engaging in standard-setting Global economic development Increasing and more volatile food prices Increasing pressure on public finances from financial and expenditure on health and pensions
Global cooperation and standard setting	Increasing cooperation in setting standards for safe food Increasing cooperation in international fora, information and early warning systems Increased relevance of private food standards

	Increased reliance upon multilateral structures, challenges from increasingly multipolar world
EU governance	Further EU enlargement, potentially coupled with further market integration Continuing reform of the Common Agricultural Policy (CAP) Continued consolidation of the food safety and nutrition legislative framework Continuing challenge of ensuring enforcement Rise in importance of communication concerning food safety and nutrition
Demography and social cohesion	Increasing global population Aging, more chronic illness-prone EU population Increasing migration flows Increasing inequality
Consumer attitudes and behaviour	Increasing global demand for meat Diversification and polarisation of diets and lifestyles Increasing prevalence of obesity Intensifying consumer values in relation to food Increasing concern about risks related to food safety and food chain inputs Stagnating levels of trust in public authorities in the EU
New food chain technologies	Expected increase in the use of biotechnology and GMOs Increase in productivity from other primary production technologies (e.g. aquaculture) Expected increase in the use of nanotechnology Increased medicalisation of food and new forms of food Increased use of information and communication technologies (ICTs) New processing and packaging technologies
Competition for key resources	Increasing demand for non-renewable energy sources Increasing scarcity of fertile soils Increasing pressure on fresh water resources Increasing scarcity of phosphorus for fertilisation Diminishing biodiversity, genetic diversity, and ecosystem services Increasing difficulty in supplying animal proteins sustainably
Climate change	Rising temperatures Changing precipitation patterns Changing agricultural productivity according to species and regions Emerging biological threats Increasing 'environmental migration'
Emerging food chain risks and disasters	Increasing risk of disease transmission from animals to humans Environmental pollution and contaminants spreading through the food chain Unintended consequences of food chain technologies Wider possibilities for bioterrorism and sabotage Continuing risk of neglect and failure of food safety mechanisms
New agri-food chain structures	Industrialisation of agriculture, from small-scale and subsistence farming to large agri-businesses Increasing concentration and integration of food chain industries to achieve economies of scale Reduction in the agricultural labour force Increase in organic farming Increasing importance of regional, local and alternative food chains Pressure for increased recycling and less waste all along the food chain

Based on the trends and uncertainties identified for each main driver, one plausible scenario per driver was described in a series of narratives; for each scenario, the main related challenges were listed (Table 17).

Table 17 – Main drivers of change affecting food safety and nutrition in a 2050 perspective (from: FCEC, 2013)

Main driver	Scenario	Related challenges
Global economy and trade & New agri-food chain structures	**Scenario 1** – Rapid surge in global trade in food and feed, with highly concentrated agri-food industries	Ensuring food safety and nutrition in the highly globalised and complex food supply chains of 2050
Global cooperation and standards	**Scenario 2** – Break-down of global cooperation in a multipolar world	Ensuring food safety and nutrition in a multipolar world in 2050, and with highly fragmented and geographically dispersed food chains
EU governance	**Scenario 3** – Long-term austerity and a shift to private food safety controls in the EU	Ensuring food safety and nutrition in an environment of tight budgetary restrictions
Demography and social cohesion	**Scenario 4** – Severe inequality linked to food insecurity of vulnerable consumers and polarised diets	Safeguarding the food security of vulnerable consumer groups and addressing lifestyle-related problems affecting the health of large parts of the EU population
Consumer attitudes and behaviour	**Scenario 5** – Strong shift in EU consumer preferences to food from alternative production systems	Ensuring food safety in EU food systems dominated by alternative food chains in 2050
New food chain technologies	**Scenario 6** – Widespread consumption of high-tech functional foods	Ensuring high levels of food safety and nutrition for consumers of functional foods in 2050
Competition for key resources	**Scenario 7** – Global resource depletion	Safeguarding food safety and nutrition when high quality resources are scarce
Climate change	**Scenario 8** – Global disruptions of agriculture from climate change	Safeguarding food safety and nutrition under disruptive climatic conditions, affecting primary production, storage and transport of food in 2050
Emerging food chain risks and disasters	**Scenario 9** – Breakdown in consumer trust in food following the emergence of food chain risks	Ensuring veterinary health and food safety under these circumstances, effectively communicating to the public in a situation of panic, and addressing a resulting loss in consumer trust in complex food chains

The report includes a detailed list of recommendations on desirable food policies and of research areas to support them. Here the main recommendations are reported.

