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

Second report:

- **Livestock**
- **Fisheries and aquaculture**
- **Forestry**

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The opinions expressed are those of the Author and do not necessarily represent those of the European Commission or of the CASA project partners.

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0. Synthesis and main messages

The first part of the report was dedicated to global trends and drivers of change that will likely affect the future of mankind and to the place agriculture and food production have in it. The focus was on its role in the production of food and as an agent and victim of climate changes.

In this second report we focus on **three specific sectors**: livestock, fisheries & aquaculture and forestry.

The first (**livestock**) is indeed part of agriculture, but so relevant in its dimension and its contribution to food security and nutrition and health on the one hand and as a driver of climate change that it deserved a specific analysis.

Fisheries and aquaculture are obviously not part of agriculture but are essential components of food systems. They provide food of high nutritional value, but again with production systems (whether from captures or fish farming) that have a non-negligible impact on fish stocks and the environment, but at the same time are impacted by climate changes.

Forests cover 1/3 of land surface, provide a variety of essential services that must achieve a balance. Wood production is the most traditional one and one that is quantifiable in terms of monetary value, and for the value added by its processing. Other functions (water regulation, biodiversity, carbon sequestration, recreation, …) are less amenable to quantification and often properly perceived only when deforestation wipes them out (fortunately not the European situation). The pressure on forests is increasing because the renewable nature of wood makes it attractive to old and new, sometimes conflicting, uses that are inspired by the need to mitigate of climate change; and the thin red line between sustainable use and overexploitation is not always well defined.

A thorough analysis of the three sectors in all their multiple facets would be outside the scope of this study. We have therefore **focused** on those aspect that are more closely linked to the theme of the fifth SCAR Foresight, exploring possible transitions towards a **"safe and just operating space"**.

0.1. Livestock

The livestock sector is **the most economically relevant** of global agriculture. In Europe more than 45% of agricultural value added is attributable to livestock. Animal farming is well rooted in cultures, traditions, landscapes and, of course, production of valuable products.

Animal Source Food (ASF) is present in all diets, except in that of the most strict vegans, and its nutritional value is undeniable.

However, animals are under scrutiny for their **direct or indirect environmental impact**, their contribution to **climate change**, their inherent inefficiency as feed-to-food converters (due to metabolic energy losses), the damages that excess consumption (other than recommended levels) cause to human health.

No wonder then that any debate concerning livestock raises hot controversies between the different stakeholders. The inefficiency argument is usually contrasted by the fact that animals (especially ruminants) eat materials that are **not suitable for humans**; this is certainly true for pastures and permanent grasslands; less so for by-products of the agro-industry (especially with the development of bio-base industries) and not so when arable crops are dedicated to feed production that could be dedicated to food.

The definition of a sustainable livestock management, with sustainability encompassing all the three canonical pillars (environmental, social, economic) has been called a **"wicked problem"**, or one that lacks a clear definition; has no clear-cut solution, but rather a continuum of options; sees clashing and opposing views expressed by different interest holders; cause/effect relationships are difficult to grasp.

Some key points, however, stand out as central to the current debate.

A. Livestock has an impact on climate due to CH_4 emissions (ruminants and effluents), N_2O release (effluents and fertilisers used in feed crops). Both can be reduced by proper management, breeding, technologies and, indeed, turned to benefits as when properly produced manure is returned to fields. However, even though advanced intensive systems are the most efficient in terms of CO_2-eq emissions per unit product, the most significant **improvements would derive from a reduction of the gap** between developed and developing countries. And this process is of course hampered by the social and economic conditions of developing countries where resources for investments are lacking.

B. Despite possible further improvements in efficiency (less GHG per unit product) that would be only marginal, anyway, it is a recognised fact that if current consumptions of ASF of the wealthy countries were extended to the whole world, animal production would not only become unsustainable from a climate point of view; it would be impossible. Therefore, there is an urgent need to **limit ASF consumption** that, fortunately, would be beneficial to health as well. The EAT-Lancet Commissions calculates that the world consumption of meat should be reduced to one third, even accounting for those parts of the world that would need to increase consumption. Once again, as of other food sectors, **it is not a matter of availability of products but of accessibility**. The poor of the world do not have the resources to access food where it is available.

C. An alarming situation is building up in **Africa** in which any growth in production is outpaced by demographic growth with the consequence that Africa, and especially Sub-saharan Africa, will face a **diminishing availability of meat and other ASF per capita** in the coming decades, already the lowest in the world. This trend is in no way affected by technological progress in the affluent world.

D. **Specialisation and intensification** of livestock systems has occurred and is still in progress: it affects mainly pigs and poultry and to some extent cattle. This led to a separation of animals form the land that produces their feed (often dedicated agricultural crops) and where manure should be returned. A return to a **closed circle**, that is one of the principles of the now accepted paradigm of a **circular economy**, is advocated also by exponents of the industry. Reconnecting land and

animals can take place at the farm level or, if properly organised, at district level. Reconnecting animals and land is also one of the basic principles of Agroecology.

E. Specialisation goes hand in hand with **concentration** in the upstream (feed, genetic material, pharmaceutical, equipment) and downstream sectors (slaughterhouses, processing, retail) with some deleterious consequences on **biodiversity** (concentration on a few breeds) and on the **economic viability of farming**, an activity increasingly performed under contract in which farmers are generally the weak link, bearing the risks and with little benefits.

F. Among the risks of the farmers, **diseases** still rank high, despite significant progress. Research on vaccines and alternatives to antimicrobials is a priority not only for the livestock sector itself, but also for the consequences on human health. Humans are under threat from **zoonoses** on the one hand and from the surge of ant-microbial resistance on the other hand.

G. **Alternatives to meat** and other ASF already exist; some have been around for millennia (protein rich plants) some are present in local traditions (e.g. tofu, insects). Some have been proposed more recently and are finding a niche market (e.g. mycoproteins, Spirulina). Some try to reproduce the taste and feel of meat (e.g. vegetable burgers and artificial meat). Despite a growing interest, it is still early to say if the traditional ASF market will be seriously affected.

H. The main unknown about the future is the **attitude of consumers** towards ASF. Some interesting trends are already visible: the young and the affluent are eating less ASF than the aged and the less affluent, at least in Europe and North America. It is too early to make predictions, but there is a **possibility that meat consumption in the western world will diminish because of a diminishing demand**.

0.2. Fisheries and aquaculture

Seas and oceans are by far the **largest ecosystems in the world**, but, at the same time, the **least known and understood**. As such, they are often abused; they are the ultimate destination of land pollution, be it through water courses or direct pouring of urban and industrial effluents into water or, as has been dramatically demonstrated recently, through discharge and indefinite accumulation of **plastics**.

Man is damaging an environment that is and will be essential to his own survival. Seas and oceans do not only provide **food**; they also fulfil an essential role in the **mitigation of climate changes**, but the risk is real that, failing to understand how delicate the balance is, we humans modify climate and the environment beyond the tipping point of no return.

Fisheries and aquaculture provide food (finfish, crustaceans, molluscs, seaweed) to a large share of mankind, with particular regard to developing countries and small islands. Indeed, the **growth of consumption of fish in recent years has outpaced the growth rate of the world population**; the amount of fish consumed per capita is increasing and has now reached about 20 kg per year.

Several elements should be highlighted:

A. An effective **regulation of capture fishing is difficult**. Fish stocks are mobile, difficult to estimate with precision, interacting along trophic chains in ways that are not yet properly understood. Monitoring and research efforts should be intensified as well as ways to enforce the observation of international agreements and to stop IUU (illegal, unreported and unregulated) fishing that still accounts for around 15% of catches. **Overfishing**, despite all efforts at regulating the sector, is still common and increasing, and this makes the recovery of stocks a "mission impossible"; should the stocks be allowed to rebuild, also captures could increase, eventually. The present situation resembles, in many parts of the world, a modern "tragedy of the commons". At the global level a governance deficit is observed, with a **plethora of treatises**, bilateral and multilateral agreements that overlap and interact; however, there is little room for optimism, as **multilateralism is losing traction** in a world where large and small countries see a resurgence of nationalisms.

B. Captures are stable (since the 1990s) and **aquaculture has surpassed** them as a source of fish (and crustaceans and molluscs) for human consumption. This has been the consequence of a very rapid growth that, although at a slower pace, is continuing today and is likely to continue in the future. Aquaculture is also **much more efficient** (1/2 the workers employed in fishing for the same amount of product) than capture fishing and is still experiencing a **high degree of technological innovation**.

C. **Fish** in general is **more efficient than terrestrial animals** in converting feed into edible products: cold blood and floating reduce the "metabolic overhead". From the point of view of mitigation of climate change **farmed fish is better than farmed animals**. Among fish, plant eaters (such as carps) are better than carnivorous fish (e.g. salmon) but it must be acknowledged that significant efforts have been made to reduce the animal component in fish feed. Technological (including biotechnological) developments may provide **further improvements**.

D. Two aquaculture models are emerging: offshore aquaculture and integrated multitrophic aquaculture. **Offshore aquaculture**, although still posing huge technical challenges, is probably the main avenue to future large scale fish production: contrary to coastal marine aquaculture, it creates little conflicts with other human activities (pollution, tourism, coastal fishing) and the potential **suitable areas are almost unlimited** (see OECD, 2019). **Integrated multitrophic aquaculture** embodies the principles of the circular economy as the excreta of farmed fish are food for filtering molluscs and the residual nutrients (nitrogen in particular) are fertilisers for seaweed.

E. **Europe** should develop strategies to **increase the degree of self-sufficiency of fish products**, with particular attention to aquaculture. Its strong dependence on imports (65%) has an impact on the viability of fish stocks and marine and coastal environments in the countries of origin (due to overfishing and pollution). Europe is known for its high environmental standards but **imports of fish** risk to **export the burden of environmental degradation** to developing countries.

F. **Certification** schemes may play a role in the buying decisions of environmentally and socially conscious consumers, but there is a need for simplification, transparency and effective communication.

G. The **impact of climate** on the marine environment is relatively well known to specialists in its **physical/chemical aspects**; less so for the consequences on the biology and behaviour of living organisms and on the reciprocal relationships in **trophic webs**; and largely **ignored by the majority of society**. The current mitigation effect of seas and oceans (CO_2 and heat absorption) will eventually counteract any (hopefully implemented) efforts at reducing atmospheric CO_2.

H. On **plastics**, microplastics and their chemical components awareness is raising but effective measures have to be adopted rapidly to stop the flow towards seas and oceans. Research efforts should be intensified on the removal of plastics from seas and oceans, partly favoured by the existence of **"garbage islands"** due to water currents.

0.3. Forestry

Forests, even more than agriculture, perform a **variety of essential roles** whose relative importance may vary according to the environmental, economic and social conditions of the different parts of the world but have to coexist. **Timber** production is rarely the first priority on a global scale, even though it is considered highly relevant in most developed countries.

Forests are also a source of **food** (both plant and animals), in particular in developing tropical and subtropical countries, where large numbers of people depend on forests for food either regularly or seasonally or in emergencies.

As the most diverse ecosystems, especially in equatorial and tropical regions, forests are also fundamental in preserving **biodiversity**.

Consolidated industrial sectors, pulp and paper, construction, furniture depend on a regular supply of wood and play a **key role in many economies** of Europe and beyond; despite the low relative of forestry (as primary production) in the gross added value of most developed countries (exceptions in Europe are Finland and Sweden) vs other economic sectors, it supports downstream industrial sectors that multiply the value of raw materials considerably.

Energy production is still a primary function of forests; whereas burning (of wood or via transformation into charcoal) is still the dominant way of energy extraction form forests in developing countries, more advanced technologies are being developed in developed countries (e.g. lignocellulosic biomass conversion into biofuels). However, a growing demand of wood as a renewable raw material is creating conflicts with the objectives of carbon storage in order to mitigate climate change.

The **main challenge** for the future of forests is then to **reconcile all the different expectations**, all of them desirable form some point of view:

A. Increasing **wood production** and extraction for transformation into long lasting products (housing, furniture) has the effect of sequestering carbon captured from the atmosphere by the photosynthetic process, at least for a more or less long time.

B. If a full **circular economy** principle is applied, there may be several cycles of reuse before a final (and irreversible) transformation into energy: this would return carbon to the atmosphere but, in any case, replacing the net emission effect of fossil fuels.

C. Wood products (e.g. in construction) may be **substitutes for energy-intensive materials** such as steel and concrete, thus sparing the fossil energy required for their production.

D. Most forests in Europe are **underutilised**: that is, less wood is harvested than the annual increment. It may seem, therefore, that there is a significant margin to increase production (withdrawing the "interest") with no damage to forests (protecting the "principal"). However, this argument should be **scrutinised at the very local level**, as some areas are not harvested to their productive potential because the cost of operations would surpass the value of wood (e.g. steep slopes, roadless areas, …). Relying on averages is risky.

E. A more intensive extraction of biomass, as has been sometimes suggested, to include branches and stumps runs the risk of **reducing fertility**.

F. Indeed, a higher harvesting rate is contrary to the increasingly important expectation about **forests to act as carbon sinks**, stocking carbon in trees and soil as well.

G. A very controversial issue is the **direct use of (virgin) forest biomass for the production of energy**. Supporters argue that the mere effect as substitute of fossil fuels justify the destination; opponents claim that the risk of environmental degradation, with consequences on the viability of forest ecosystems is too high. The carrying capacity of the different forest environments is certainly a matter on which research should focus in the coming future.

H. The most interesting field of innovation will be the **full development of the circular economy paradigm**. Bio-factories for the production of new materials and chemicals from side-streams are already developing around pulp and paper industries and the whole field is extremely promising of new applications.

I. Innovation is also expected (and indeed already occurring) in the more traditional **wood industry**, with a shift from sawn wood to engineered panels that optimise the use of raw material and often improve the mechanical properties of products.

J. Another area of research, given the present speed of climate changes (in particular rising temperatures and drought spells) is on **adaptation mechanisms** and active **adaptation strategies**, including targeted breeding and assisted migration.

K. **Precision forestry**, or the application of ICT, remote sensing, big data, artificial intelligence, analytic instruments to monitoring and management is another area that promises significant breakthroughs to improve the sustainable management of forests, the traceability of wood and the reduction of illegal logging.

L. A final, but **socially very relevant**, area of improvement would be that of **workers' safety**, that, despite considerable progress in recent decades, is well established only in advanced economies thanks, in particular, to a high degree of mechanisation.

1. Livestock

1.1. Foreword

An in-depth analysis of the perspectives of the livestock sector, even if limited to Europe, would be an overwhelming enterprise, due to its complexity and socio/economic importance (direct and indirect) and its strong roots in the agricultural and food systems.

Therefore, the main aspects that will be touched in this review are those most directly **linked to the theme of the 5th SCAR Foresight**: a development pathway that is compatible with planetary boundaries and with the wellbeing of society.

A lot has been written recently on the negative (but also positive) contribution of livestock sector on the mitigation of **climate change**, as well as on the positive (but also negative) role of **meat** (more specifically some types of meat and processed products) on **human health**. Both issues are controversial: in the first place because effects depend on specific conditions and circumstances, but also because livestock and agriculture are inextricably linked and because the social, cultural, economic aspects of the sector or sectors are extremely relevant and cannot be dismissed, in the context of sustainable development (Buckwell and Nadeu, 2018). This is particularly so in Europe where the livestock sector, and in particular dairy cattle, goats and sheep gave origin to an incredibly rich range of cheese types that are not only rooted in regional traditions, but have become a driving element of agricultural exports (ATF, 2019).

It is estimated that livestock is responsible for about 40% of the value added of all agricultural output, globally, 45% in Europe (ATF, 2019) but reaching far higher figures in some countries, both in the developing (pastoral societies) and developed (specialised animal farming) world: e.g. 80% in Mauritania and New Zealand. More than half of the rural households of the world depend on livestock for their livelihood.

Livestock does not mean only meat, milk or eggs. Livestock is part of the cultural identity of rural societies; it is often the only way available to **build up capital** that can be mobilised in emergencies or in special circumstances and is not affected by inflation. Livestock generates **draught power** and produce **manure**, that is often the only source available to fertilise agricultural fields in developing countries (HLPE, 2016), although it must be conceded that animals, at best, return to the environment part of the nutrients that they received from grass and feed (Buckwell and Nadeu, 2018).

Sustainable development of animal farming has been defined a **"wicked problem"** (Committee on considerations for the future of animal science research, 2015), that is, a problem characterised by four elements: **1)** there is no definitive formulation of the problem; **2)** there is no clear cut solution (true/false) but only a continuum from better to worse; **3)** stakeholders hold radically different views depending on different principles, values and interests; **4)** cause/effect relationships are complex, unknown or uncertain. No wonder, then that often diametrically opposite opinions are expressed and fiercely defended by different components of society.

On the other hand, the current upward trends in meat consumption, pushed by the growing income of many developing countries and a general trend toward declining prices (HLPE, 2016), should not be considered as irreversible and there are clear signs that wealthy societies, although consuming more meat per capita than the world average, are on a stable or downward path. Concerns for one's own health, animal welfare and, increasingly, climate may change the direction of consumption even though world economic growth should persist.

According to a recent study prepared by the Oxford Martin School (Oxford University) for the World Economic Forum "*It would be* ***impossible for a global population of 10 billion people to eat the amount of meat typical of diets in North America and Europe*** *and keep within the agreed sustainable development goals (SDGs) for the environment and climate: it would require too much land and water, and lead to unacceptable greenhouse-gas and other pollutant emissions. In addition, excess meat consumption and current production have significant effects on human health, livelihoods and the economy. Meat thus poses a special challenge to the future development of the global food system*" (WEF, 2019b).

Indeed, the consumption of ASF (Animal Source Food) products is decreasing in Europe, as a consequence of new products being offered on the market as meat substitutes (e.g. veggie burgers) and health concerns. Veganism, vegetarianism still represent minority habits but **"flexitarianism"** (meat is not excluded from the diet but eaten rarely or in small amounts) is spreading (ATF, 2017). However, Europeans are still consuming more than the world average and Europe is second only to North America and Oceania in per capita meat consumption (Buckwell and Nadeu, 2018). Quite interestingly, and suggestive of possible future developments, the younger generations and the richer part of the European population eat less meat than the older and less affluent (Buckwell and Nadeu, 2018).

In Europe meat represents little more than half of protein intake (52%). Milk and especially its derivatives (cheese, yogurt, cream) and, to a lesser extent, eggs are also consumed by Europeans at higher levels than the world average (Buckwell and Nadeu, 2018).