1. Cross-cutting policy measures are vital for the future of EU food safety and nutrition.

2. The area of food safety and the area of nutrition need distinct, separate approaches.
3. Policy measures and research programmes and projects to address both consumer and producer behaviour jointly are needed, particularly education and communication.
4. Conducting and encouraging scientific research and innovation directed towards safer foods and healthier diets are key measures for dealing with the challenges under the different scenarios.
5. International food chain governance should be consistently advanced.
6. Promoting diversity in the food system is critical to increase resilience to future shocks or disruptions.
7. Conducting and encouraging scientific research and innovation directed towards safer foods and healthier diets are key measures for dealing with the challenges under the different scenarios

Agricultural Knowledge and Innovation Systems Towards the Future

The SCAR-AKIS-3 report (EU SCAR. 2015) explores the future role of, and adaptations needed in, agricultural knowledge and innovation systems under three different scenarios:

a) a high-tech, globalised world dominated by multinationals, with a strong European leadership and weaker national governments; advanced technology is the driving force of development; wealth, but also is unequal distribution, are rising.

b) a scattered world of regions cooperating or competing with one another, weak European institutions and a rising inequality between successful and unsuccessful regions; attempts at direct democracy and bottom-up politics are widespread but increase fragmentation.

c) a "collapse" scenario where political upheavals, migrations, unchecked climate impacts drive towards self-sufficient communities and the loss of any residual European leadership in technological and economic development. Agriculture recedes towards a labour-intensive technology-poor practice; the center of innovation shifts to China, India and Brasil.

Global Food Security 2030

"Global Food Security 2030; Assessing trends with a view to guiding future EU policies" (Maggio *et al.*, 2015) is a JRC report that addresses the causes and effects of food insecurity following the evolution of the general debate from a focus on production to a broader view, taking social, cultural, political and economic aspects into consideration. The overall goal of the exercise is to provide factual elements to guide sectoral European policies in the Food sector. The study foresees a technology-driven progress towards a "sustainable intensification" of agriculture in a context that favours investments, research and the uptake of innovation, with consumers in the driving seat of future food demand.

The JRC report foresees a significant reduction in the relative number of undernourished people and that food security will be guaranteed on a sustainable basis via:

- The significant transformation of agriculture production systems (through investments, research and training);
- Maintenance of an adequate enabling environment in rural areas (rural development);
- A food system where production and consumption are balanced between local, regional and global levels (markets and trade); and
- A largely demand-driven food system where responsible consumer behaviour shapes sustainable objectives.

Vision 2030 calls for concrete actions to build and promote a more **balanced mix between local and global food systems** while acknowledging that such systems will become increasingly demand-driven. Consumers, especially urbanites, in the driving seat.

Food security will increasingly be considered as securing food supply in response to a new and emerging demand. This requires that the extent of these global trends in changing demand, as well as the future role of trade and markets in securing this supply, should be increasingly considered for and integrated into EU food security policy.

This definitely optimistic view of the future is quite isolated in the landscape of foresight exercises. The impact of climate and of possible mitigation measures appears underestimated.

Sustainable intensification of agriculture (achieving more with less, thanks to a technology-driven efficient use of resources) is the main development anticipated/advocated in the report; as already mentioned in the context of agroecology, the concept of "sustainable intensification" is criticised by the organic and agroecological movements as it does not fundamentally change the production systems but merely aims at reducing some of its negative effects (e.g. less chemicals) while potentially increasing others (e.g. loss of biodiversity).

EC Megatrends Hub

The EC Megatrends Hub[41] was devised as a knowledge hub and repository of documents on 14 "global megatrends" that will most likely drive the future evolution of European and world societies.

Here follow the list of the 14 Megatrends and their description as it appears on the dedicated website:

https://ec.europa.eu/knowledge4policy/foresight_en

1. **Diversifying Inequalities**

   Absolute number of people living in extreme poverty has been declining. The gaps between the wealthiest and poorest of the population are widening.

2. **Accelerating technological change and hyperconnectivity**

   Technologies are changing the nature and speed of new scientific discoveries and are transforming systems of production, management, and governance.

3. **Climate change and environmental degradation**

   Continued unabated, anthropogenic pollution and greenhouse gas emissions will further increase changing climate patterns.

4. **Increasing demographic imbalances**

   World population may reach 8.5 billion by 2030, with rapid growth in many developing economies, while shrinking in many developed countries.

5. **Changing nature of work**

   New generations entering the workforce and older generations working longer are changing employment, career models, and organisational structures.

6. **Growing consumerism**

   By 2030, the consumer class is expected to reach 5 billion people. This means 2 billion more people with increased purchasing power than today.

7. **Continuing urbanisation**

   By 2030, 60% of the population - 4.9 billion people - will live in urban areas. The importance of urban identity is increasing.

8. **Increasing influence of new governing systems**

   Non-state actors, global conscientiousness, social media and internationalisation of decision-making are forming new, multi-layered governing systems.

[41] EC Megatrends Hub: (https://ec.europa.eu/knowledge4policy/foresight_en)

9. Aggravating resource scarcity

Demand for water, food, energy, land and minerals are rising substantially, making natural resources increasingly scarce and more expensive.

10. Increasing significance of migration

The significance of migration as a social and political concern has intensified significantly.

11. Diversification of education and learning

New generations and hyperconnectivity are rapidly changing both educational needs and modes of delivery.

12. Shifting health challenges

Science and better living standards reduced infectious diseases. Unhealthy lifestyles, pollution, other anthropogenic causes turn into health burdens.

13. Expanding influence of east and south

The shift of economic power from the established Western economies and Japan towards the emerging economies in the East and South is set to continue.

14. Changing security paradigm

Diversification of threats and actors is generating new challenges to the defence and security communities, as well as to society as a whole.

Final considerations

Foresight exercises are typically guesswork, the fruit of educated guesses about possible (not necessarily likely) futures. One can then try to identify commonalities that could represent convergent hypotheses on future developments, with the added weight of a shared opinion.

We hereby try to focus on the main convergent opinions as to driving forces and critical factors of development.

The first and obvious driving forces are demography and climate.

Demography: the prospect of 9.8 billion human beings by 2050 is one of the most solid forecasts, with the figure moving upwards at every new estimate round. However it is not so much the total number that matters (however disquieting the figure may be) but the "geography" of growth. Most of the growth will be in Africa and South Asia, the areas of the world that already suffer most form undernourishment and malnutrition and where the effects of climate change are expected to hit hardest. Malnutrition and poverty (linked to SDGs 2 and 1 respectively and with obvious links with one another) are then challenges that have a precise geographical connotation. The "feed the world" narrative, in all its variations and sources, is misleading if it gives the impression that increasing global productivity is the most important goal, as though food could spread evenly throughout the world.

Climate change: the perspective presented by the IPCC are indeed dramatic, although "frightening" might be a more appropriate term. The broad evidence base and the convergence of expert opinions leaves to the still existing "negationists" a sort of "folklore" role, much as creationists or the defenders of the flat earth theory. What is disquieting is that despite the clarity of the "diagnose" and of the need for an immediate "cure", no action of a scale adequate to the dimension of the problem has been adopted anywhere. Positive initiatives, such as the "Energiewende" of Germany or the efforts of China towards photovoltaic electricity or of Denmark on wind do not address the main point: reducing demands of energy and of natural resources and turning to a truly circular economy; the "Holy Graal" of GDP, invariably correlated to the exploitation of environmental "commons" is still the main concern of governments.

Multilateralism and global governance: several foresight exercises adopt the strength/weakness of global governance mechanisms as a key dimension for the interpretation of future developments. What can be noticed is the growing awareness that multilateralism (the wish to seek global solutions though concertation and dialogue worldwide) is fading away[42]. Nationalisms are gaining strength in many parts of the world, including Europe. Distrust in global governance institutions (UN and its Agencies, but also the EU, OECD, WTO, G8 and G20) is spreading. A new version of the "Tragedy of the Commons" is ahead.

[42] The tendency of many political leaders to claim the primacy of the Nation and of national interests over multilateral agreements and settlements is confirmed as a perceived global threat also in the 2019 WEF Risk Report (Collins *et al.*, 2019), as fragmentation of global governance mechanisms increases the risk of local challenges and conflicts escalating to uncontrollable levels. Unrestricted capacity to manoeuvre in the economic sphere and trade is perceived as a way to gain full control of domestic privileged interests and gain consensus at the local level.

Technology: technology in all its forms (genetics, ICT and big data, mechanics and robotics, nanotechnology, artificial intelligence) are seen both as a driver of prosperity and as a threat. Distrust in science and technological advancements is mounting and this is due in part to the evidence of misuse (or unintended consequences) of technologies of the past (e.g. the environmental damages produced by the "green revolution"), in part to the anticipation of possible negative consequences (e.g. unemployment, loss of control on data) and in part to the perception that as for food, the main problem is not of availability but of affordability: technology could widen the divide between the "haves" and the "have nots".

Diets: that diets affect climate and the environment is well demonstrated. Healthier diets (especially with less consumption of red meat) would be beneficial to the environment and to climate as well. However, unless a bottom-up, consumer-driven, change of eating habits occurs, the current trends do not authorise any optimism. Obesity is still growing at an exponential rate; the consumption of meat is increasing in parallel with wealth; the consumption of cheap junk food and beverages is mounting and the big food conglomerates have a clear role in all that. National governments have little space for manoeuvre or do not want to use it for fear of unpopularity.

Public vs private. Many studies point at the need for huge investments of public and private money to make transitions towards a sustainable world possible. But when it comes to private investments either fast and congruous returns are foreseen, or investments will take different routes. There is probably a need for a clear distinction between private interests and public missions as far as policies and research are concerned. Instead of public efforts being directed at the solution of private problems (i.e. financing industrial research) research financed with public money should aim at protecting safety, health, citizens' rights, etc. The real innovation would be (with the help of science) to provide solutions that are desirable and cheap at the same time. The circular economy has good chances in this line.

Cities. There is a growing interest on cities as laboratories of social, technological and economic innovation. The rate of urbanisation clearly contributes to an increased focus on urban centres. However, cities can be hubs of innovation if they are smart, not big; size in itself is neutral or possibly dangerous. The explosion of urban settlements is also shifting power away from rural areas also in matters regarding the use of land for the sheer power of numbers in democratic systems.