The Committee on considerations for the future of animal science research (2015) identifies, as major uncertainties about the future of the livestock sector: **a)** the impact social movements related to animal welfare, organic foods and vegetarianism; **b)** the impact of science based health information on consumer preferences; **c)** the future of international trade, allowing or restricting trade of ASF and feed.

The growing dependence of many livestock systems on externally sourced feed has pushed the level of production and **trade of grains** on a **faster** track than the growth of **animal sourced products** themselves. China, that is strongly dependent on soybean for pigs and poultry, is absorbing the largest share of production of S.America and is increasingly resorting to land acquisitions outside China (in particular, but not only, in Africa)(HLPE, 2016).

Europe itself, almost self-sufficient in the production of grains used for feed, is largely **dependent on imports for protein crops**: almost totally for soybean (5% self sufficient) and largely, if total proteins are concerned (38% self sufficient). Proteins are essential ingredients of compound feeds for

monogastrics and important also for dairy cows, due to the huge individual daily production of milk that cows have reached in specialised farming systems (Buckwell and Nadeu, 2018).

It seems therefore important to preserve a detached view and consider the different scientific positions without preconceived attitudes.

Livestock is the single sector with the highest fraction of land use: pastures, grasslands and feed crops occupy 40 percent of the Earth (except Greenland and Antarctica). In advanced economies, over 50% of the arable land is used to grow animal feed. **In Europe 58% of cereals and 67% of oil & protein crops are for animal use** (Poux and Aubert, 2018).

The livestock sector is responsible for 72 percent of deforestation (mainly in S.America), of 32 percent of global freshwater use and 14.5% of global GHG emissions (Committee on considerations for the future of animal science research, 2015).

The figures for Europe are even higher, with an estimated 72% of agricultural surface dedicated to animal feeding; half of which is grassland (for ruminants) and the rest agricultural crops (Buckwell and Nadeu, 2018). Indeed, one of the arguments that the Animal Task Force uses to state the importance of livestock in Europe is that it provides **added value** to cereal and protein crops (ATF, 2019).

In many parts of Europe, and especially on mountainous areas, pastures are being abandoned and left to degradation or to be reconquered by an expanding forest.

A research cited in HLPE (2016) calculated the amount of plant derived feed that should be needed in case the "western diet" was adopted by all the people of the world. The hypothesis is entirely theoretical, but it helps in guiding foresight exercises as an upper boundary. The result is that feed should be doubled now and increased by 117% by 2050.

A drastic reconsideration of the quantity (and mix) of livestock and of feeding and rearing systems that would keep the whole sector within a "safe operating space", ensuring sufficient levels of nutrition for European citizens and avoiding trespassing planetary boundaries on GHG emissions an Nitrogen and Phosphorus pollution, is likely to shake relevant economic and social interests form their foundations (Buckwell and Nadeu, 2018). No question that the debate is already red hot. What is certain is that any development shall have to be based on sound evidence, unbiased by preconceived ideas and vested interests, however legitimate.

A high-level critical contribution has recently come from the **EAT-Lancet Commission** (Willett W *et al.* 2019) that tried to define a "safe operating space" for the food system and **advocated a drastic reduction of meat consumption**; in particular, for health reasons, of red meat. The daily intake of proteins should move from red meat to plant proteins, especially legumes and nuts, fish and, to some extent, to poultry. According to the EAT-Lancet Commission, the consumption of red meat (and starchy vegetables, by the way) should be reduced, globally, to a third of present-day consumption. Averages, of course, mask big differences in different regions of the world as can be seen in **Figure 1.1**.

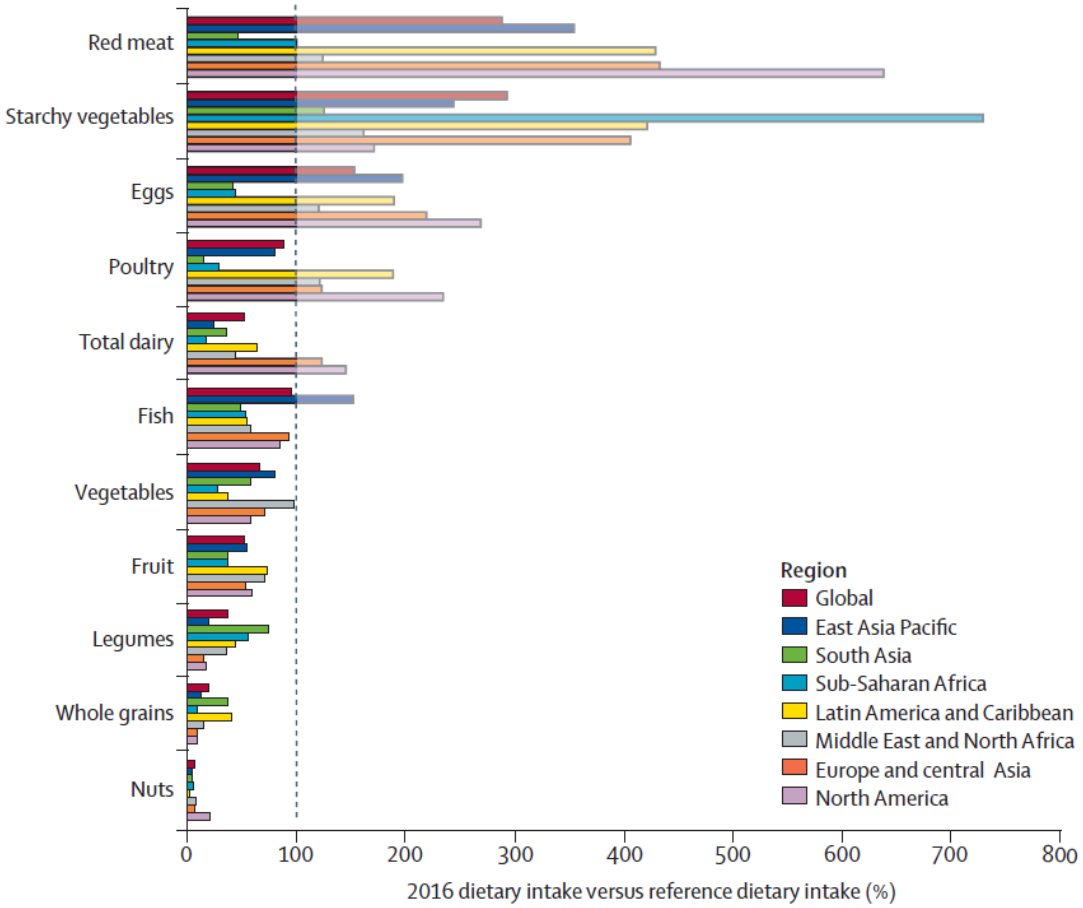

Figure 1.1 - Diet gap between dietary patterns in 2016 and the EAT-Lancet Commission reference diet intakes of food (From Willett W *et al.* 2019).

The real big challenge is how to fill the gaps between the "haves" and the "have-nots", but also how to modify current habits and cultures where overconsumption is the norm.

1.2. Recent trends

For centuries livestock was a **"supply driven"** sector. Domestic animals fed on materials that were not used for human consumption being either grazers (herbivores) or "scavengers" feeding on waste or on food found in the natural environment (insects, seed, herbs, roots, fruits).

Animals were limited in number, at least compared with the space available and only rarely did they compete with agriculture or represented a problem for the environment (Robinson TP *et al.*, 2011).

Things changed when the livestock sector became **"demand driven"** and livestock became an economic activity competing with other sectors for space and resources. **Environmental impacts** began to be appreciated (especially pollution from excess nitrogen and phosphorus) and, more recently, one of the major concerns within the environmental aspects, the contribution of livestock to climate change, emerged as a headline topic (Gerber PJ *et al.*, 2013).

In the last decades livestock production increased dramatically (**Figure 1.2**), driven by the demand for animal-source foods of an increasing world population and the changes in dietary preferences pushed by economic growth, that increased wealth in many developing countries, and by urbanization. So far, urban dwellers have enjoyed a broader range of options on food, with access to a wider range of products, including ASF, mainly due to a more structured market system and higher incomes than rural people. However, a new landscape is emerging in many megacities of the developing world, with urban "food deserts", due to poor organisation, lack of welfare protection and increasing poverty (HLPE, 2016).

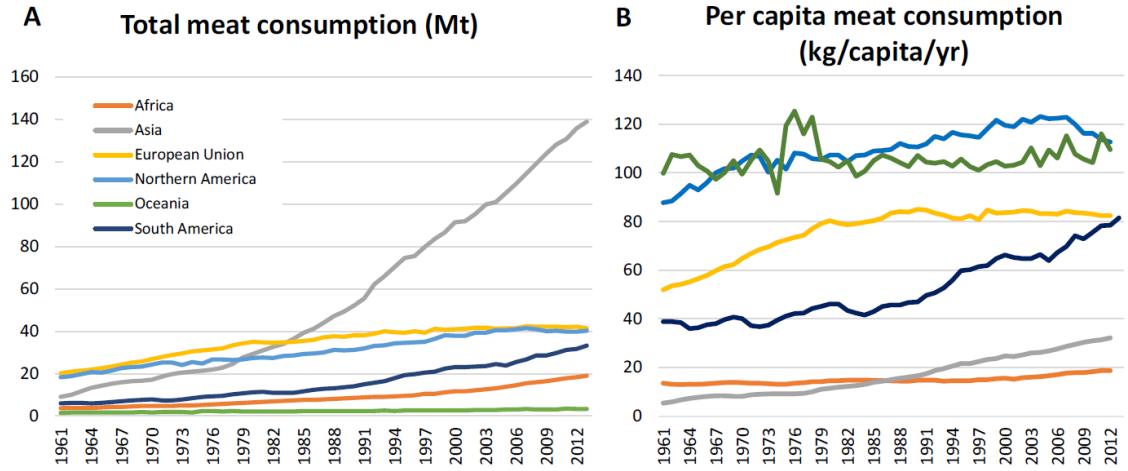

Figure 1.2- A) Total meat consumption, for selected world regions between 1961-2012; B) Per capita consumption, same regions between 1961-2012 (From Buckwell and Nadeu, 2018).

The global demand for ASF is anticipated to grow by 73 percent for meat and eggs and 58 in dairy products by the year 2050, with the year 2011 as a reference point (Committee on considerations for the future of animal science research, 2015). Most of the growth in demand will take place in Asia and

Africa; however, whether **in Asia** increased consumption will be mainly a consequence of **higher incomes**, **in Africa** the main cause will be **population growth**, with per capita consumption remaining stagnant and at levels well below the world average or even decreasing (WEF, 2019a). The situation of Africa is particularly desperate as self-sufficiency is not within sight: Africa currently imports $22 billion worth of meat, $5 billion of milk and more than $200 million of eggs a year (WEF, 2019a).

Most ASF products are consumed locally, but the role of international trade is growing, with the dairy sector (especially milk powder) having the highest share (over 50%) of production traded internationally (HLPE, 2016). While **trade** can make products available to places where they would not be produced, it also run the risks of **undermining the development of local productions**; in large parts of Africa powder milk (mainly coming from Europe) is sold at a price that is lower than that of locally produced milk (WEF, 2019a).

Europe is both an exporter and importer of meat and other ASF. It imports beef and poultry (main source is Brazil), sheep (New Zealand) and exports pig (mainly to China), poultry and veal. Despite higher production costs in Europe than the rest of the world, **Europe is a net exporter** (with a surplus of about 10%), mainly due to the **high quality** of its products and the **high safety standards** it guarantees (Buckwell and Nadeu, 2018). Exports are expected to increase further as a consequence of steady or diminishing domestic consumption and increasing international demand.

In many parts of the world, and many production systems, feed for the livestock was and is being increasingly derived from dedicated crops that compete with food production, at least for land, or with forests, when these are cleared to make room for pastures or feed crops. Of course, this is a rather simplistic picture: not infrequently animal feed is derived from by-products of food production (e.g. soy or canola cake).

Livestock production reacted to increasing demand essentially by shifting from an extensive "backyard", mainly subsistence form to more intensive types, with higher animal concentrations, higher specialisation, higher investments, all leading to economies of scale and market orientation.

This intensification and **specialisation** are particularly evident with **pigs** and **poultry**, mainly due to their high feed conversion efficiency and fast reproduction rates.

The concentration of specialised systems that rely entirely on externally sourced feed often leads to an **impoverishment** of **soils** where **intensive crops** are raised and an **excess of nutrients in the areas where animals are kept**, leading to soil pollution and water eutrophication (HLPE, 2016)(Buckwell and Nadeu, 2018).

Intensification brings along veterinary control, improved diets, access to extension and support services, control of the living environment but also the abandonment of most traditional animal breeds for a restricted genetic pool of highly productive breeds. For example, Fresian-Holstein breeds dominate the dairy cattle sector; Large White the pig sector.

Another effect of "industrialisation" of the livestock sector was the appearance of big **conglomerates** that often extend their presence,

vertically from the production of young animals (especially chicks and piglets) and their feed, outsource their rearing to farmers and receive from them the finished animals that they slaughter and sell to industries or retail companies. In most cases the **big companies reap most of the benefits and the farmers bear most of the risks**. The effect of "industrialisation" is to render the sector more efficient but also to progressively expel small operators (Gerber PJ *et al.*, 2013). The risk of concentrations leading to abuse of dominant position is real (HLPE, 2016).

In animal genetics concentration is particularly disquieting: in the poultry sector, two companies control around 94% of the breeding stock of commercial layers and virtually all turkey stocks, with a range of breeds that grows thinner and thinner; the main four companies control two thirds of the genetics of pig and cattle (IPES-Food, 2016).

Figure 1.3 - Genetic erosion of livestock breeds (from IPES-Food, 2016).

Concentration is occurring also in the retail sector that increasingly dominates the choices of consumers on the one hand, but also pushes farmers into a corner where higher and higher demands on quality are accompanied by imposed low prices that farmers have to accept to stay on the market.

Aa specific chapter is dedicated to the concentration of industry in the animal sector (Chapter 1.9).

However, in many parts of the world, especially in developing countries, it is the **difficulty to access the market** that determines the **poverty** of animal farmers and herders; they lack access to sanitary support, improved breeding stock, technical assistance, capital and are thus excluded from further improvements of farming methods and higher incomes (HLPE, 2016).

Trade in ASF (as in grains!) has often the effect of distorting local markets in developing countries when product imported from efficient, low-cost an often **subsidised industrial systems of the wealthy economies outcompete locally produced meat, milk and other dairy products**, undermining the possibility of small farmers or pastoralists to obtain a decent reward (HLPE, 2016).

Indeed, as far as trade and markets are concerned, in livestock, as in agriculture in general, two "philosophical" points of view oppose one another.

One is the liberal "market approach", with markets representing the neutral meeting ground that establish a price based on demand and offer and provide

the seller with an income to be spent again on the market. An extension of this logic leads to providing **a price** for positive (incentives) and negative (taxes, charges) **externalities**.

The opposite one is the "food sovereignty" approach in which production serves essentially a social function for the local community and resources are considered common assets to be shared for the benefit of the community (HLPE, 2016).

We (in wealthy countries) probably received an imprinting by the first approach, but the spread and deep roots of the second one should not be underestimated, nor should we fail to acknowledge that **the market is not devised to protect the poor** and the weak actors. The whole Agroecology movement, implicitly or explicitly dominant in many developing countries and strongly supported by the FAO is based on a food sovereignty paradigm.

1.3. Livestock and climate

According to the IPCC (2014), Agriculture, Forestry and Other Land Uses (AFOLU) are responsible for around 25% of all anthropogenic GHG emissions. Between 50 and 60%, or around **14,5% of all anthropogenic emissions are caused by the livestock sector**, including emissions by the animals themselves (especially CH_4 by ruminants), emissions due to the production of feed (CO_2 and N_2O) and emissions due to excreta (CH_4 and N_2O). A minor share of livestock-connected emissions is represented by energy (**Figure 1.4**).

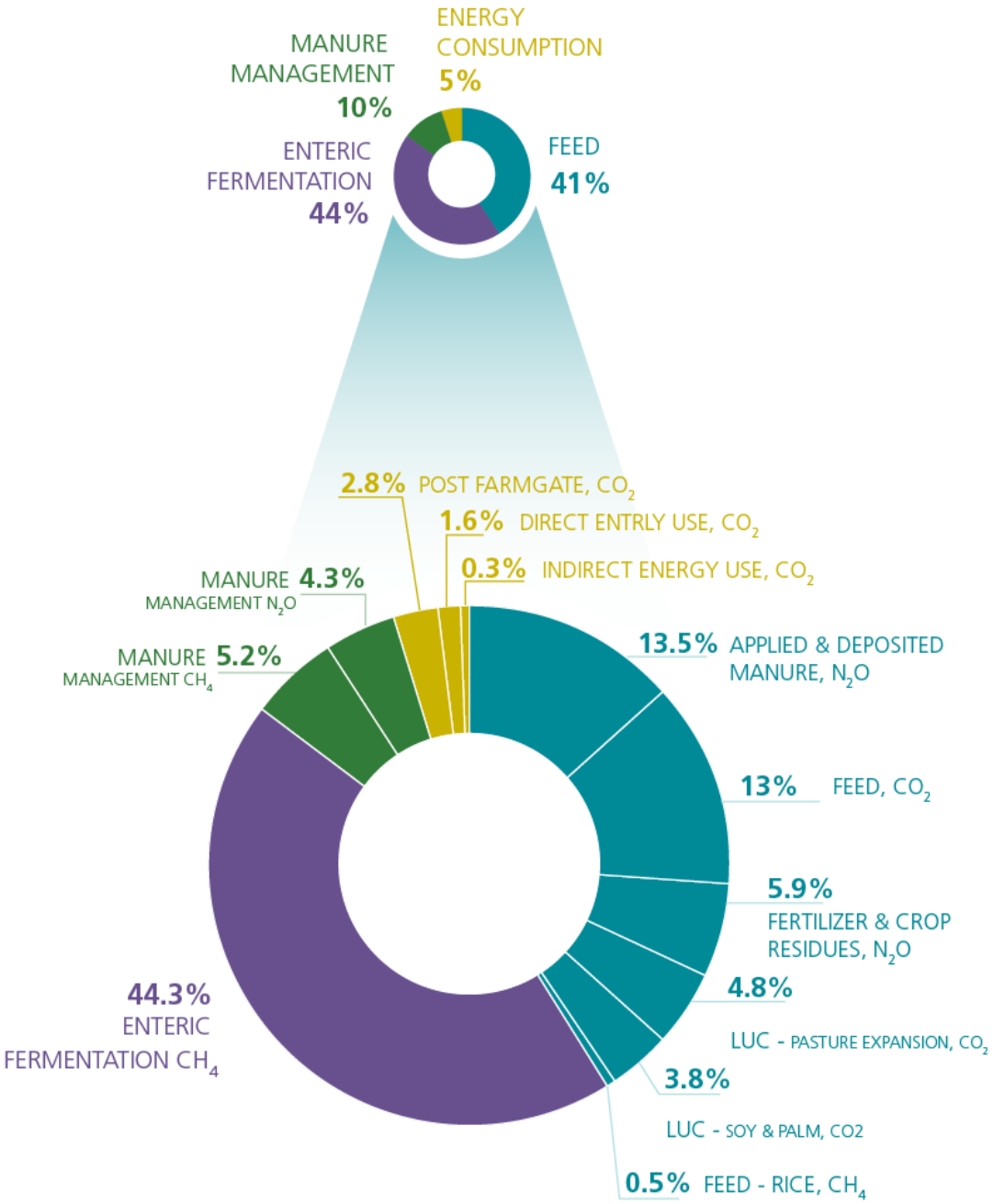

Figure 1.4 – Relative contribution of main sources of emissions from global livestock supply chains (http://www.fao.org/gleam/results/en/).