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The SCAR-AKIS-3 report explores the future role of, and adaptations needed in, agricultural knowledge and innovation systems under three different scenarios: a) a high-tech, globalised world dominated by multinationals, with a strong European leadership; b) a scattered world of regions cooperating or competing with one another, weak European institutions and a rising inequality between successful and unsuccessful regions; c) a "collapse" scenario where political upheavals, migrations, unchecked climate impacts drive towards self-sufficient communities and the loss of any residual European leadership in technological and economic development

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This FAO document illustrates FAO's principles towards sustainable agriculture as the foundation of sustainable food systems. It includes agriculture, livestock, forestry, fisheries and aquaculture. It enunciates five principles for sustainable agri-food systems and four areas of action for a transition. The report, targeted at policy makers, is the outcome of broad consultations orchestrated by FAO.

FAO, IFAD, UNICEF, WFP, WHO. 2017. **The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security**. Rome, FAO.

The report is a joint effort of FAO, UNICEF, WHO, IFAD and WFP and is aimed at monitoring the current state of FSN in the World with the SDGs of the UN Agenda 2030 as a reference and SDG#2 (Ending hunger) in particular. It is composed of two main parts: the first is an attempt at mapping the current (2017) situation of FNS throughout the world. The second part describes the fundamental link between conflict situations and nutrition.

Food Chain Evaluation Consortium (FCEC). 2013. **Scoping Study – Delivering on EU Food safety and Nutrition in 2050: Final report**. DG SANCO Framework Contract on Evaluation, Impact Assessment and Related Services – Lot 3 (Food Chain)

The study was commissioned by DG SANCO to a Consortium of consultants in order to identify the main challenges that the European food system is likely to face in the coming decades in the area of food safety and nutrition, their likely impacts and the actions necessary to stick to the current high standards. The study is mainly based on the consultation of a broad panel of experts and stakeholders.

Global Panel on Agriculture and Food Systems for Nutrition. 2016. **Food systems and diets: Facing the challenges of the 21st century**. London, UK.

The document is a is Foresight report from the Global Panel on Agriculture and Food Systems for Nutrition on the future of diets with a worldwide outlook and emphasis on developing countries. It describes the recent changes in dietary patterns and their likely evolution given the current trends in demography, incomes, urbanization and globalization. The contributors to the report are a panel of experts from national and international institutions appointed by the UK Government in 2013.

Hart K., Allen B., Keenleyside C., Nanni S., Maréchal A., Paquel K., Nesbit M., Ziemann J. (Institute for European Environmental Policy). 2017. **Research for Agri Committee – The Consequences of Climate Change for EU Agriculture. Follow-up to the COP21 – UN Paris Climate Change Conference**. European Parliament – Directorate General for Internal Policies, Policy Department B: Structural and Cohesion Policies – Agriculture and Rural Development (ISBN 978-92-846-0646-7 doi:10.2861/295025. Available at: http://www.europarl.europa.eu/supporting-analyses

The document, requested by the European Parliament's Committee on Agriculture and Rural Development, reviews and discusses the implications for the agriculture sector of the COP21 UN Paris climate change conference and the EU climate policy proposals for 2030. It looks specifically at the role that the Common Agricultural Policy (CAP) plays in supporting climate action within the agriculture sector and considers how the CAP might evolve post 2020 to support the agricultural sector in reducing GHG emissions and adapting to climate change.

HLPE. 2017. **Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.** Rome, FAO.

The report analyses the influence of food systems on diets and on people's nutritional status. Three main components are identified that interact reciprocally: food supply chains, food environments and consumer behaviour. The food environment is pivotal in determining healthy and sustainable food choices. The report also invokes transformation in policies and programmes to shape food systems in order to contribute to FSN.

Hudson R *et al*. 2015. **The Knowledge Future: Intelligent policy choices for Europe 2050**. Publications Office of the European Union. Luxembourg

The document is the outcome of a Foresight exercise carried out by a panel of experts with diverse expertise in order to advise on fundamental policy orientation in the area of knowledge management and exploitation, with Europe in 2050 as a target. It depicts two contrasting landscapes: one positive from an economic and social point of view, with Europe leading in many areas of development and one negative: a fragmented, marginalised, culturally impoverished Europe, struggling not to lose contact with the world leaders. The recipes to maximise the chances of moving towards the rosy picture are openness (of knowledge education, intellectual property), flexibility and creativity in the development of new social and economic models, Europe-wide cooperation in research and innovation. A common, coordinated approach to taxation is also considered a fundamental pre-requisite.

IEA. 2015. **Energy and Climate Change - World Energy Outlook Special Report**. OECD/IEA, 2015, Paris, France (http://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChangeExecutiveSummaryUKversionWEB.PDF, accessed 19 October 2018)

The report, published a few months before the Paris Conference COP21 assesses the effect of recent low-carbon energy developments and the Intended Nationally Determined Contributions (INDCs) proposed at the time of publication. The main finding is that while global energy-related emissions slow, they still increase. Realistic and attainable longer-term goals are required, with constant monitoring of their progress.

IPCC. 2007. **Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change** (Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

IPCC – Intergovernmental Panel on Climate Change. 2018. **Global Warming of 1.5°C; an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty - Summary for Policymakers**, Incheon, Republic of Korea, 6 October 2018.

IPES-Food. 2016. **From uniformity to diversity: a paradigm shift from industrial agriculture to diversified agroecological systems.** International Panel of Experts on Sustainable Food systems. http://www.ipes-food.org/images/Reports/UniformityToDiversity_FullReport.pdf

This IPES-Food report explores the windows of opportunity and the obstacles for a shift in agriculture and food systems from the now dominant "industrial" model to a diverse paradigm characterised by diversity, nutritional quality, shared benefits, based on agroecological concepts. "Lock-ins" and possible ways to overcome them are presented and discussed.

IPES-Food. 2017. **Too big to feed: Exploring the impacts of mega-mergers, concentration, concentration of power in the agri-food sector**. http://www.ipes-food.org/images/Reports/Concentration_FullReport.pdf

IPES Food explores the current wave of mergers and acquisitions in the Food sector, all along the chain. Conglomerates already dominate most sectors from agricultural inputs to commodity trade, industrial processing and retail. Concentration is considered a threat to farmers' livelihood, freedom of initiative, commitments to sustainability, innovation, traceability, food nutritional quality and has become a powerful factor locking in agriculture in the current industrial model.

Kriegler E, O'Neill BC, Hallegatte S, Kram T, Lempert R, Moss R, Wilbanks T. 2012. **The need for and use of socio-economic scenarios for climate change analysis: a new approach based on shared socio-economic pathways**. Global Environmental Change **22**, 807–822.

Le Mouël C., Forslund A. 2017. **How can we feed the world in 2050? A review of the responses from global scenario studies**. European Review of Agricultural Economics **44** (4) 541–591.

A review of 25 scenario studies, mainly published between 2005 and 2014 (one in 2017) and therefore out of the temporal range adopted for this meta-analysis. However, as a link to previous relevant studies and influential studies, the main findings are reported here.

Le Mouël C, de Lattre-Gasquet M, Mora O (Editors). 2018. **Land use and food security in 2050: A narrow road (Agrimonde-Terra)**. Quae.

*"The Agrimonde-Terra's scenarios point out a diversity of pathways of change for agricultural land use and food security in 2050. They highlight the fact that we are entering a period of great uncertainty and instability, which finds its origin in the dynamics and the interconnectedness between trend factors (demography, urbanization, climate change…), uncertainty and risk factors (economic growth, employment, eating patterns, climate change mitigation…), private actions and public policies at local, national and international levels. Agrimonde-Terra's scenarios also suggest that ensuring world and regional food and nutrition security in a context of climate change is a difficult, long and narrow path" (*Le Mouël *et al*. (Ed.s), 2018*)*

Maggio A., Van Criekinge T. and Malingreau J.P. 2015. **Global Food Security 2030; Assessing trends with a view to guiding future EU policies**. JRC Science and Policy Reports. Foresight Series

Global Food Security 2030 addresses the causes and effects of food insecurity following the evolution of the general debate from a focus on production to a broader view taking social, cultural, political and economic aspects into consideration. The overall goal of the exercise is to provide factual elements to guide sectoral European policies in the Food sector. The study foresees a technology-driven progress towards a "sustainable intensification" of agriculture in a context that favours investments, research and the uptake of innovation, with consumers in the driving seat of future food demand.

Mazzucato M. 2018. ***MISSIONS. Mission-Oriented Research & Innovation in the European Union. A problem-solving approach to fuel innovation-led growth****. EC RTD/A.6. Publications Office of the European Union, Luxembourg*

OECD. 2016a. **OECD Science, Technology and Innovation Outlook 2016**, OECD Publishing, Paris, https://doi.org/10.1787/sti_in_outlook-2016-en

OECD. 2016b. **Alternative Futures for Global Food and Agriculture**. OECD Publishing, Paris, https://doi.org/10.1787/9789264247826-en

The report develops three contrasting scenarios to illustrate alternative futures, based on several global economic models and extensive stakeholder discussions, and outlines policy considerations to help ensure that future needs are met sustainably". Three main scenarios are developed: a BAU scenario (although not defined as such in the report), a society-driven development based on widespread awareness of climate and environment issues and a big-business-dominated scenario with technology as the main source of solutions to the world's problems".

OECD. 2017, **Measuring Distance to the SDG Targets. An assessment of where OECD countries stand**. Paris

OECD/FAO. 2017. **OECD-FAO Agricultural Outlook 2017-2026**, OECD Publishing, Paris. http://dx.doi.org/10.1787/agr_outlook-2017-en

The report is the 13th in a series co-produced by OECD and FAO and provides ten-year projections for the major agricultural commodities, as well as for biofuels and fish that provide a benchmark necessary for assessing the opportunities and threats to the sector.