CH_4 and N_20, despite being produced in relatively small amounts (with respect to CO_2) have a much higher warming potential (34 and 298 times that of CO_2, respectively[1]) and therefore represent significant amounts when expressed, according to conventions, in CO_2 equivalents.

The share of emissions due to the production of feed includes **deforestation** (not the European case, but still relevant, although decreasing, in South America and Asia) (HLPE, 2016), emissions due to the production of fertilisers and pesticides, energy for transports, N_2O emissions from the application of manure and other nitrous fertilisers, etc. Deforestation or the conversion of pastures into crop fields to meet the international demand of feed ingredients (mainly soybean from South America) is stirring a debate in Europe on the environmental sustainability of the livestock sector; in fact, Europe, as a major importer of soybean is indirectly contributing to considerable amounts of GHG emissions from land use changes outside its borders (Buckwell and Nadeu, 2018). It is estimated that 35 million hectares of soybean are cultivated outside Europe to satisfy the European demand (Poux and Aubert, 2018).

Manure is a very important source of nutrients and of organic matter that should contribute to the reduction of the share of soils that are currently classified as degraded (33% globally, according to Raffa DR *et al.*, 2018). However, as manure can also contribute to pollution (and for that reason its distribution is heavily regulated in the EU) and to GHG emissions, the way it is managed is of the highest importance.

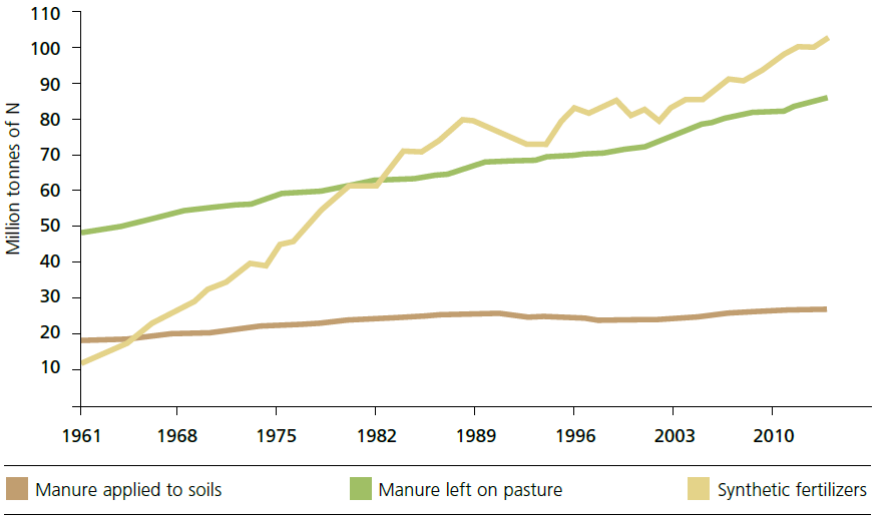

Figure 1.5 - Nitrogen applications from manure and synthetic fertilisers, 1961-2104 (From Raffa DR *et al.*, 2018).

If we count GHG emissions by species (or group of species) cattle, including beef and dairy, takes the lion's share, dwarfing all the rest.

[1] According to IPCC, 2014: **Climate Change 2014**

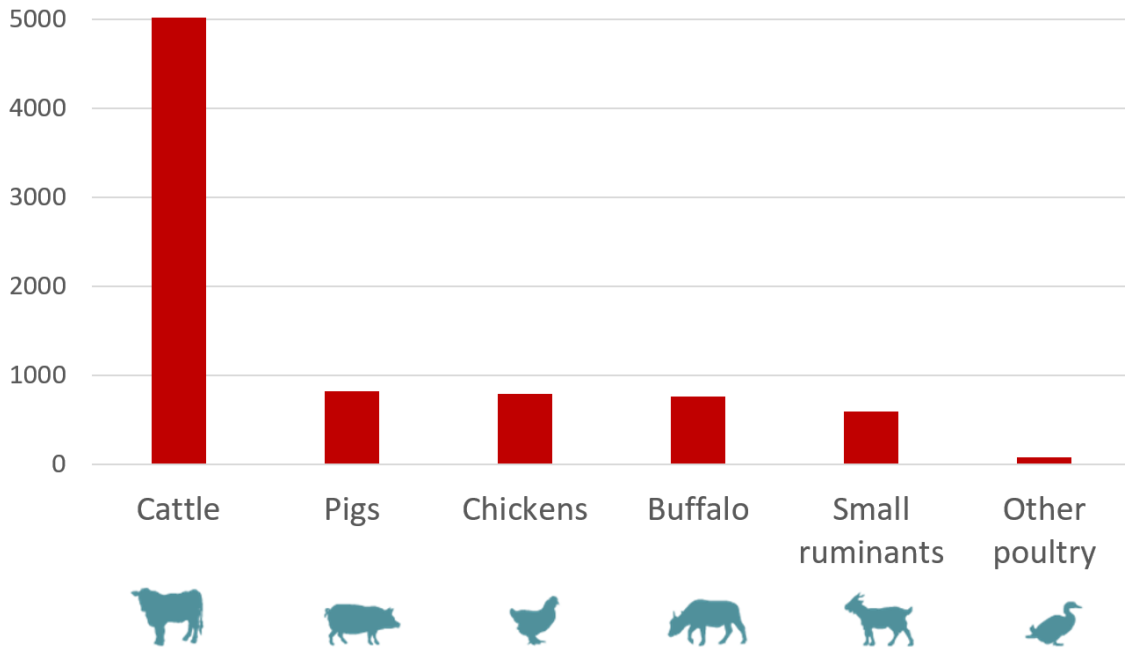

Figure 1.6 - Global estimates of emissions by species in million tonnes CO_2-eq. It includes emissions attributed to edible products and to other goods and services, such as draught power and wool. (http://www.fao.org/gleam/results/en/)

However, as animals are raised mainly for their products, meat, milk and eggs (not considering here work, hides and wool) a more equitable comparison should be made between the **"emission intensity"** of the unit of product. In **Figure 1.7** emissions are expressed in kg CO_2-eq per kg of protein.

Some aspects should be emphasised here:

1. When meat is compared with recurrent products (milk or eggs), **meat is invariably more CO_2 intensive**.
2. The broad 50% and 90% ranges of beef, buffalo for meat and small ruminants is likely due to the fact that these data cover all production systems, from extensive pastoral to intensive feedlots.
3. On the contrary, the strikingly narrow range for pig and poultry reflects the widespread standardisation (and intensity) of production systems and the low emissions of pigs and poultry in "backyard" systems.
4. White meat and pork are by far the most "climate friendly" types of meat. The 90% range of both is entirely below the lower limit of the 90% range of beef and buffalo.

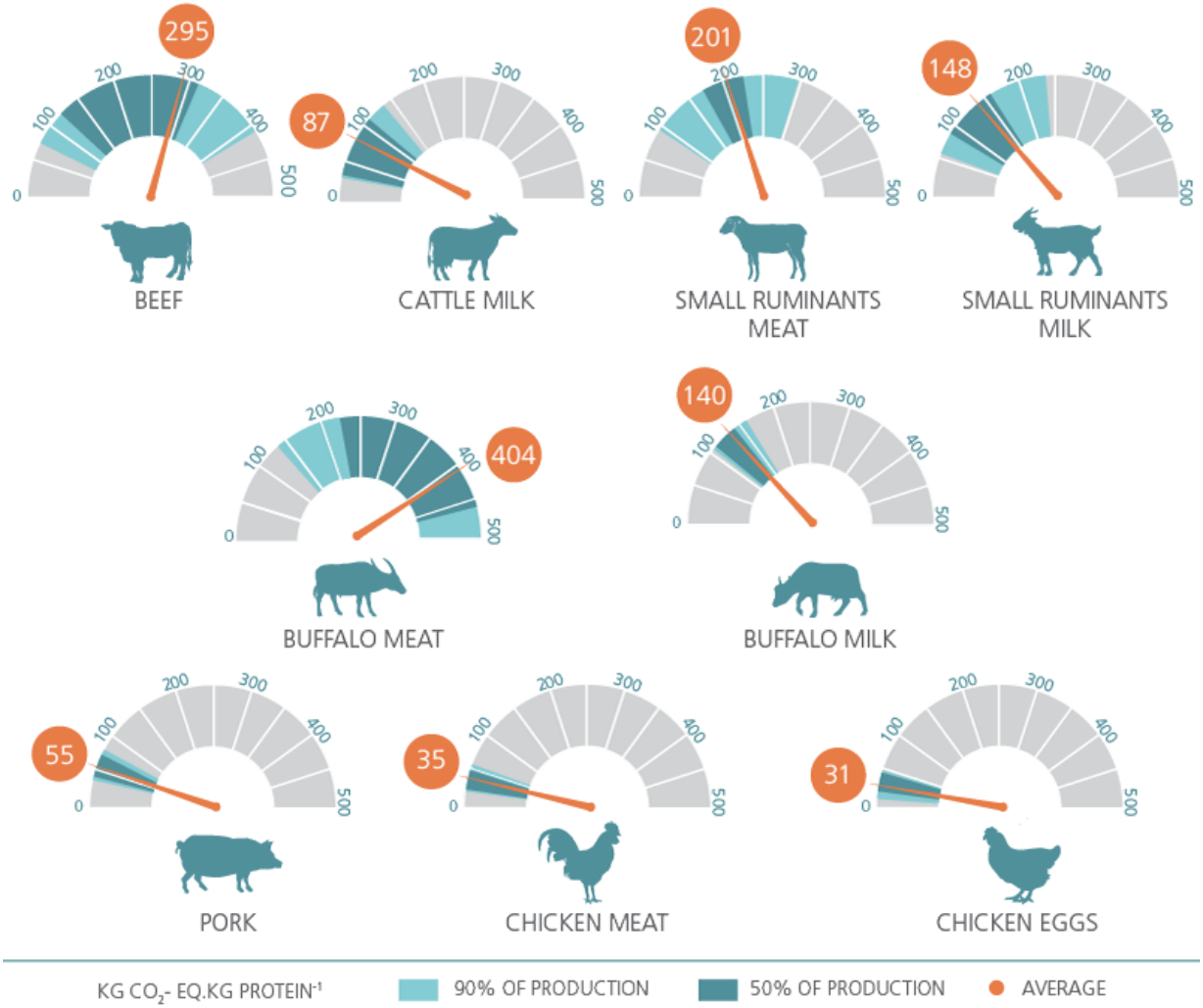

Figure 1.7 - Emission intensities by product expressed in a per protein basis. Averages are calculated at global scale and represent an aggregated value across different production systems and agro-ecological zones (http://www.fao.org/gleam/results/en/).

In beef and dairy systems the **most efficient** (lowest CO_2-eq intensity) are the **intensive ones** (Committee on considerations for the future of animal science research, 2015). This is mainly due to the fact that enteric fermentation leading to CH_4 emissions is highest with coarse, less digestible feed that require more bacterial activity to decompose into digestible components. Other reasons are: a) for extensive systems that are prevalent in developing countries, lower weight and older age at slaughter and; b) more efficient manure management of specialised systems (Gerber PJ *et al.*, 2013).

An example of the effects of improved efficiency comes from the dairy sector, whose emissions grew by 18% between 2005 and 2015, while milk production increased by 30% (FAO and GDP, 2018). Despite this overall trend, **huge differences in emissions per kg milk produced persist between geographic areas and management systems**. Indeed, whereas global milk production increased worldwide, in some parts of the world this was due mainly to the expansion of herds than to increased productivity; for instance, in Sub-Saharan Africa the herd increased by 3.8% p.a. while yield decreased by 2.5% p.a. between 2005 and 2015 (FAO and GDP, 2018).

The higher efficiency of intensive specialised beef and dairy systems is an argument that the livestock industry of the wealthy economies (mainly N.America and Europe) often brings into the public debates on environmental sustainability; the reasoning is that it is not the most efficient systems that should be penalised by measures aimed at defending the climate.

However logical that may seem, it evidently misses the social aspects; **producing efficiently in the developed world** does not contribute to the welfare of pastoralists in Africa and Central Asia, **nor does it ensure food and nutrition security to the poor** of the world who lack the resources to have access to animal source food. Once again FSN (Food Security and Nutrition) is not so much a matter of **availability** as of **accessibility**.

Indeed, the greatest contribution towards a reduction of global emissions would come from improvements of efficiency in developing countries rather than further efforts on already well performing management systems (FAO and GDP, 2018).

Pigs and poultry have a much **lower impact** on climate **per unit protein** produced than ruminants. One of the reasons, of course, is that they produce far less methane during the digestion process (but both methane and nitrous oxide are produced by manure); the other is that both pigs and poultry are raised either in intensive systems that depend on external inputs for feed but in an efficient way, or in backyard systems where their feed comes from residues of human food or of other agrifood processes that are accounted for CO_2 in other sectors.

Another interesting comparison can be made between regions (**Figure 1.8**). Five regions of the world combined, East/S.East Asia, Latin America, Western Europe, North America and South Asia produce more than 83% of all the (terrestrial) animal proteins of the world.

But the makeup of the mix is different from region to region and this affects total emissions, as has been shown before. East/S.Asia (dominated by China) produce proteins mainly with pigs and poultry (low emissions per unit protein), whereas beef has a large share in America (particularly in S.America).

Eastern Europe, the Russian Federation, Oceania and the whole African continent represent a very small share of global animal protein production.

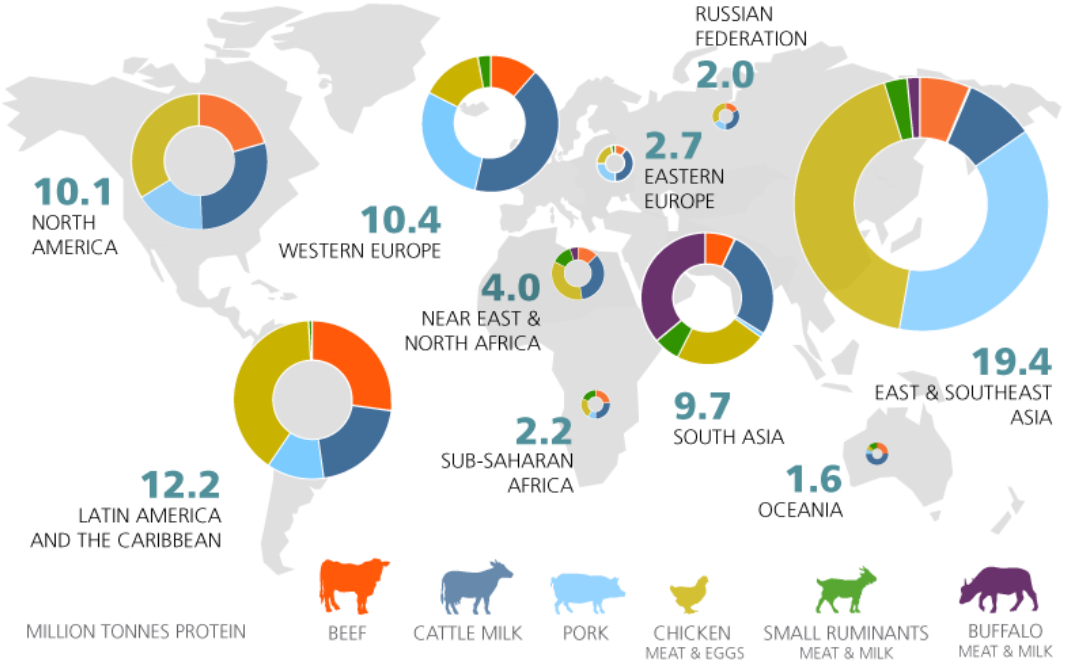

Figure 1.8 - Regional production of animal proteins by animal group (http://www.fao.org/gleam/results/en/) .

This translates into a different ranking of regions by GHG emissions, with S.America leading the group, due to the prevalent beef industry and by deforestation to increase surfaces for pastures and soy crops, followed by East/S.East Asia and S.Asia (**Figure 1.9**).

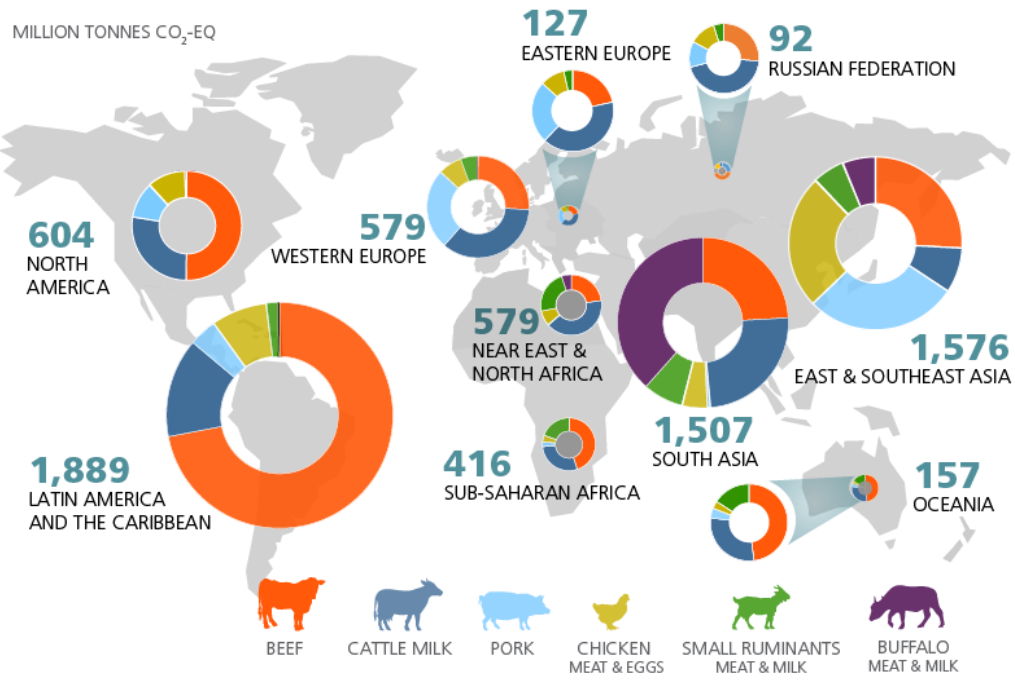

Figure 1.9 - Regional total emissions and their profile by animal group (http://www.fao.org/gleam/results/en/).

A visual representation of different criteria in the comparison of the contribution of livestock systems to GHG emissions is represented by **Figure 1.10** where emissions are reported per unit protein produced (a), per unit of land (b) and per unit of people (c).

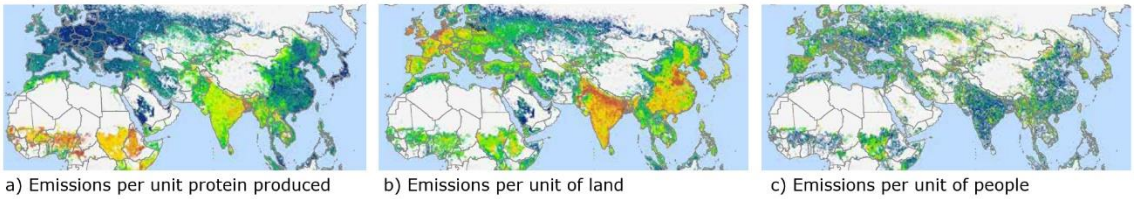

Figure 1.10 - GHG emissions by the livestock sector expressed according to different criteria: by production, by land and by human population density (from Gerber PJ *et al.*, 2013, mod.). Cold colours represent low emission, hot colours high emissions.

Figure 1.11 provides a synthesis of emissions due to production of feed and livestock management subdivided by animal group, taking into account the different composition of feed between species. The figures may differ slightly from those reported above due to different periods considered, but the relative proportions are robust.

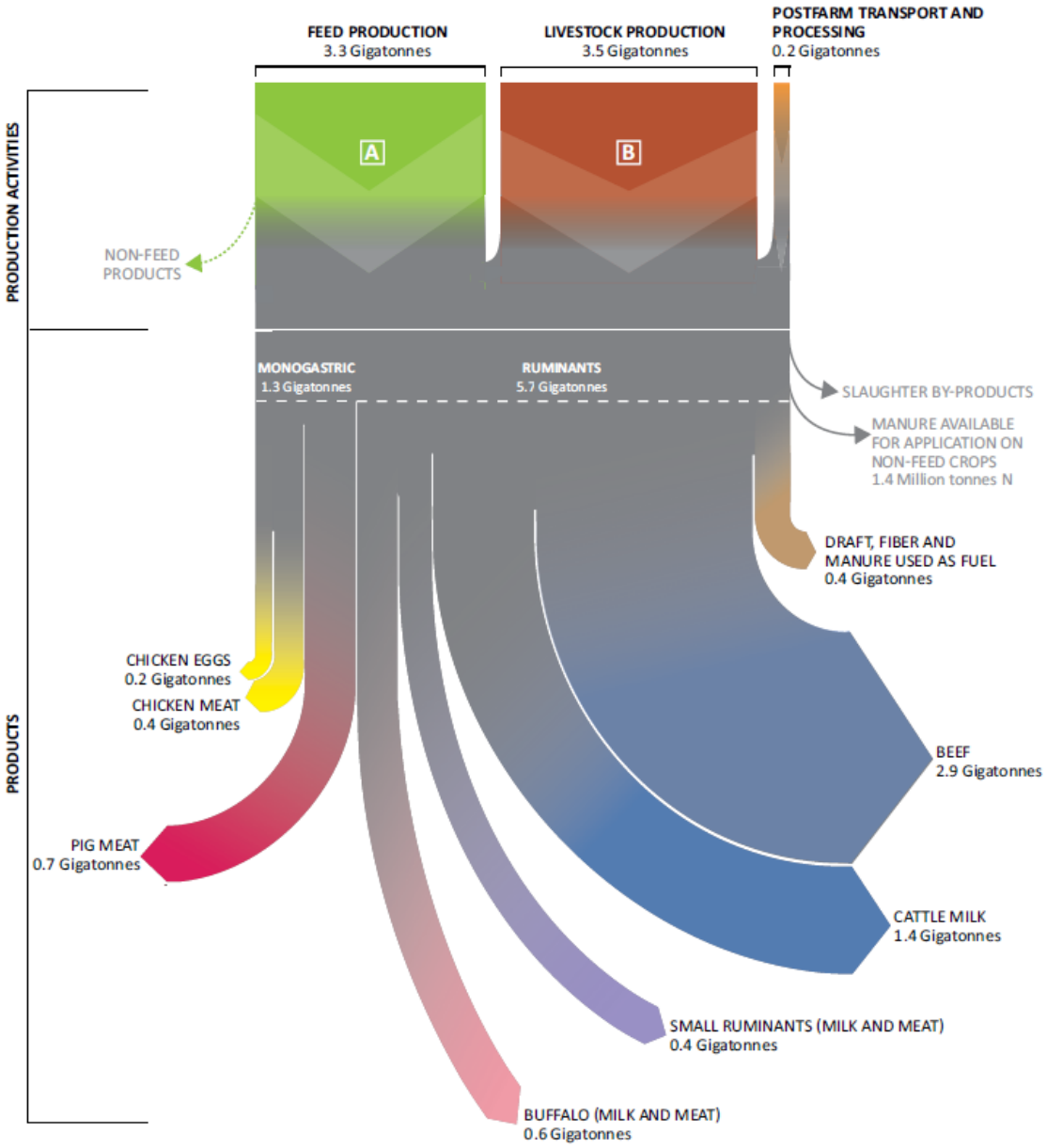

Figure 1.11 - GHG emissions from global livestock supply chains, by production activities and products (from Gerber PJ *et al.*, 2013)

1.4. Mitigation options

A broad range of mitigation options exist for the different sectors and regions, according to the species, the type of livestock system, the availability (technical, economical and legal) of solutions.

Upstream (feed production) and downstream (manure treatment) improvements can come from better techniques applied to crop/meadow fertilisation and to the way excreta are collected, stored, treated and distributed.

The **animal efficiency** can be increased by improving productivity with **selective breeding** (more product per unit input), by reducing the breeding overhead (number of animals kept to reproduce the stock but otherwise unproductive), by reducing the time to the first pregnancy and of weaning (less unproductive time), by extensive use of sexing in assisted reproduction (to increase the share of females in dairy systems and of males in beef systems) by improving health (less losses), by improving the digestibility of feed (different components and/or pre-treatments), by improving the management of grazing (intensive grazing followed by rest periods on a rotational basis).

Other options, such as vaccines or supplements to alter the make-up of the rumen flora in ruminants are still the object of research and under scrutiny by regulatory authorities for their safety (Gerber PJ *et al.*, 2013).

It must be emphasised, however, that all **mitigation options** should be considered in the context in which they are applicable and should be both **technically feasible and economically convenient**. Economic advantages can derive either from increased revenues (e.g. more products per unit input), reduced costs (e.g. valorisation of slurry and other excreta for the production of energy) or incentives.

One of the strategies proposed to reduce the contribution of the livestock sector to climate change is the widespread adoption of the techniques in use by the best performers in their class, that is, by **closing the gap between the producers with highest emission intensity and those with the lowest**. This process can be facilitated by improving access of farmers to extension services and technical education, by providing access to credit for investments, by sharing the cost of improvements between public and private.

However, a generalisation of solutions is a dangerous temptation. All should be considered within the social, economic, cultural, environmental context in which they are to be applied. Solutions applicable to grazing beef systems in Ireland cannot be blindly exported to Masai herders in Kenya or to the Argentinian Pampa.

A final consideration on the improvement of efficiency. One should be aware that **improved efficiency is a powerful incentive to increase the volume** of the activity to profit from economies of scale. The advantages obtained on a per unit basis would stimulate a global expansion of the industry, thus exacerbating the overall environmental impact (the Jevons paradox[2])

[2] https://en.wikipedia.org/wiki/Jevons_paradox

1.5. Animal health

Animal health is fundamental *per se*, as a means to protect capital, incomes and trade, as a way to reduce impact on climate (loss of production and waste of the resources employed) and as a way to preserve human health, due to the many zoonoses that are shared by animals and humans. Animal diseases are a major cause of losses to livestock systems in developing countries and a constant major concern of advanced economies as well (HLPE, 2016).

Various estimates in different parts of the world and livestock systems calculate the burden of diseases at 6-15% of the total value of the industry (HLPE, 2016), with cattle more affected than other animals, young animals more than adults and pastoral systems more than mixed or intensive ones.

Veterinary surveillance and preventive medicine (especially through vaccinations) are the most effective options, but usually available in wealthy economies in a really effective structure.

One major concern is the excessive use and often erroneous use of **antibiotics** that leads to a loss of efficacy in the treatment of human diseases[3]. Although many restrictions have been imposed by regulatory agencies in many parts of the world, AMR (Anti-Microbial Resistance) remains as a top priority in animal science. The main threat concerning AMR comes indeed from the wrong use of antibiotics in human medicine (unnecessary prescriptions, therapy interruptions) but their use in animal farming should be limited to therapy and not as a way to improve production (e.g. by selecting bacterial strains in ruminants).

Although most developed countries have posed restrictions on the use of antibiotics, especially as growth promoters, many countries in the developing world are still massive users; it has been estimated that China alone consumes around one third of all the antibiotics produced in the world (HLPE, 2016).

[3] it is estimated that **antimicrobial resistance results in the annual death of 25 thousand people** across the **EU** and 700 thousand people globally due to induced resistance in pathogen bacterial strains, popularly called "super-bugs" (Buckwell and Nadeu, 2018).

1.6. Animal welfare

Opinion movements on the welfare of animal farms started already half a century ago, when a British *ad hoc* committee stated that farm animals should have at least the space needed to lie down, stand, turn around, scratch and groom (the so-called five freedoms); these "rights" were then expanded to include freedom from "fear, distress, discomfort, pain, injury, disease, hunger, and thirst" and the right to express a normal behaviour, including the company of fellow animals.

Many regulations have been issued and enforced in different parts of the world, with Europe as a leader (ATF, 2019), but many cases of voluntary adhesion to animal welfare principles and practices are observed nowadays by big producers and pushed by retailers, in response to public concern that translates into consumer's choice.

Welfare impairment is generally the consequence of overcrowding or confinement in restricted spaces. However also gory practices are a growing source of concern by the public and of regulation by Authorities: tail docking of lambs, de-beaking of poultry, castration of male pigs, etc. are being restricted in Europe (Buckwell and Nadeu, 2018).

Animal welfare is a key component of the concept of **"food integrity"** (ATF, 2017) that is becoming a guiding principle in the choices of consumers and includes also authenticity, safety, quality, respect for the environment, minimal impact on climate, fair compensation of farmers, safe and decent working conditions, etc.).

1.7. Human health and diets

The role of meat and other ASF products as components of healthy human diets is the subject of controversies. Undoubtedly the **quality of proteins of meat** (and of milk, eggs and fish) is higher than that of plants, due to the similarity of amino-acid composition with human proteins, high iron content and availability (more in red than white meat and higher in meat than plants), vitamins (D and B12) and minerals (Buckwell and Nadeu, 2018).

ASF (meat, eggs, milk) are essential in the early phases of life and for the nutrition of pregnant and lactating mothers (WEF, 2019a).

However, dietary advice from governments (health services) and the scientific community (nutritionists) often **warn against an excessive consumption in many developed countries** and in more **affluent sectors** of societies also in the **developing world**, leading to an increased risk of cardiovascular diseases and other NCD (Non-Communicable Diseases) (HLPE, 2016).

The real responsibility of meat in the increase of NCD is a subject of debate; excess of sugars and fats are indicated as the main culprits for type 2 diabetes and obesity, but saturated fats, more abundant in meat than fish or vegetables, certainly play a role in cardiovascular diseases. In addition to that, certain processed meats contain nitrite and N-nitroso compounds (NOCs), polycyclic aromatic hydrocarbons (PAHs) and heterocyclic amines (HCAs). These latter compounds are likely increasing the risk of cancer (**colorectal cancer**), which induced the IARC (International Agency for Research on Cancer - WHO) to include red meat in the group "Carcinogenic to humans" (although not unanimously)(Buckwell and Nadeu, 2018).

On average, European countries, as most developed countries, consume much more meat than what is recommended by NDG (National Dietary Guidelines)(Buckwell and Nadeu, 2018). Campaigns to moderate the consumption are generally opposed by the industry, often borrowing communication and lobbying strategies that had characterised the tobacco industry in previous decades.

However, it must be pointed out that most nutritionists point at excessive overall quantities of food as the cause most health problems and do not demonise meat *per se*. In fact, **a Manichean exclusion of any group of foods is likely deleterious**, be it fat, sugars, meat as most foods are rich combinations of nutrients, each one likely to have a metabolic function (ATF, 2017). Quantity is indeed the key and, as far as meat and other ASF products, the European average consumption is still far above the WHO recommendations[4]; if one should be careful in reading averages[5], as a society

[4] The World Health Organization and the Food and Nutrition Board of the US National Academy of Sciences recommend a dietary reference intake (DRI) of 0.8 grams (g) of protein per kilogram of body weight (WEF. 2019a).

[5] "*Da li conti che se fanno/secondo le statistiche d'adesso/risurta che te tocca un pollo all'anno:/e, se nun entra ne le spese tue,/t'entra ne la statistica lo stesso/perché c'è un antro che ne magna due"* (Trilussa, roman dialect poet, 1871-1950) [According to current statistics, it turns out that you get a chicken a year: but if that does not appear in the records of your expenses, you still get it according to statistics, because there is another one that gets two].

there is still room to manoeuvre to reduce the impact on climate that the livestock sector contributes to.

The industry is mainly aiming at improving convenience, taste (sweet, fat, salty), shelf life and low price in standard products with respect to nutritious properties; and to offer health promoting food and food supplements at premium prices (HLPE, 2016), aided by vigorous marketing strategies.

Zoonoses are another reason for concern. It is estimated that 60% of all diseases and 75% of new diseases have an origin among animals; quite often from wild animals mediated by domestic animals. Although the high densities of specialised systems are ideal for harbouring zoonose agents, more careful surveillance and the wide use of antibiotics in intensive systems shifts to mixed animal farming, especially in the developing world, the ideal breeding ground of old and new zoonoses (HLPE, 2016).

The largest source of zoonoses are eggs (especially Salmonella) and poultry meat (Campylobacter), often caused by incorrect storage and preparation at home (Buckwell and Nadeu, 2018).

1.8. Feed technology

The livestock sector is often criticised from the point of view of an optimal use of limited natural resources for being **inefficient**. In fact, a variable share of the energy intakes by animals are used for their metabolism and only a fraction (higher in pigs and poultry than in ruminants) is recovered in the final product.

However, it must be clarified that an estimated **75% of dry matter the goes into animal feed is inedible for humans** and that only half of the remaining 25% is represented by grains that could have a human food use. A further increase of the number of animals, however, would probably come into conflict with human food production, at least for surface, as further expansion of pastures is not desirable from an environmentally point of view (a still existing phenomenon in S.America) and arable lands should be preferentially used to produce food for a population that will reach 9.8 billion in 2050.

Feed sources that do not compete with human food production or come as by-products of human food industrial processing are increasingly scrutinised for animal feeding.

The Committee on considerations for the future of animal science research (2015) provides a non-exhaustive list of such by-products: "*bakery by-products, wheat midds, wheat bran, corn gluten feed, corn gluten meal, brewers grains, fish meal, meat and bone meal, poultry by-products, peanut meals, peanut hulls, rice mill by-product, rice hulls, soybean meal, canola meal, almond hulls, citrus pulp, sugar beet pulp, sugar cane molasses, yeast, animal fat, whey, and blood meal*".

It must be pointed out, however, that the new bio-based technologies in the production of chemicals and materials provide in many cases alternative pathways for the utilisation of such by-products (Buckwell and Nadeu, 2018).

Insects are being proposed as efficient sources of proteins for animal (especially mongastrics) and fish (especially carnivores) feeding.

Research is also ongoing on additives, probiotics and prebiotics that would enhance the activity of the gut microbiome without the use of antibiotics.

Another important area of research regarding feed is its safety, and, in particular, the possible contamination of ASF by toxins contained in feed ingredients (e.g. mycotoxins from cereals) or in pasture herbs.

1.9. Industry concentration

The agri-food sector is witness of a wave of mergers and acquisitions that **concentrate economic power** and increase the opportunities for capital owners to control and direct key sectors not only by **directing investments**, but also by **reducing the autonomous decisional space of enterprises in neighbouring domains** and exerting a strong influence on policy and regulation development.

Concentration can be horizontal (acquisition of competitors in the same product line) and vertical (creation a complementary group of industries that operate at different levels of production chains).

Some of the industrial sectors involved have a direct or indirect influence on the livestock industry.

Livestock genetics is increasingly becoming a high-tech sector, after the introduction of artificial insemination, semen selection, embryo transfer, cloning, genomics. If this improves the performance of livestock, it also pushes the industry to focus on the most rewarding breeds and neglect the rest, with a dramatic impact on biodiversity (IPES-Food, 2017).

- **Broilers** (meat): three firms (DE, FR, US) produce 95% of the commercial breeding stock.
- **Layer hens** (eggs): two firms (both US) control 90% of genetics worldwide.
- **Turkeys**: two firms (same as for layers) control virtually all the industrial genetics worldwide.
- **Pigs**: three firms (UK and two US, same as for layers and turkeys) supply almost all global pig stock for industrial systems.