Philippidis G, M'barek R, Ferrari E. 2016. **Drivers of the European Bioeconomy in Transition. (BioEconomy2030) - an exploratory, model-based assessment**; EUR 27563 EN; doi:10.2791/529794

This JRC report is based on a quantitative modelling of agriculture and the bioeconomy sectors under three different scenarios with regard to measures undertaken by Europe to combat climate change. The BaU scenario consists of keeping the blending commitments of biofuels stable and a CAP much along current compliance lines; the contrasting scenarios imply either giving up

blending requirements or strengthening them; the latter case would be accompanied by more restrictive environmental compliance rules in CAP. Quite interestingly, both alternative scenarios display critical outcomes in terms of agriculture and food production, farmers' incomes and the development of the bioindustrial sector. Tight environmental prescriptions would probably be undermined by lack of a global coordinated approach towards the mitigation of climate change.

Poux X, Aubert P-M. 2018. **Une Europe agroecologique en 2050: une agriculture multifonctionnelle pour une alimentation saine. Enseignements d'une modelisation du systeme alimentaire europeen**. Iddri-AScA, Study N°09/18, Paris, France, 78 pp.

Raworth K. 2017. **Doughnut Economics. Seven ways to Think Like a 21st - Century Economist**. Random House Business Books. London

Reilly M, Willenbockel D. 2010. **Managing Uncertainty: a review of food system scenario analysis and modelling**. Philosophical Transactions of the Royal Society, B Biological Sciences **365**, 3049-3063

Riahia K *et al*. 2017. **The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview**. Global Environmental Change **42,** 153–168.

Ricci A., Sessa C., Weber M. (with contributions from Schaper-Rinkel P. and Giesecke S.). 2017. **New Horizons: Future Scenarios for Research & Innovation Policies in Europe**. Report from project BOHEMIA (Contract no. PP-03021-2015)

Report from project BOHEMIA "Beyond the Horizon: Foresight in Support of the Preparation of the European Union's Future Policies in Research and Innovation" (Contract no. PP-03021-2015). Scenarios illustrate policy options vis-à-vis a number of challenges that humanity faces, having the SDGs of Agenda 2030 as a goal. Possible options in response to the main trends and uncertainties are discussed by presenting contrasting views (pessimistic and optimistic) towards the future and analysing the conditions and circumstances that will likely determine which future humanity will face. The objective is to provide a window on the options that research should aim at creating in order to make future choices available to society

Rockström J *et al*. 2009. **A safe operating space for humanity**. Nature **461**, 472–475. doi: 10.1038/461472a; pmid: 19779433

ScMI AG. 2017. **Die Zukunft der Ernährungswirtschaft. Wie essen wir 2030?** Cube Werbeagentur GmbH, München

Foresight study carried out for the Bavarian Food Cluster (Cluster Ernährung am Kompetenzzentrum für Ernährung) to explore possible scenarios in which the food industry would operate in 2030. Scenarios are created according to the level of regulations, the degree of innovation, the role of free trade and digitisation, the importance of consumers' attitude towards values, regionality and quality and the drivers of innovation (consumers' demand or industry initiative?). Eight contrasting scenarios are developed.

Springmann M, Mason-D'Croz D, Robinson S, Garnett T, Godfray HC, Gollin D, Rayner M, Ballon P, Scarborough P. 2016. **Global and regional health effects of future food production under climate change: a modelling study**. Lancet 387(10031), 1937-1946.

Steffen W, Sanderson A, Tyson PD *et al*. 2004. **Global Change and the Earth System: A Planet Under Pressure**. The IGBP Book Series. Springer-Verlag, Berlin, Heidelberg, New York. 336 pp.

Steffen W *et al*. 2015. **Planetary boundaries: Guiding human development on a changing planet.** Science **347**, 1259855 (2015). DOI: 10.1126/science.1259855 Downloaded from http://science.sciencemag.org/ on March 14, 2017

Steffen W., Broadgate W., Deutsch L., Gaffney O., Ludwig C. 2015. **The trajectory of the Anthropocene: The Great Acceleration**. The Anthropocene Review 2 (1), 81–98

The paper presents and discusses updated versions of graphs originally published in 2004 to show socio-economic and Earth System trends from 1750 to 2000. The correlation (if not causation) between socio-economic indicators and earth-system variables is even more striking than a decade before. Some signs of deceleration (e.g. in population growth, methane emissions, …) are apparent, the world seems bound to continue on an unsustainable development path, requiring rapid and drastic changes in order to trespass tipping points that would make some fundamental modifications irreversible.

Swinburn BA. 2019. **The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report**. The Lancet, published online 27 January, 2019 http://dx.doi.org/10.1016/S0140-6736(18)32822-8

This Lancet report addresses the nexus between nutritional disorders and the major factors driving climate change that is defined, for its multiple burden on health, a "syndemic". It is acknowledged that most of the scientific knowledge needed to take responsible decisions is already available but that socio-economic factors are preventing public authorities to take effective actions. The most relevant single obstacle is the strong opposition by vested interests (in particular the "big food" industry) to the implementation of policies aimed at more healthy diets that would make less use of ultraprocessed and salt/sugar rich food. A broad range of strategies is outlined but the single most relevant concept is that public authorities should get rid of private sector interests when dealing with public health (human and environmental).