Another sector of ongoing concentration that is relevant for the livestock industry if that of animal **pharmaceuticals**, with eight firms having sales for almost 80 % of the industry's total (IPES-Food, 2017).

It must be said, however, that despite the (alarming) degree of concentration, the two sectors of animal genetics and animal pharmaceutical are the smallest in the whole agri-business in terms of value. Agrochemicals, fertilisers, machinery, grain trade, etc. are far bigger businesses, as well characterised by a concentration trend.

Big global players are found also in the **meat processing** sector, with three companies from Brazil, three from the US, and one each from China, Germany, Japan and the UK dominating the market.

A phenomenon is spreading worldwide, especially with pigs and poultry: the **production by farmers under contracts that dictate the source of the breeding stock and the purchaser of the finished animals**. The farmer bears the risk of rearing the animals but has no real freedom of operation.

Concentration has detrimental effects also on research and innovation. Whereas the resources for such activities are huge, the scope is reduced, with big companies concentrating on the most lucrative segments of business and using acquisitions mainly to obtain economies of scale (IPES-Food, 2017).

1.10. Alternatives to meat

The future of meat and other ASF also depends on the range, quality, cost, palatability and cultural acceptance of alternatives.

The traditional alternative to animal proteins (including fish) is plant proteins that are present (albeit at a lower quality and quantity) in plants, especially pulses. Indeed, a large share of humanity, either for traditional cultures (e.g. India) or individual conviction (for health reasons or on moral grounds) avoid meat (much less ASF). They can generally lead an absolutely healthy life (even healthier than meat eaters) provided that a sufficiently diverse diet guarantees the intake of all the nutrients and minerals required by the organism.

The most commercially successful alternative to meat, so far, have been proteins from fungi (**mycoproteins** from fermented *Fusarium*) (WEF, 2019b). New alternatives include **"meat-like" meatless products** that reproduce the feel and taste of meat without it being an ingredient. Some non-meat burgers are even enriched with a synthetic "haemoglobin" that confers to the "burger" sensory qualities of the standard meat ones.

Insects are advocated as a key alternative to conventional meat, as a source of proteins, and indeed insects are already a common food in many parts of the world[6]. It is not possible to foresee their role in feeding Europeans, likely restrained from consumption by cultural aversion only.

Cultured meat is obtained in the lab from stem cells and should in principle be acceptable to those who refuse the sacrifice of animals on moral grounds. The prospective use is again as substitutes of burgers. There are two main constraints at the moment: the high cost and the doubts about sustainability, as ingredients for the culture media have to be produced somehow; some (like serum) are of animal origin, and the whole process requires energy and infrastructures that are now in their infancy. According to some LCA studies, cultured meat is only marginally less impacting on climate than beef meat, at least under current production techniques (WEF, 2019b).

Not all alternative sources of protein, however, are likely to improve health. For instance, the fashionable alga *Spirulina* (actually a *Cyanobacterium*) is rich in sodium; artificial heme in vegetable burgers can bring about the same risks as red meat heme, the main culprit of red meat negative effects on health (WEF, 2019b); insects have generally a high cholesterol content.

[6] See: **Edible insects - Future prospects for food and feed security**. FAO Forestry Paper n. 171 (2013) http://www.fao.org/3/i3253e/i3253e.pdf.

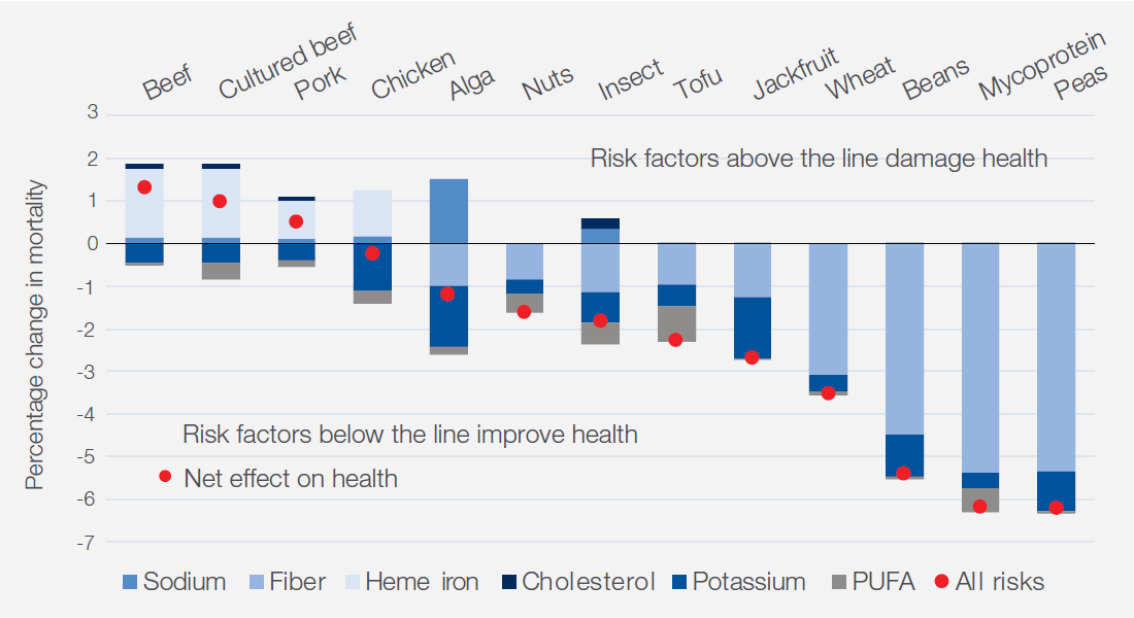

Figure 1.12 - The health effects of consuming an additional portion of 200kcal/day of different alternative proteins (From WEF, 2019b). Sodium, heme iron and cholesterol would increase mortality; fibre, potassium and poly-unsaturated fatty acids decrease mortality. The overall effect of a type of meat or its substitutes is calculated as the algebraic effect of all factors combined.

Despite the many new developments and the already well established alternatives to meat (e.g. tofu), not to mention the traditional protein rich legumes and derived products, it is only a **matter of speculation whether a real competition from alternative proteins will come to the meat sector**. The future will not depend only on the technological advancements in quality, taste, feel and palatability, but also on the importance that society will attribute to individual health, the preservation of climate from further changes and animal welfare (in particular the idea of sacrificing 66 billion animals each year).

1.11. Safe operating space

The concept of a "safe operating space" for the livestock sector is inspired by the seminal work of Rockström[7] and prompted the RISE Foundation (Buckwell and Nadeu, 2018) to try and figure out if one could be defined for Europe, despite the complexity of the issue.

In theory the problem can be framed in a simple way. **A)** define the lowest "size" of the livestock sector that ensures essential benefits (food security and nutrition, maintenance of pastures, nutrient cycling, etc.) and take the highest among them as a lower boundary; **B)** define the lowest "size" that is compatible with negative effects (GHG emissions, antimicrobial resistance, pollution, excessive consumption, etc. and take the lowest as an upper boundary (see **Figure 1.13**).

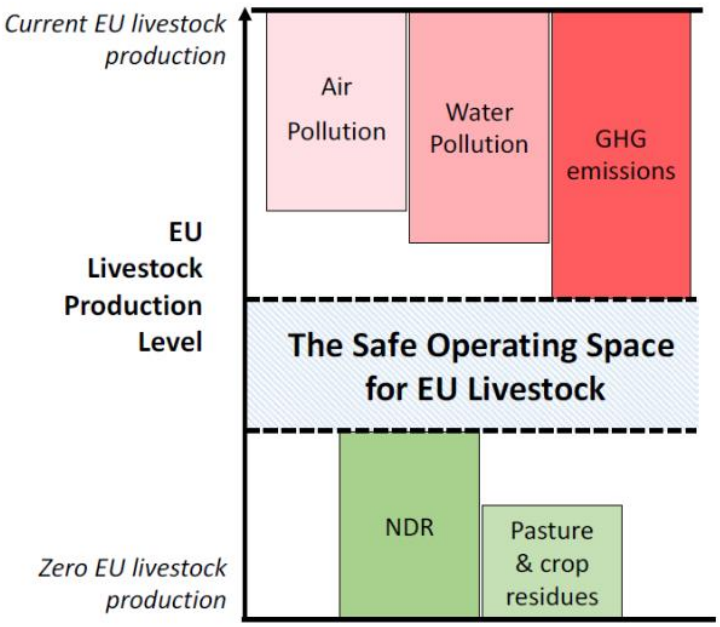

Figure 1.13 - Conceptual frame for a "safe operating space" for the European livestock sector. Factors, scales and proportions are only for discussion purposes and do not correspond to observations or estimates (From Buckwell and Nadeu, 2018).

Moving from a theoretical frame to the real world is fraught with difficulties. There is a non-negligible influence of imports and exports; the quantification of many variables is subject to interpretations; some are not even measurable (cultural values, for instance); the regional effect is certainly relevant. It is even possible that a "safe operating space" did not exist. However, the importance of the issue should not discourage further investigations; quite the contrary: it should recommend a significant effort towards a reliable modelling and quantitative analysis.

[7] Rockström *et al.* 2009. **Planetary boundaries: Exploring the safe operating space for humanity**. Ecol. Soc. **14**, 32. http://www.ecologyandsociety.org/vol14/iss2/art32/.

A preliminary quantification is proposed by the RISE Foundation (Buckwell and Nadeu, 2018) for the evaluation of a boundary on meat and other ASF consumption based on **NDR** (National Dietary Recommendations), which can vary considerably from country to country within Europe but are **invariably lower than observed actual consumptions for meat**. For dairy and eggs the situation is more varied with some countries exceeding recommended levels and some countries failing to reach them.

Similarly broad calculations are made to estimate the stock of grazing animals that would be necessary to preserve the European pasture lands. Depending on the grazing intensity hypothesised (1 or 0,5 LSU/ha) few (Estonia, Latvia, Slovakia, Bulgaria and Romania) or none of the EU countries would need to increase their stock.

Estimates based on GHG emissions are complicated by the way statistics treat agriculture, focused on non-CO_2 emissions (under the "best effort strategy"), and ignoring emissions connected to imported feed.

The main changes in **GHG emissions by the European livestock sector** in the recent decades are attributable to a **decline of stocks** (especially in Eastern Europe) and, to a lesser extent by improvements in management (particularly in manure management). However, if agriculture should contribute to international reduction commitments as other sectors, the 2020 target would be reached just because of the decline of stocks in the new MS and the commitments for the years up to 2050 would require a significant further reduction (Buckwell and Nadeu, 2018). There might be room for improvements from a better management, but a further reduction of stocks would be hardly avoidable.

The estimates of boundaries for Nitrogen are complicated by the interaction of the different sources: manure, synthetic fertilisers, nitrogen fixation by plants and deposition from the atmosphere.

Even more indeterminate would be evaluations of impacts of variations in livestock on jobs, biodiversity, soil degradation, zoonoses, etc.

1.12. Agroecology as a possible transition

The agroecological approach to farming relies on the synergies that can be established between components of a complex agroecosystem to guarantee productivity, plant and soil health without recurring to external inputs of synthetic chemicals.

In this respect, **animals** can be well integrated into mixed farming systems as useful **producers of manure** to fertilise fields. Keeping animals outside a circular integration into farming systems contributes to a waste of resources as animals are, by definition, inefficient producers of food, due to the waste of energy for their own metabolism and are thus considered as "land multipliers" (make use of more land than would be necessary to produce the equivalent amount of plant source food)(IPES-Food, 2016). The argument about the inefficiency of animals as source of food, when the intake exceeds what is needed for a good health, is based on the consideration that proteins in excess of dietary needs are used by the human body just as a source of energy and, as such, meat and other ASF are, by definition, more inefficient than plant products (Buckwell and Nadeu, 2018).

One of the main objections that is addressed to Agroecology (as well as to Organic and Biodynamic farming) is that without the use of external inputs (synthetic pesticides, herbicides, fertilisers, whose negative consequences on environmental and human health are well established) agricultural production would be reduced to such an extent that it would fail its first goal, that is ensuring FSN. IDDRI (*Institut du développement durable et des relations internationales*) performed a model-based analysis (Poux and Aubert, 2018) of a possible future landscape in which the European agriculture adopted agroecological principles and practices and tried to figure out if and how such a perspective could materialise. It is assumed that recommendations of the international health agencies as to the appropriate levels and mixes of foods would be followed. A reduction in crop productivity is acknowledged and estimated at 35% by extending observations of the organic sector. In such a scenario the European agriculture would provide safe, nutritious and sufficient food to Europeans, while preserving some capacity of export; it would reduce the food footprint of Europe (now extending to other continents through imports); it would reduce GHG emissions from agriculture 45%; it would allow a recovery of biodiversity and natural resources.

As far as the animal sector is concerned, the model *TYFAm* used by IDDRI (Poux and Aubert, 2018) postulates an overall reduction of animal production by 40%, which would meet the WHO and EFSA recommendation for healthy diets. A reduction of the "herd/flock" would require less dedicated crops and less imports (with domestic production based on less grains and more protein crops), replaced by broader areas left as grasslands and pastures. Biodiversity would be enhanced (less chemicals, more accompanying crops, hedges and new woodlands), imports would be strongly limited (coffee, tea, palm oil) and exports focused mainly on high quality/high value products, such as wine and cheese.

A reconnection between agriculture and livestock on a territorial basis is necessary for a number of reasons: **a)** Manure would be a key source of nitrogen for crops (cereals, vegetables and oil crops); **b)** More dependence

on pastures and grasslands and less on externally sourced feed would imply a broader distribution of herds on land; **c)** legumes, that represent the other source of nitrogen fixation, are better exploited in mixtures in grasslands (Poux and Aubert, 2018).

For the very same reasons, and contrary to the current dominant view, **it is the ruminants, despite their high methane emissions, that should be considered the livestock of choice**, as they can feed on grass. This does not mean wiping out the pig and poultry sectors, but that these would be the most affected by numeric reductions; soybean imports, that are now necessary to keep the two sectors alive would be only partially replaced by an expansion of protein crops and an integration with other productions at the farm level or at the territorial level (e.g. exploitation of by-products of agro-industrial processes) would limit the availability of side-streams of the food industry.

Accordingly, cheese would become a central product for European exports (along with wine). Meat would cease to be an exported good.

Contrary to the agroecological approach are those systems that segregate animals from the land that nourishes them, and especially those livestock management models that go under the acronym CAFO (Concentrated Animal Feeding Operations) and rely on feed produced by specialised monocultures (maize, soy). CAFO and any system that segregates animals from land, increase the risk of point contamination of soil, water and air from effluents.

Another fundamental principle of agroecology is diversity, as a factor providing resilience and robustness to systems. The genetic uniformity of many animal groups (especially poultry, pig and, to a lesser extent, cattle) increases susceptibility to epidemics, the emergence of zoonoses and the preventive use of antibiotics (IPES-Food, 2016).

Therefore, agroecologists suggest **mixed crop–livestock systems** as "*particularly promising in terms of ecosystem services, given that animal manure can be utilized to enhance soil health, fertility and carbon sequestration*" (IPES-Food, 2016).

Quite often, even outside the agroecological framework, small and medium mixed farms, combining crops and livestock are among the most successful in economic terms, as the synergies between different activities and an optimal use of manpower produce economies of scope, if not of scale (WEF, 2019a). An intensification of mixed farms, optimising the use of resources, is probably more successful, also from an economic point of view, than turning to an "industrial" model of livestock management.

1.13. Foresight and forward-looking studies

1.13.1. **Critical Role of Animal Science Research in Food Security and Sustainability** (Committee on considerations for the future of animal science research, 2015)

The report was commissioned by the National Research Council of the USA to a Committee of experts with a mandate to identify research areas and organisational issues that would help to meet the expected growing demand of ASF, with the year 2050 as a temporal target. The FAO projections on future consumption based on current trends are not questioned; increasing population and incomes are expected to drive the growth of consumptions.

The perspective adopted is US centred, although a favourable impact on global animal productions is the expected fall-out of US research.

Recommendations:

1. Increase public funding, especially on poultry.
2. Favour the adoption of scientific and technological innovation into practice, removing barriers.
3. Understand public opinion and its attitude towards technological innovations.
4. Improve research efforts on the physiology and metabolism of animals.
5. Develop alternative feed sources that do not compete with food production.
6. Develop alternatives to the use of antibiotics.
7. More research, capacity building and awareness raising on animal welfare.
8. Climate change: mitigation options for the livestock sector.

The following research areas are seen as the most promising ones towards a sustainable development of the animal sector:

- *Advances in general biology and other basic research pertinent to understanding animal growth and welfare*
- *Advances in breeding and growth techniques*
- *Advances in nutrition and management*
- *Advances in genetics*
  - *Improve growth characteristics*
  - *Protect against diseases (e.g., reduce antibiotic use)*
  - *Identify and select for traits in animals that increase their adaptability and resilience to climate change and variability*
  - *Identify and select for traits in animals and in gut microbiomes that increase animal nutrient and energy utilization, and decrease nutrient excretion*
- *Advances in technology*

  - *Minimize animal production wastes and improve nutrient recycling in animal and plant agriculture*
  - *Minimize environmental and resource use footprints*
  - *Improve animal welfare*
  - *Protect against disease*
  - *Minimize spoilage of food (e.g., through better packaging)*
- *Advances in social sciences*
  - *Improve communication among the public, the food animal industry and scientists*
  - *Improve understanding of the economic and social drivers that govern (impact) food animal development*
  - *Improve understanding and development of policy tools that optimize animal food production*

1.13.2. An updated SRA covering animal health and welfare (ANIHWA, 2015)

The FP7 ERA-Net ANIHWA produced an update of a Strategic Research Agenda worked out under a previous ERA-Net, EMIDA, and published in 2011. The goal was stated as follows: "*To identify the scientific and technological needs to prevent, control or mitigate animal health and zoonotic challenges and address animal welfare requirements for 2030 and beyond*".

The approach used for its development was that of a foresight exercise based on scenarios that do not have the ambition to predict future developments or to assign likelihoods to any of them, but rather to represent possible futures and derive coherent research priorities.

The first stage consisted of an enumeration, followed by a prioritisation, of drivers with a significant prospective effect (either positive or negative) on the health/welfare binomial. The main drivers upon which the experts from different disciplines converged were:

- Population size, density and demographic changes, including movement of people
- Economics of farming including profitability and competitiveness
- Balance between economy, ecology, environmental impact, animal welfare and sustainability
- Climate change, including extreme weather events
- Pathogen evolution, including drug resistance

The major drivers were then plotted on a cartesian space with disease groups on one axis and animal welfare on the other assigning a "degree of impact" to the driver on each dimension. The selection of drivers led to the identification of two critical uncertainties (high potential effect, highly uncertain evolution) that were combined to create four scenarios (**Figure 1.14**).

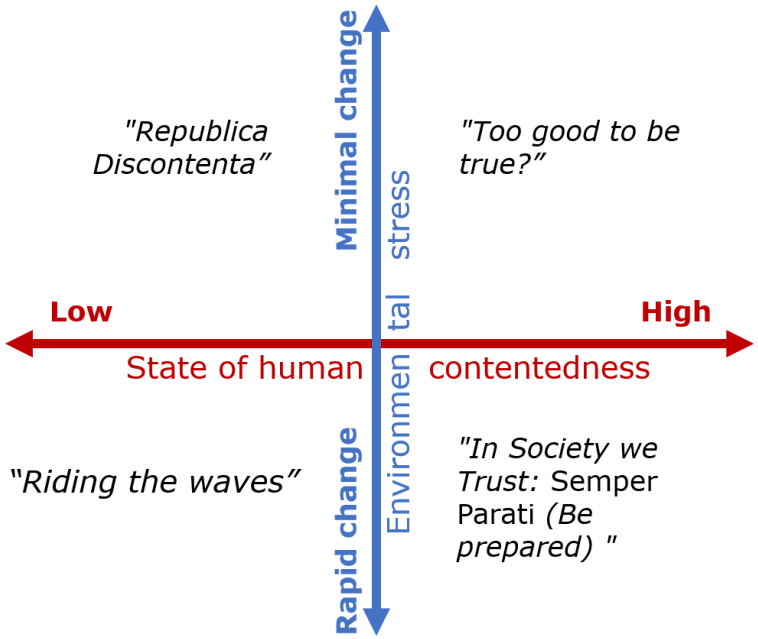

Figure 1.14 - Four scenarios developed by ANIHWA combining two critical uncertainties: the possibility of a rapid change in environmental conditions and the "mood" of society.

"*Republica discontenta*" – Stagnating society, with an ageing population, few opportunities for the young, agriculture taken up by companies. Investors prefer developing countries leaving Europe without or with limited perspectives of a new prosperity. Less attention to animal health and welfare in farms leads to a loss of confidence by citizens in the production system. Immigration creates tensions within societies.

"Too good to be true?" – Reinforcement of the political union process in Europe, with new investments in research and innovation that bring Europe into a leading position in the world. Immigration continues, but the favourable economic situation of Europe makes inclusion a smooth process. Coordination of veterinary services leads to the eradication of several infectious diseases.

"In Society we Trust: *Semper Parati* (Be prepared)" – A cohesive society, with trust in public institutions is prepared and organised for the persisting immigration as well as to tackle new emergencies: new diseases, new outbreaks of old diseases, extreme meteorological events. Free movement of people, a large and free market and good international relationships make of Europe a vibrant society that reacts to new challenges with a constructive attitude.

"Riding the waves" – No real recovery after the 2008 economic crisis, rising inequality in incomes and wealth; immigration creates conflicts with a society that is struggling to cope with economic stagnation. Distrust in European political institutions is mounting, fuelled by nationalist parties that are gaining popularity on the wave of public discontent. The livestock sector is either highly industrialised, but with minimal profit margins or subsistence operations. Sanitary controls and welfare are largely neglected, leading to frequent outbreaks of diseases.

The analysis of the four scenarios and of the challenges posed in each one of them led to the identification of a "desired scenario" for the livestock sector,

described as: "Sustainable livestock production, with healthy animals reared under high welfare standards, disease minimised or rapidly contained, ensuring a safe and secure food supply and economic development" and to a backcasting exercise: that is, to the identification of conditions that would make it a possible future. These conditions were classified, with the help of experts in a dedicated workshop as "barriers" or "enablers" and "under-" or "outside-our control[8].

This process finally led to the identification of Scientific, technological and related needs to prevent, control or mitigate animal health and zoonotic challenges for the following 20 years, with the obvious *caveat* that the

[8] **Conditions leading to a possible desirable future** (ANHIWA, 2015)

	Barriers	Enablers
• Under our control	• Insufficient compliance with the legislative system (AW) • Cost of the AW • Lack of effective indicators for AW • AW, AH: Lack of coordination, access to existing data • Lack of resources • Lack of proactivity • Lack of understanding of decision-making process, public perception • Subsidy system / strategy • Shortage of feed protein within the EU, dependence on import • Lack of knowledge of adaptation measures to environmental changes	• Technology availability • Increase of awareness and communication • IT • Investments • One-health approach (multidisciplinary approach) • Traceability of animal movements
Outside our control	• Water scarcity (including competition) – welfare implications (esp fish), ducks • Health – poor sanitation (endemic diseases and zoonoses) - water capture – water recycling • Water quality (pollutants) (esp imp for fish) • Food – feed conflict (esp. imp for monogastricts) • WTO • Need to include ethical issues, welfare and environmental • Sustainable Resource management (for ruminants) • Carrying capacity • Land use/land use change – competition for resources • Pasture use. Methane production - role of disease in GGH emissions. Disease implications of using different feeds to mitigate GGH emissions • Waste management • Water distributed animal waste on pasture – pathogen spread • Pollution from minerals (phosphorous deficiency) • Public acceptance • Conflict between perceived welfare vs health • Sustainability of rural communities – bigger farms • Balance between livestock production and wildlife • Adaptation of vectors to new environments • Extreme weather events • Natural disasters • Population growth	• Education including introduction to agriculture earlier • Systems approach/systemic thinking • Current disease control infrastructure • Social network • Research networks • Investment in science • Existing technologies in other disciplines • CAP • Public private partnership • International financial system • Environmental stability • Competition • Harmonised international trade regulations

situation might evolve rapidly, with new emergencies that would impose a revision of the priorities identified.

1.13.3. Sustainable agricultural development for food security and nutrition: what roles for livestock? (HLPE, 2016)

This report was produced by the High Level Panel of Experts for the Committee on World Food Security of the FAO. The report analyses the status, challenges, and perspectives of the main livestock systems of the world grouped by animal species, intensity of operations and wealth of countries, exposing the frequent clashes and contradictions among goals, constraints and interests of economic groups *vs* society.

The report then derives key directions for policies that States and international regulatory authorities should undertake in order to promote the role of livestock in the overall sustainable development of agriculture.

In order to ensure a coherent approach in a variety of environmental, social, cultural and economic circumstances, the HLPE first proposes a methodological approach to be adapted to the local situation; see **Figure 1.15**.

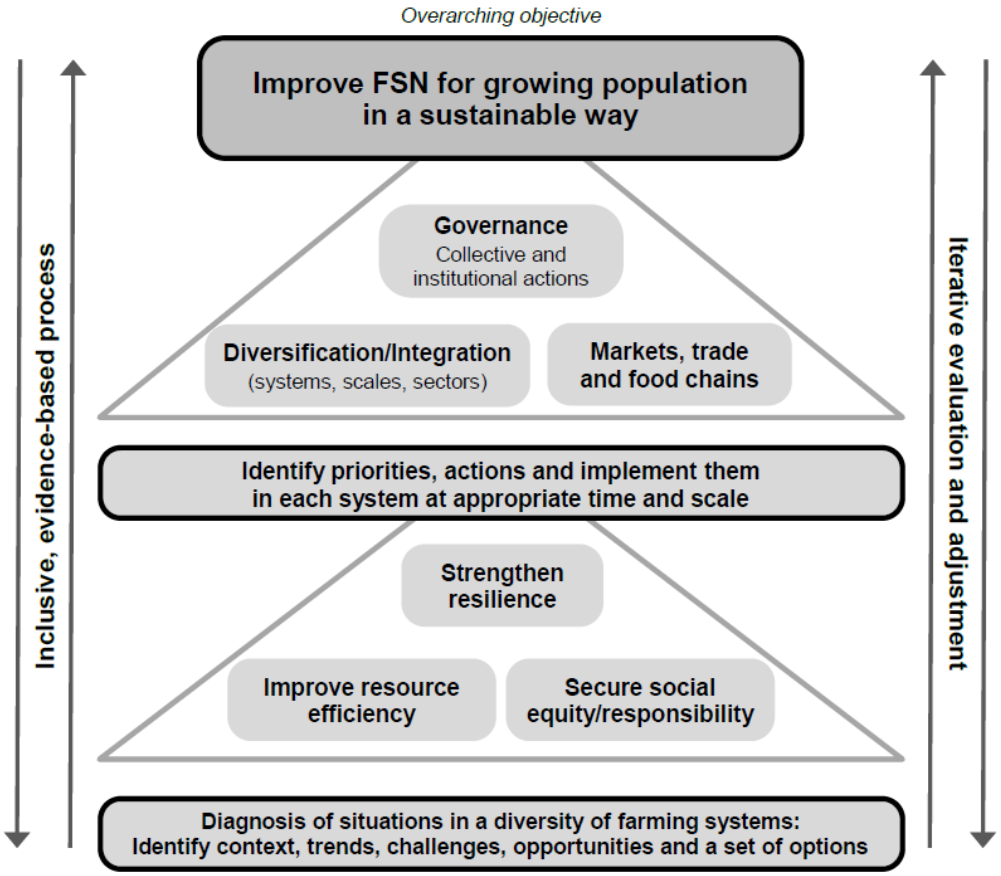

Figure 1.15 - Pathways and responses for Sustainable agricultural development towards food security and nutrition (HLPE, 2016)

Whatever the context, the three principles of HLPE for sustainable agricultural development are:

- **Improve resource efficiency**. This does not mean imposing advanced "industrial" models on developing countries, but rather to close the yield gap between the best and worst performers in a specific socio-economic context. This means facilitating the exchange of knowledge and increasing the participation of stakeholders. Narrowing the yield gap has the potential to improve diets, nutrition, health and wealth without compromising societal fabrics and cultures.
- **Strengthen resilience**. Resilience to environmental, economic, financial and animal disease shocks is based on diversity, on the creation of networks without single-points-of-failure; diversity of crops, farm animals, landscapes as well as biodiversity, including patches of nature intermixed with agriculture are at the basis of agroecology, as a productive model in which the different components interact synergistically reinforcing one another. The agroecological model is often criticised as less productive than conventional "industrial" models and thus unable to "feed the world", but to a large extent this opinion depends on the metric used to evaluate productivity (IPES-Food, 2016). Livestock can be a way to increase resilience, as it can exploit, as feed, parts of agricultural production that are not edible by humans and represents in itself a sort of insurance in case of crop failure. The choice of species and breeds should be dictated by robustness rather than maximum productivity.
- **Secure social equity/responsibility**. The principle is easily stated but its implementation needs a careful adaptation to different social and cultural contexts. It includes "*income distribution, social protection, human rights, gender, tenure and property rights, social discrimination and marginalization, … the responsibility of all actors (individual, corporate, collective) to safeguard the environment, to protect human health and well-being, and improve animal welfare*". The concept should be applied in access to land, protection of customary rights, gender equity, child labour, access to credit, etc.

The HLPE (HLPE, 2016) then identifies the main areas of action towards the development of a sustainable livestock sector as a pillar of sustainable agricultural development and provides suggestion that are applicable in specific models of animal farming (from specialised to extensive) and social contexts (from developing to wealthy economies).

1.13.4. **Focus Group Robust & Resilient dairy production systems** (EIP-Agri, 2018)

EIP-Agri focus groups are teams of experts (from academia, research institutions, industry, administration) that are asked to define sectoral priorities based on an analysis of the current status and the innovation priorities of a productive sector. The group on dairy productions had resilience and robustness as a key target, which they interpreted at three levels: the animal, the farm, the system. The task, at the European level, is not straightforward, due to the broad range of productive systems (herd size, feed type, technological level, economic context, etc).

At the cow level genetics, health, welfare, milk quality are all interlinked factors reinforcing one another. Technologies can help in the early identification of stress factors, health impairment, physiological status (e.g. oestrus, digestion), calf delivery, milk quality (based on a broader range of indicators than those currently in use). A recommendation is made about the use of crossbreeding and the maintenance of genetic diversity as strategies to long term viability of healthy herds.

At the farm level a planning approach is recommended, although a sufficient flexibility is needed to avoid the risks of rapid changes in the economic and social context. Feeding strategies are central, with emphasis of farm self sufficiency, local procurement or exploitation of by-products of the agri-food industry. Independent advisory systems (not flawed by the interests of suppliers), the development of soft skills and integration into community management are advocated for "resilient" farmers.

Concerns for the whole dairy sector are a constant attention to the evolution of societal needs and priorities (quality, welfare, climate and environment); failure to keep a broad view and concentrating on efficiency and cost reduction may determine a fracture between the dairy sector and consumers with negative consequences for all.

The group identified three common pathways for development, all of which would deserve research and innovation efforts:

1. **Precision Livestock Farming** (data integration & interpretation, devices, systems).
2. **Systems**: programmes for dairy farmers to constantly review their production systems and implement the best sectoral practices.
3. **Indices** (integrating selected indicators) to score the degree of robustness and resilience at an animal, farm and system level.
4. **Skills**: skills and knowledge for robust and resilient dairy farms, farmers' training curricula.
5. **Socio-economics**: Coherent sectoral policies, regulations, contracts.

1.13.5. What is the Safe Operating Space for EU Livestock? (Buckwell and Nadeu, 2018)

The report by the RISE Foundation frames the discussion on the sustainability of the livestock sector in Europe within the concept of "safe operational space", one that guarantees the satisfaction of a range of benefits brought about by animal productions (food security and nutrition, maintenance of pastures, field fertilisation, …) and at the same time avoids damages to the environment (GHG emissions, pollution by Nitrogen, loss of biodiversity, …). It goes so far as to devise an interpretation model and to suggest its application, but not further than trying to quantify a few variables ad enouncing what should follow with appropriate research.

The main domains to investigate are:

1. human health and nutrition;
2. utilisation of pasture, crop by-products and residues;
3. culture and livelihoods;

4. climate harm;
5. nutrient cycles;
6. biodiversity;
7. land use and soil degradation;
8. Anti-Microbial Resistance (AMR) and zoonoses; and
9. compromised animal welfare.

The preliminary conclusions are:

- *"EU livestock production and consumption are not in their safe operating space.*
- *Current EU livestock production is associated with greenhouse gas emissions and nutrient flows which are currently far higher than the upper boundaries of the SOS and is therefore unsustainable. Reductions in these leakages of the order of 60% or more are indicated.*
- *Current livestock consumption and production are considerably greater than the lower boundaries of the SOS based on national dietary recommendations and on pasture utilisation. Also, the boundaries established for these two variables imply production levels greater than those required to respect the upper boundary for GHG emissions.*
- *These findings imply uncomfortable choices for society. However, it is clear that respecting the upper environmental limits should take precedence over the cultural lower boundaries."*

In the current level of development, the modelling is rather crude and does not lend itself to confident operational choices. One problem is the level of granularity; whereas GHG emissions can be considered a global issue, due of the broad circulation in the atmosphere, and biodiversity more or less the same, other factors have to be detailed at the levels of states, regions or even smaller territories to be significant (soil degradation, point pollution, social aspects).

A further limit, that could be removed or mitigated by advanced modelling, is the complexity of relationships between variables, some acting synergistically and some in an antagonistic way.

The report advocates further research to address these uncertainties and provide structured reliable data to the model. It also advocates a higher consciousness by citizens leading them to informed decisions that will shape the future of the market, eventually.

The real merit of the report is to have started a debate on these crucial issues and to have proposed a valid conceptual framework for further modelling work.

The study acknowledges the difficulties any transition towards a smaller livestock sector would face. It is not only a matter of changing cultures, habits, tastes of citizens (which cannot be enforced anyway) but of meeting with fierce resistance from farmers but, even earlier, form the producers of inputs, such as genetic material, feed, machinery and of the downstream sectors (abattoirs, meat processing industries, dairy industries, retailers).

1.13.6. The Safe Operating Space of livestock, Rise report - Panel discussion at launch event (Peyraud, 2018)

This short document is a written version of the positions expressed by the Chairman of the Animal Task Force at the launch event of the RISE Foundation report (Buckwell and Nadeu, 2018)

Some of the background considerations of (Buckwell and Nadeu, 2018) are confirmed, especially the need to tackle the issue of climate change and of the livestock contribution to GHG emissions. However, the main responsibility of altering a previous ecologically sound integration of animals in farm activities is attributed to the progressive specialisation of animal farming and its isolation from other farming activities; this has transformed manure from a resource to waste, from a valued input to a burden.

It goes on by reminding the fact that a large share of animal feed would be inedible for humans (however failing to mention a possible competition for land with food crops). The document also criticises the RISE Foundation approach for failing to adopt a systems approach, for applying a silo type of reasoning, for minimising the role of complex interactions [*A criticism that does not appear justified. Author's Note*].

Other criticisms expressed are:

- What is exposed for livestock in terms of GHG emissions, pollution, loss of biodiversity, etc should also be considered for crops;
- The consequences of a large reduction of livestock production have not been assessed (agronomic consequences, effects of animal rearing modes, expansion of forests);
- Flaws in current LCA analyses leading to an overestimation of livestock impact on climate and an underestimation for crops [*No reference provided. Author's Note*];
- Loss of soil organic carbon and of nitrates if ruminants are reduced in number;
- Loss of jobs.
- Limiting production of livestock in Europe can boost imports from countries (Russia and Ukraine are mentioned) that could produce cheap meat but at lower safety standards;
- It is not a matter of just reducing numbers but rather of finding the right livestock mix considering the type of feed (ruminants *vs* non ruminants), the ecosystems services provided (maintaining pastoral landscapes), types of manures, etc.
- The potential effect of new technologies on the reduction of negative impacts is underestimated (genomics, additives that reduce CH_4 emissions, precision livestock farming, manure management, waste exploitation as bio-industrial feedstock).

The ATF proposes:

- The adoption of an agroecological approach to farming that includes livestock.

- The full implementation of a cascading and circular approach.
- Full use of technological innovations available.
- Dialogue and cooperation between stakeholders.

Finally, ATF warns against:

- Reasoning on averages about consumption, as this fails to address the varying needs of different age groups, genders and physiological states (e.g. pregnancy, lactation, body development, etc.).
- Extreme vegan or vegetarian attitudes: omnivorous diets (albeit with a moderate meat intake) are the most balanced form a nutritional point of view.
- The cost of suggested meat substitutes *vis-à-vis* cheap (chicken) meat.