TWI2050 (The World in 2050). 2018. **Transformations to Achieve the Sustainable Development Goals** (Report prepared by the World in 2050 initiative). International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria. www.twi2050.org. ; http://pure.iiasa.ac.at/15347

United Nations, Department of Economic and Social Affairs, Population Division. 2017. **World Population Prospects: The 2017 Revision, Volume I: Comprehensive Tables**. ST/ESA/SER.A/399.

The Report has a standardised form and is regularly updated every two years; it reports aggregated and disaggregated (down to the Country level) data on

past and predicted future population until the year 2100. For each table a medium, low and high variant (95% confidence intervals) are proposed, together with a prediction of variations at present rates kept constant.

United Nations Convention to Combat Desertification. 2017. **The Global Land Outlook**, first edition. Bonn, Germany. 337 pp.

Land is the foundation of life. The preservation of its regenerative capacity is fundamental for ensuring the survival of mankind. The way land is managed affects its capacity to produce food today and in the future and to provide for an environment that is healthy and durable. The report analyses the current and prospective status of land with global perspective and with due attention to regional differences. The focus is on land degradation, risks of biodiversity loss and the influence of current trends (demographic growth, urbanisation, linear industrial models, economic inequalities) on the chances of preserving a viable future for humanity. *"The GLO presents an overview of the status of land and a clear set of responses to optimize land use, management, and planning, and thereby create synergies among sectors in the provision of land-based goods and services"* (UNCCD, 2017)

UNEP. 2017. **The Emissions Gap Report 2017**. United Nations Environment Programme (UNEP), Nairobi, Kenya.

The report, the eighth Emissions Gap Report produced by UN Environment, focuses on the "gap" between the emissions reductions necessary to achieve COP21 agreed targets at lowest cost and the likely emissions reductions from full implementation of the Nationally Determined Contributions (NDCs) forming the foundation of the Paris Agreement. It also explores potential for enhanced mitigation efforts in a number of key sectors, presenting cost-effective options for enhanced action to close the emissions gap.

Van der Esch S, ten Brink B, Stehfest E, Bakkenes M, Sewell A, Bouwman A, Meijer J, Westhoek H and van den Berg, M. 2017. **Exploring future changes in land use and land condition and the impacts on food, water, climate change and biodiversity: Scenarios for the Global Land Outlook**. PBL Netherlands Environmental Assessment Agency, The Hague

The study was carried out as an input to the Global Land Outlook developed by the UNCCD. It adopts three (plus an additional one) Shared Socio-economic Pathways (SSP 1, 2 and 3) to develop scenarios of future land use. It considers variation in areas dedicated to agriculture, the effects of water use and management, factors and consequences of land degradation, use of fertilisers, etc. with a 2050 perspective. The central scenario (based on SSP 2) is a BAU scenario; SSP 1 depicts a future earth in which stewardship for climate and environment dominate; SSP 3 is a scenario in which competition for resources is exacerbated, multilateral concertation much weakened and pressure on the environment higher than in BAU. Quite interestingly, GDP pre capita in the "sustainability" scenario (SSP 1) is twice as high as in SSP 3. The study is taken up entirely as Part 2 of the Global Land Outlook

Willett W *et al*. 2019. **Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems**. The Lancet. Published online January 16, 2019 http://dx.doi.org/10.1016/S0140-6736(18)33179-9

The EAT-Lancet Commission report addresses the two ends of food systems, namely primary production and eating behaviours (diets), omitting all the intermediate sectors of food processing and distribution. The two ends, however, if properly reconfigured, could ensure a healthy diet for all and a respect of (almost) all the major planetary boundaries. The report advocates a plant-rich, meat-poor (relative to today's levels) diet. A shift of diets away from animal source food (especially red meat), with a higher intake of plant food (especially plant proteins) would reduce NCDs and at the same time drastically diminish the negative impact of agriculture on climate and the environment. A multiple strategy is proposed to achieve this goal.

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Australian Government, Rural Industries Research and Development Corporation. 2105. **Improved Agricultural Productivity through enhanced collaboration and information sharing among G20 countries**. Publication No. 15/023. Canberra

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Bontoux L, Bengtsson F. 2015. **2035 Paths towards a sustainable EU economy Sustainable transitions and the potential of eco-innovation for jobs and economic development in EU eco-industries 2035**. Luxembourg. doi:10.2760/256478

Buckwell A *et al*. 2017. **CAP - Thinking Out of the Box: Further modernisation of the CAP – why, what and how?** RISE Foundation, Brussels

Caron P *et al*. 2018. **Food systems for sustainable development: proposals for a profound four-part transformation**. Agronomy for Sustainable Development 38: 41 https://doi.org/10.1007/s13593-018-0519-1

Cuhls K., (with contributions by Weber M. and Andrée D.). 2015. **Bringing Foresight to decision-making - lessons for policy-making from selected non-European countries** - Policy Brief by the Research, Innovation, and Science Policy Experts (RISE). EC DG R&I/A6

EC RTD/F. 2018, **A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment. Updated Bioeconomy Strategy.** Publications Office of the European Union. Luxembourg

EC RTD/F.3. 2016. **European Research & Innovation for Food & Nutrition Security (FOOD 2030 High-level Conference background document)**. Publications Office of the European Union, Luxembourg

EC RTD/F1. 2017. **Review of the 2012 European Bioeconomy Strategy**. Publications Office of the European Union, Luxembourg

EC RTD/I.3. 2015. **Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities** (Final Report of the Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities'). Publications Office of the European Union, Luxembourg

EC. 2019. **Reflection Paper "Towards a sustainable Europe by 2030"**. Brussels.

EFSA (European Food Safety Authority), Afonso A, García Matas R, Maggiore A, Merten C. Robinson T. 2017. **Technical report on EFSA's Activities on Emerging Risks in 2016**. EFSA Supporting publication 2017:EN-1336. 59 pp. doi:10.2903/sp.efsa.2017-EN-1336

Elsevier. 2015. **Sustainability Science in a Global Landscape**.

ETP 'Food for Life'. 2016. **Food for Tomorrow's Consumer**. Brussels.

Eurofound. 2019. **Trade scenario: Employment implications in Europe of a large increase in global tarifs**, Publications Office of the European Union, Luxembourg

European Commission. 2016. **A strategic approach to EU agricultural Research & Innovation** (Document been prepared for the European Conference: "Designing the path: a strategic approach to EU agricultural research and innovation" - 26-28 January 2016, Brussels

European Court of Auditors. 2016. **Combating Food Waste: an opportunity for the EU to improve the resource-efficiency of the food supply chain**. Publications Office of the European Union, Luxembourg

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Summary proceeding of a workshop "designed to enable participants to develop a shared understanding of the language around food systems and foresight; explore visions for improved foresight; share knowledge and experience of current foresight work; and identify priorities for future collaboration to improve foresight for the food system"

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HLPE. 2015. **Water for food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security**. Rome, FAO.

HLPF. 2018. **From incremental steps to transformations: leveraging interactions across the SDGs to secure long-term sustainable development outcomes**. Science and Technology Major Group Position paper. https://sustainabledevelopment.un.org/content/documents/18809ScienceandTechnologyMajorGroupSectotalPaper_HLPF2018.pdf

ILRI. 2019. **Options for the Livestock Sector in Developing and Emerging Economies to 2030 and Beyond**. White Paper, prepared for the WEF's "Meat: the Future" dialogue series, Geneva.

IPCC. 2007. **Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change** (Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)). IPCC, Geneva, Switzerland, 104 pp.

IPCC. 2014. **Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change** (Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)). IPCC, Geneva, Switzerland, 151 pp.

The Report confirms that human influence on the climate system is clear and growing, with worldwide impacts. The more human activities disrupt the climate, the greater the risks of severe, pervasive and irreversible impacts for people and ecosystems, and long-lasting changes in all components of the climate system. Stabilizing temperature increase to below 2°C relative to pre-industrial levels requires urgent and fundamental departure from business as usual; the longer it takes to undertake appropriate actions, the higher their cost and the challenges humanity will face.

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The report provides a detailed overview of Joint Research Centre (JRC) research on food safety, food quality and authenticity, food security, agriculture and land use, food for health, and innovation in this area as the European Commission's in-house science service.

Laboratorio Expo, Expo 2015, Fondazione Giangiacomo Feltrinelli. 2015. **Il Patto della Scienza di Laboratorio Expo. Oltre la Carta di Milano: ricerca, divulgazione e formazione per vincere la sfida al Diritto al Cibo**. Milano

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Ronzon T, Lusser M, Klinkenberg M (ed.), Landa L, Sanchez Lopez J (ed.), M'Barek R, Hadjamu G (ed.), Belward A (ed.), Camia A (ed.), Giuntoli J, Cristobal J, Parisi C, Ferrari E, Marelli L, Torres de Matos C, Gomez Barbero M, Rodriguez Cerezo E. 2017. **Bioeconomy Report 2016**. JRC Scientific and Policy Report. EUR 28468 EN

Spatial Foresight, SWECO, ÖIR, t33, Nordregio, Berman Group, Infyde. 2017. **Bioeconomy development in EU regions. Mapping of EU Member States'/regions' Research and Innovation plans & Strategies for Smart Specialisation (RIS3) on Bioeconomy for 2014-2020**. Publications Office of the European Union. Luxembourg.

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World Economic Forum & McKinsey & Co. 2018. **Innovation with a Purpose: The role of technology innovation in accelerating food systems transformation**. Geneva

Woodhill J, Zurek M, Laanouni F, Soubry B. 2017. **Foresight4Food**. Working Paper prepared as discussion material for Global Food Systems Foresight Workshop Oxford, 22-23 March 2017