The ATF finally provides interesting and useful inputs to the way the carbon footprint should be calculated, so as to integrate complex reciprocal interactions of components and the effects of feedback loops, as well as to bring non-food animal products into the loop: workforce, wool, skins, fats, …

1.13.7. ATF - Vision Paper - Towards European Research and Innovation for a sustainable and competitive livestock production sector in Europe (ATF, 2019)

The document underlines the importance of the European livestock sector in a global context: its strength factors are high quality of production, high food safety standards, strict veterinary controls, attention to animal welfare, the creation of a monetary surplus between imports and exports, lower than average GHG emissions per unit of product.

Exports do not include only meat (pigs and poultry in particular) but, increasingly, genetic material and technologies. The competition by countries that cannot guarantee the same standards of safety, quality and welfare but have lower production costs is felt as a main threat.

ATF anticipates a future for the European livestock sector that fully implements the concept of a circular economy, minimising waste and favouring recycling at all levels of the food/feed chain, with the least possible competition with food crops on the one end and best use of effluents (including energy production) on the other end of the production chain.

Improvements in sustainability, health, environmental performance shall have to be based on a strong research and innovation basis. It is also considered necessary to reconnect livestock and crops, avoiding the compartmentalisation that specialisation has introduced, depriving the fields of manure application and creating environmental problems in its management where manure is produced.

A strong position is expressed towards the preservation of animal genetic diversity with the protection of local breeds, generally adapted to the local environment but also as a gene pool that will favour adaptation to possible changes.

The reduction of antibiotic use is fundamental for the implementation of the "one health" concept, considering that 60% of human pathogens have origin

in animals and induced resistance of animal bacterial pathogens to antimicrobials might deprive human medicine of essential tools.

The ATF foresees a future in which agroecological principles on the integration of livestock in agriculture as a key element of a functional agroecosystem, the full exploitation of new and emerging technologies (biotechnologies, ICT, precision livestock management tools) under the circular economy paradigm will, together, ensure the sustainability of agriculture and food systems in Europe. No single solution (one-size-fits-all) is anticipated, but rather different models adapted to local specificities.

Breeding should be based on a broad set of objectives having resistance to diseases, robustness and longevity as targets, not just productivity. Veterinary research should focus on prevention, by the use and development of vaccines, when possible, by the avoidance of antimicrobials, by the use of pro- and pre-biotics that would boost natural defences, accompanied by efficient and effective veterinary surveillance.

Research should also address the "soft" dimensions of human behaviours and expectations towards food, animal welfare, personal health; the economic effects of policies, regulations and norms; their consequences on job availability and attractiveness in the livestock sector.

The following seven impacts are expected by ATF from European research and innovation efforts.

1. Maintain an innovative and efficient research base in animal production in Europe
2. Promote a diversity of livestock systems
3. Increase preventive healthcare
4. Improve European livestock production autonomy by linking more closely plant and animal production
5. Foster rural vitality through the supply of agro-ecological, social and economic services
6. Regain consumer confidence
7. Contribute to global food supply

1.14. List of documents

ANIHWA. 2015. **An updated SRA covering animal health and welfare**. Animal Health and Welfare – FP7 ERA-NET. Deliverable D5.2

ANIHWA is an FP7 ERA-Net that provides an update of e previous (EMIDA) Strategic Research Agenda on animal health and welfare. The perspective is for the 20 years ahead, that is until approximately 2035. The work was carried out as a foresight exercise involving experts and stakeholders. The priorities already identified by EMIDA are confirmed; a great importance is attributed to research on "*vector-borne diseases, antibiotic effectiveness and availability, vaccine development, diagnostic tests and biosecurity"*, to the role of wildlife in harbouring and spreading farm animal diseases and to gut health

ATF. 2017. **Food integrity in the food chain: How can the animal production sector contribute?** Report of the Animal Task Force 7th Seminar, 26.10.2017, Brussels

Synthetic report of a seminar organised by the Animal Task Force in 2017 with participants form science, farmers (several livestock sectors), the EC. There is a shared perception of the importance of transparency on food integrity (intrinsic and extrinsic values) and of a commitment of the producers to animal welfare, for the environment, mitigation of climate change. However, it is a common perception that information reaching the public is often incomplete if not twisted to the interests of producers on the one hand or of a preconceived opposition to the livestock sector by certain opinion groups. As far as diets are concerned, ther is agreement on the need to preserve a balanced diet that includes meat, but that the total amount of food should be carefully scrutinised, as excess consumption, rather than specific ingredients make the difference between a healthy and an unhealthy diet.

ATF. 2019. **Vision Paper - Towards European Research and Innovation for a sustainable and competitive livestock production sector in Europe**. Brussels

The ATF aims to provide a common framework and a scope for suggested priorities for R&I within Horizon Europe towards a resource efficient, sustainable, competitive and safe livestock production sector in Europe.

Buckwell, A. and Nadeu, E. 2018. **What is the Safe Operating Space for EU Livestock?** RISE Foundation, Brussels.

The report by the RISE Foundation frames the discussion on the sustainability of the livestock sector in Europe within the concept of "safe operational space", one that guarantees the satisfaction of a range of benefits brought about by animal productions (food security and nutrition, maintenance of pastures, filed fertilisation, …) and at the same time avoid damages to the environment (GHG emissions, pollution by Nitrogen, loss of biodiversity, …). It goes so far as to devise an interpretation model and to suggest its application, but non further than trying to quantify a few variables ad enouncing what should follow with appropriate research. However, some preliminary conclusions can be drawn: a) current EU livestock production provokes GHG emissions and N flows which are

currently far higher than admissible on environmental considerations; b) Current consumption and production are considerably greater than what would be required under national dietary recommendations.

Committee on Considerations for the Future of Animal Science Research. 2015. **Critical Role of Animal Science Research in Food Security and Sustainability**. The National Academic Press. Washington, D.C.

The report produced by the committee appointed by the US National Research Council provides an overview of animal farming in the world and identifies research priorities with a main focus on the US context. The report is based on the unquestioned assumption of a growth of consumption of ASF that reflects current trends (with world population and growing average wealth as drivers). The Committee advocates an interdisciplinary approach combining research on technical matters with socio-economics and fostering a dialogue between citizens, the industry and the research community.

EIP-Agri. 2018. **Focus Group Robust & Resilient dairy production systems – Final Report**. Brussels

This document represents the final report by a Focus Group of the EIP-Agri dedicated to dairy farming in Europe, with a view to identify critical factors leading to a higher resilience of milk producing farms. The analysis was carried out at three levels: the cow, the farm, the whole system. The Focus Group identified factors which can enhance robustness and resilience and five key areas for development: a) Precision Livestock Farming; b) Systems improvement; c) Indicators and indices; d) Skills improvement; e) Socio-economics.

FAO and GDP. 2018. **Climate change and the global dairy cattle sector – The role of the dairy sector in a low-carbon future**. Rome. 36 pp. Licence: CC BY-NC-SA- 3.0 IGO

This FAO study focuses on the relationships between dairy cattle and GHG emissions. It reports a growing trend in production that is due mainly to increased production efficiency (i.e. less emission intensity per unit product) than to higher numbers of animals, although both are moving up. As the lowest efficiencies are found in South East Asia, Oceania and in particular in Sub-Saharan Africa, the highest contribution towards a reduction of GHG emissions would come from the transfer of technologies from developed to developing countries, unless some breakthrough could change the landscape of production systems also in the global "North". Improvements should consider feed but also manure management and a stop to land use change.

Gerber PJ, Steinfeld H, Henderson B, Mottet A, Opio C, Dijkman J, Falcucci A, Tempio G. 2013. **Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities**. Food and Agriculture Organization of the United Nations (FAO), Rome.

The report provides an extensive review of current GHG emissions by the livestock sectors broken down by species, type of production (meat, milk, eggs) and regions. The document is particularly useful in order to appreciate the diversity of a sector that is often treated as a monolith but cannot be tackled

without due consideration to the geographical, environmental and social context. The many options available to improve the fundamental contribution of the livestock sector to FNS have to be compared and evaluated with a high granularity that the report contributes to support.

HLPE. 2016. **Sustainable agricultural development for food security and nutrition: what roles for livestock?** A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.

This HLPE report produced for the CFS of FAO explores the roles, challenges, problems and perspectives of different animal production systems worldwide with a focus on their role on human food security and nutrition and the welfare of people. From the overall analysis, the panel derives recommendations for states and international agencies on the way to foster a sustainable agricultural development with a key role of livestock as a major driver.

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 Synthesis Report (SYR), constituting the final product of the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), is published under the title Climate Change 2014. This report distils, synthesizes and integrates the key findings of the three Working Group contributions – The Physical Science Basis, Impacts, Adaptation, and Vulnerability and Mitigation of Climate Change – to the AR5 in a concise document for the benefit of decision makers in the government, the private sector as well as the public at large*" (from the Preface"

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.

Peyraud JL. 2018. **The Safe Operating Space of livestock, Rise report - Panel discussion at Launch event on Sept. 13th, 2018**. Brussels.

The document reports a positions expressed by the Chairman of the Animal Task Force at the launch event of the RISE Foundation report (Buckwell and Nadeu, 2018). Some of the background considerations of (Buckwell and Nadeu, 2018) are confirmed, especially the need to tackle the issue of climate change and of the livestock contribution to GHG emissions. Some methodological approaches and conclusions are criticised, mainly for a supposedly reductionist approach an oversimplification of key issues (e.g. innovations in genetics, feeding, manure treatment, etc.)

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.

The study proposes a model of a European agriculture in 2050 based on agroecological principles. With the use of a specific mathematical model, *TYFAm*, the study provided sufficient ground fot such a vision, based on some fundamental concept: a) diets shall be based on WHO and EFSA recommendations (less meat); b) no synthetic chemical inputs (fundamental principle of agroecology); c) stop imports of soybean that causes highly negative impacts on the environment and climate. The envisaged landscape is one with 40 less animals, with a stronger reduction of non-ruminants because an expansion of pastures and grasslands would be more suited to ruminants. While the technical aspects of such a transition are outlined in detail, social and economic considerations are left as a subject of further studies.

Raffa DR, Tubiello FN, Turner D, Montero Serrano J. 2018. **Nitrogen inputs to agricultural soils from livestock manure - New statistics.** ISSN 1020-4555, Integrated Crop Management vol. 24.

The report use FAO datasets to quantify the amount of N applied to soils via livestock manure at global and regional levels. Manure is compared with the application of synthetic N fertilizers. On a global scale, manure applications (left on pastures and distributed to fields) and synthetic N are almost equal but the latter is increasing at a faster rate, with East Asia being the main engine. Europe is the only Region where the application of all forms of nitrogen decreased since the 1980s, a likely consequence of the nitrates EC-Directive.

Robinson TP, Thornton PK, Franceschini G, Kruska RL, Chiozza F, Notenbaert A, Cecchi G, Herrero M, Epprecht M, Fritz S, You L, Conchedda G, See L. 2011. **Global livestock production systems**. Rome, Food and Agriculture Organization of the United Nations (FAO) and International Livestock Research Institute (ILRI), 152 pp.

This FAO & ILRI book does not provide statistics on the distribution and types of livestock systems but is more of a methodological nature, dealing with classification processes. It proposes a number of approaches to mapping production systems in relation to livelihoods, and discusses ways in which intensive production can be accounted for.

WEF. 2019a. **Meat: the Future series - Options for the Livestock Sector in Developing and Emerging Economies to 2030 and Beyond**. Prepared by the International Livestock Research Institute for the World Economic Forum's Meat: the Future dialogue series.

The report analyses the current status and perspectives of the livestock sector from the point of view of developing countries but with reference to the evolution that meat and other ASF is undergoing throughout the world. The multiple roles of livestock as well as the variety of management systems that are found in the developing world are emphasised, with particular regard to smallholder mixed farming systems whose improvement, rather than superintensive "industrial" models could be the key to sustainable livelihoods.

WEF. 2019b. **Meat: the Future series - Alternative Proteins**. Prepared by the Oxford Martin School, Oxford University for the World Economic Forum's Meat: the Future dialogue series.

The study was prepared by the Oxford Martin School for the World Economic Forum to investigate the potential development of new protein rich foods as alternatives to meat and other traditional AFS. The report clarifies that not all prospective alternatives can claim better effects on human health but some may have a future depending on further technological progress (e.g. cultured meat) or changes in consumers' attitudes. The challenge of providing sufficient and nutritious food for almost 10 billion people by 2050 and the acknowledgement that current patterns of meat consumption in the western world cannot be sustainably extended to the whole world might be the trigger that encouraged a significant shift from meat to alternative protein sources. However, it is acknowledged that traditional plant proteins would remain the cheapest, most accepted and climate friendly alternatives to meat.

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.

2. Fisheries and aquaculture

2.1. Setting the scene

Seas and oceans are the **largest ecosystems** on earth; they play an essential **role on climate**; they provide **food** that is essential for many peoples of the world and beneficial for all. Yet, they are still relatively little understood in their functioning; the actual impact of climate change and human activities is not adequately perceived; the consequences of pollution from oil spills, seabed mining and litter (especially plastics) are underestimated (Scientific Advice Mechanism, 2017, OECD, 2016).

Agenda 2030 dedicates **SDG 14** to marine resources (*Conserve and sustainably use the oceans, seas and marine resources for sustainable development*), but several other SDGs are relevant as well.

With **global captures more or less stable** over the recent past (since the mid-1990s), **aquaculture** (inland and marine) has been essential in satisfying an increasing consumption, boosted by population growth and increasing incomes in many parts of the developing world. This production resulted in a record-high of per capita consumption of fish of 20.3 kg in 2016 (FAO, 2018b). Rising income levels and urbanisations are seen as the main drivers of fish consumption (HLPE, 2014).

The growing income divide between the "haves" and the "have-nots" of the world will further exacerbate the current inequality of access to healthy and nutritious food (Béné *et al.*, 2015) as prices display an upward trend, although moderated by the dramatic growth of aquaculture and a worldwide competition.

Over the last fifty years, the annual growth of fish[9] consumption (3.2%) was higher than the rate of growth of the world population (1.6%) and of meat consumption (2.8%) (FAO, 2018b)

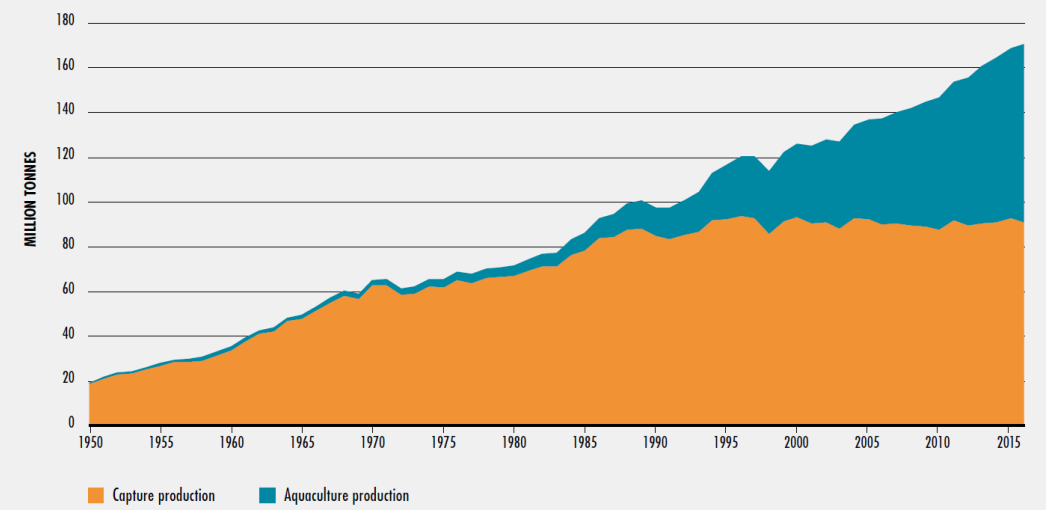

Figure 2.1 - World capture fisheries and aquaculture production 1950-2016 (FAO, 2018b).

[9] We here follow FAO's definition of "fish" that includes fish, crustaceans, molluscs and other aquatic animals, but excludes aquatic mammals, reptiles, seaweeds and other aquatic plants (FAO, 2018b).

Both captures and aquaculture occur in marine and inland waters, with captures prevailing in seas and oceans and aquaculture production inland (**Figure 2.2**).

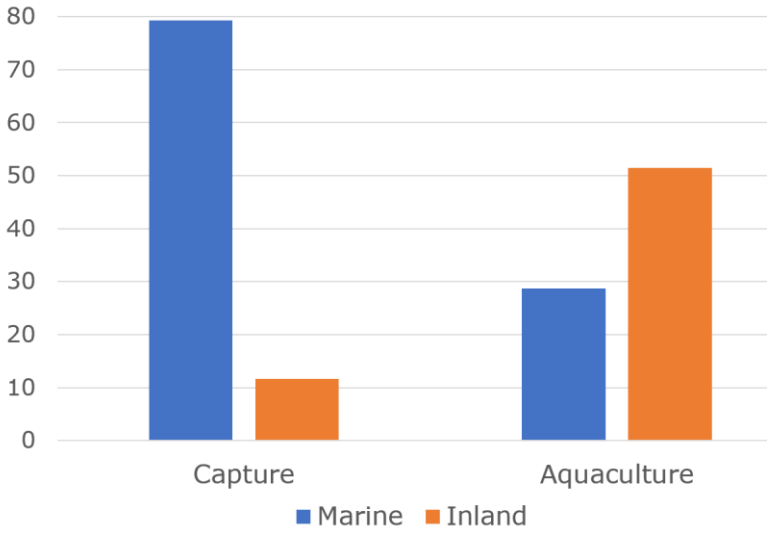

Figure 2.2 - World fisheries and aquaculture production and utilisation in 2016, in million tonnes (Data from FAO, 2018b)

Marine captures amounted in 2016 to almost 80 million tonnes[10], with China taking by far the largest share (almost 20%) of the total (or 15.2 of the world total 79.3 M tonnes). Only five European countries are in the group of the first 25 of the world (Norway, Iceland, Spain, UK and Denmark) (**Figure 2.3**).

It has been estimated that illegal, unreported and unregulated (IUU) fishing represents approximately 15 per cent of total catch and has a cost estimated at between $10 billion and $23.5 billion (GO-Science, 2018)

Between 80 and 90% of fish production is for **human consumption**. The second largest destination is as **feed**: primarily for farmed fish, but also for terrestrial animals (pigs and poultry), in the form of fishmeal and fish oil (HLPE, 2014).

Fish is the largest combined source of animal proteins if terrestrial animals (bovine, pigs, poultry and sheep) are considered separately (not so if combined)(Béné *et al.*, 2015).

[10] According to common practice, figures are expressed in live weight equivalent (including offal, shells, etc. that are usually discarded) and without accounting for post-harvest losses.

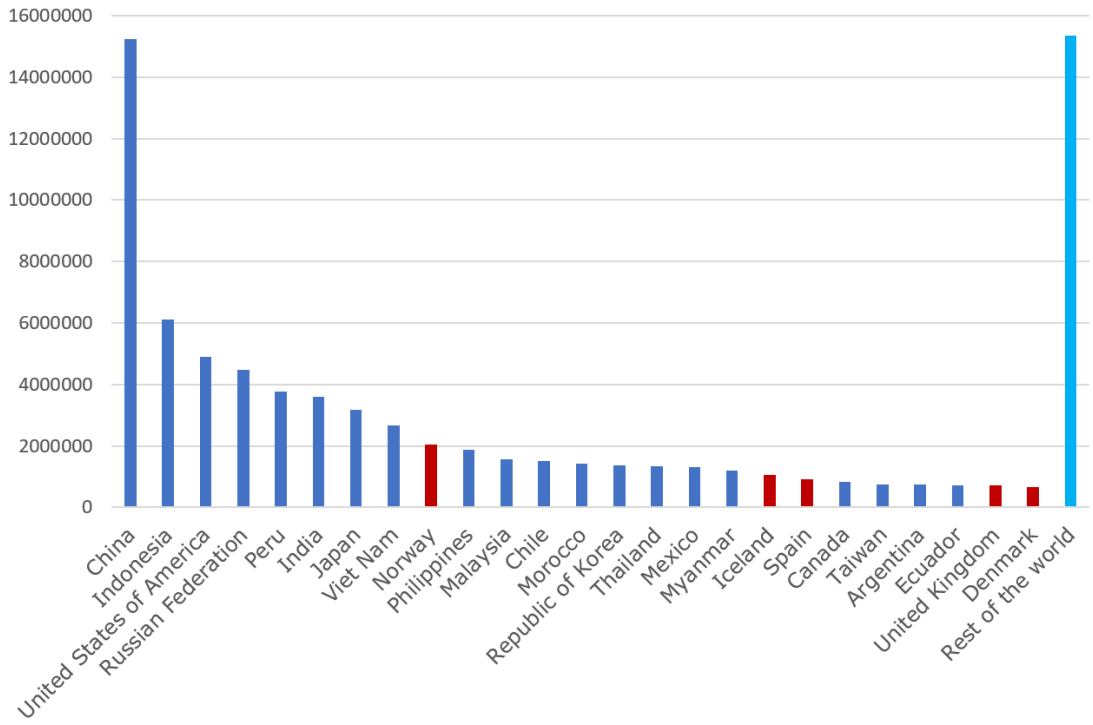

Figure 2.3 - Marine captures by country in 2016 (tonnes); the first 25 countries are reported individually (Data from FAO, 2018b)

Theragra chalcogramma (Alaska or walleye pollock), *Engraulis ringens* (Anchoveta or Peruvian anchovy), *Katsuwonus pelamis* (Skipjack tuna) and *Sardinella spp*. (Sardinellas) represent, in weight, the most harvested species, each with more than 2 million tonnes in 2016 (FAO, 2018b). The harvest of Peruvian anchovy is very variable depending on the El Niño stream fluctuations and is often the first in the list. Ups and downs in marine capture of marine species, anyway, are a common feature of many species.

As far as marine captures are concerned, the Pacific Northwest (FAO area 61) is the most productive in the world, followed, at a distance, by Pacific Wester Central (zone 71) and Atlantic Northeast (27).

Asia has the leadership in inland captures (two thirds of the world total and China, again, the leader), followed by Africa (25%). Europe represents a mere 3.8% globally, but **inland captures** are a significant component of fisheries in **Finland** and, to a lesser extent, in Sweden (FAO, 2018b).

2.2. Aquaculture

The growth of aquaculture has been steady and impressive since the early 1990s. The amount of **fish produced annually** (marine and inland together) **equals captures** and the trend is still pointing towards a further expansion of production, although at a slower pace than in the first decade of this century. If we restrict consideration to human consumption, aquaculture has surpassed captures in 2013 and still holds the leadership.

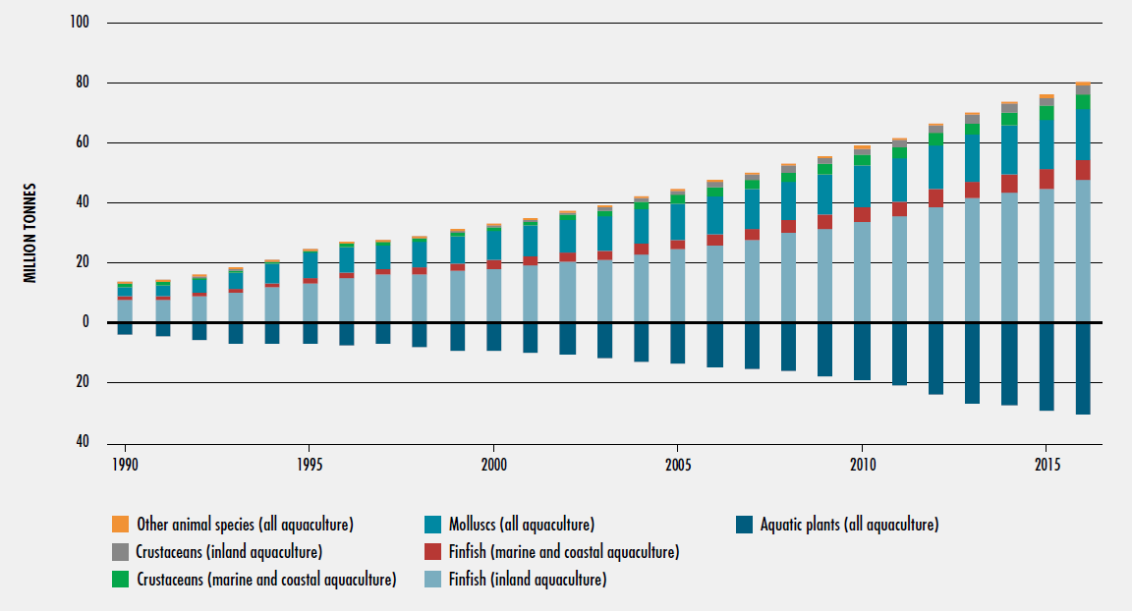

Figure 2.4 - Aquaculture production (marine and inland) 1990-2016 (FAO, 2018b).

Finfish, molluscs and crustaceans among animals (and seaweed among plants) are the most important products.

Aquaculture still represents a minor share of fish consumed in most continents (12% to 18% in Europe, the Americas, Africa and Oceania; 40% in Asia excluding China), but **China**, where **73.7% of fish comes from aquaculture** (in 2016), by the sheer weight of population numbers, brings the world average to around 45% (FAO, 2018b).

Europe, as most OECD countries, has **not followed the rapid growth of aquaculture** of the developing countries, mainly due to its negative environmental externalities. This, however, has pushed research and innovation towards better technologies and improved farming practices (OECD, 2015).

In the European Union, the leading position (by volume of production) is taken by **Spain**, followed by UK, France, Italy and Greece (Ministerial Group for Sustainable Aquaculture, 2014). If the ranking is done on value, the **UK** comes first, thanks mainly a lucrative salmon farming sector. **Norway**, however, surpasses all EU countries, both in volume and in value.

Aquaculture is done both inland and in marine environment with an intermediate sector of coastal aquaculture (e.g. in lagoons) where freshwater and salt water often blend. Whereas inland aquaculture is mainly dedicated

to the production of finfish and crustaceans, molluscs represent the most significant share of production from mariculture and coastal aquaculture (58%).

Marine aquaculture production (all products combined) currently stands at about 59 million tonnes (FAO, 2018b), equivalent to around one-half of global aquaculture production. It produces some 6.6 million tonnes of **finfish**, 5 million tonnes of **crustaceans**, and 17 million tonnes of **molluscs**. But the biggest share of marine aquaculture production, by weight, is represented by **macro-algae**, with around 30 million tonnes (with a much lower share of value and a high concentration in China and Indonesia).

A further distinction is between aquaculture with fed species and without feeding. Both are growing, but **fed species** at a **faster rate than unfed species**. The latter, however, mostly bivalve molluscs and carps, are attracting increasing attention for their ability to use (extract) the residues of fed species, thus contributing, when combined, to reducing the levels of pollution caused by fish farming.

Integrated multitrophic aquaculture is a smart development of this concept that combines fish, other aquatic animals and plants to feed on wastes from fish farming, thus closing the nutrient cycle and removing residues.

Feed is especially important for carnivorous species and it was traditionally derived from small pelagic fish, discarded fish or fish processing by-products (mainly fishmeal and fish oil). Decreasing by-catches through improved fishing techniques, the use of a higher part of captured fish as human food, as well as environmental concerns have pushed the feed industry towards a **larger share of vegetables in industrial feed**, also for typical carnivores such as salmons.

Indeed the use of fishmeal as feed is hard to justify[11]: for omnivorous farmed fish, the amount of fishmeal necessary to produce 1 kg of farmed fish is in the range of 0.2 to 1.41 kg of wild fish equivalent; for carnivorous fish, the range is 1.35 to 5.16 kg (Béné *et al.*, 2015).

The current average composition of aquaculture feeds sees a balanced contribution from fish, terrestrial animals, terrestrial plant protein and oils and other terrestrial plant products, but with marked variations between fish types, as can be seen in **Figure 2.5**.

[11] "*It's foolish to fish fish to feed farmed fish with fishmeal, so that farmed fish has fish-oil as fished fish*" (popular saying).

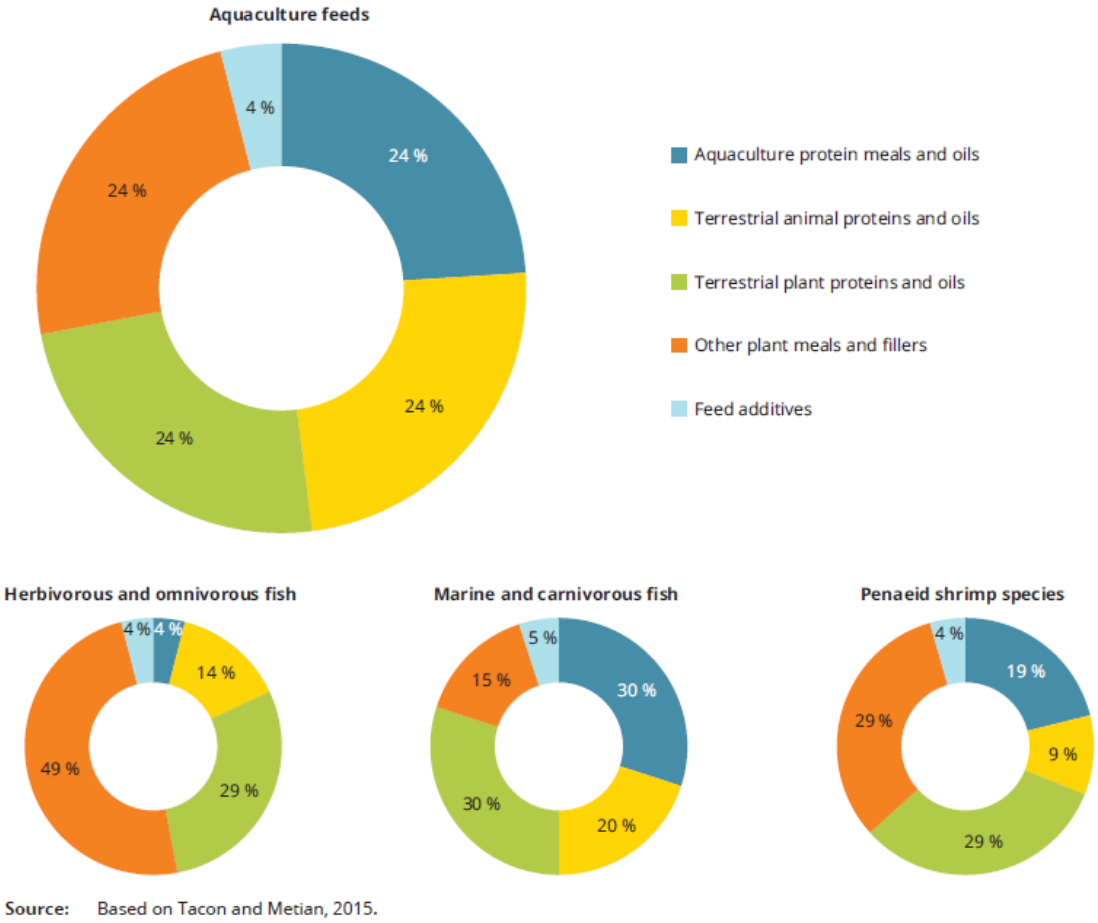

Figure 2.5 - Major categories of feed ingredients within compound aquaculture feeds (From EEA, 2016)

Another option, although still fraught with uncertainties about the ecological consequences on trophic chains is the use of **zooplankton (krill)** as feed source. The capture of krill has indeed started already in the cold ocean zones surrounding Antarctica (Scientific Advice Mechanism, 2017).

Seaweeds represent another very important share of aquaculture production (30 M tonnes in 2016) whose destinations are human consumption, the food industry (as additives or ingredients) and the feed industry. The two main producers are China and Indonesia, with 47.9% and 38.7% of the world production, respectively.

The development of aquaculture is not free from conflicts at the local level: **a)** competition between different forms of aquaculture; **b)** competition with fisheries (inland and marine); **c)** competition with other activities, including tourism and agriculture (HLPE, 2014).

Indeed, although fishing and fish farming are often seen as two worlds apart, they interact (and often collide) in many ways. One is the already mentioned question of captured fish being used as farmed **fish feed**. A second area of possible conflict is that many operations do not complete the whole reproductive cycle of breeding stocks but rely on **captures for immatures** that are then farmed to market size, with a risk of depletion of wild stocks (OECD, 2015). Conversely, immatures raised in captivity may be released to

increase wild fish stocks for commercial or recreational fishing with the risk of altering the genetic makeup of wild populations.

Another is the **use of space**; quite often the same areas that are optimal for mariculture (e.g. for caged finfish) are the same as for fishing, or for wind turbines to produce renewable energy (OECD, 2015). Multiple use of offshore installations is now seen as a key area of research and innovation.

2.3. The state of fish resources

Fish species are generally classified, according to the level of harvest *vis-à-vis* the **"maximum sustainable yield"** (MSY = the level that would avoid the decline of the resource) into three broad categories (FAO, 2018b):

- Overfished: having abundance lower than the level that can produce MSY
- Maximally sustainably fished: having abundance at or close to the level of MSY
- Underfished: abundance above the level corresponding to MSY

The percentage of overfished stocks has been increasing for the last forty years, reaching about 33% in 2015. The proportion of underfished stocks, conversely, has declined steadily and is now estimated at a mere 7% (**Figure 2.6**)

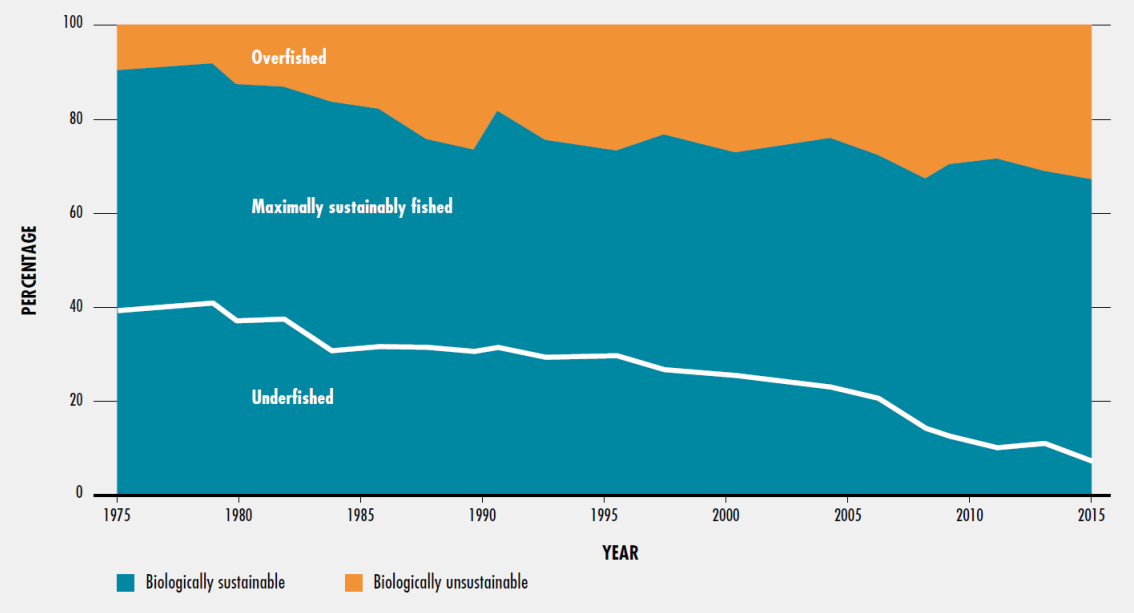

Figure 2.6 - State of the World marine stocks 1974-2015 (FAO, 2018b)

The situation is particularly critical in the Mediterranean and Black Sea, where the overfished stocks are in excess of 60%.

Overexploitation of fish stocks often goes in parallel with the degradation of the marine environment by unsustainable fishing practices, such as trawling (OECD, 2015).

The pattern of development of catches over time is far from uniform in the different fishing zones of the world, with some displaying a steady growth, other that peaked in the more or less distant past and are now declining and other oscillating, often with ranges that equal the average of a decade or more. Therefore, **no generalisation can be made about the degree of exploitation of fish stocks**.

With the obvious *caveat* of such estimate, inherently difficult, an increase of 13% of production from captures could be obtained by 2030 if fish stocks were allowed to recover and fishing limited to MSY (maximum sustainable yield) (OECD, 2015).

The level of exploitation of inland fish stocks is much harder to establish for lack of adequate statistics (especially on a basin basis) and to market structures, usually limited to local areas that evade precise statistics.

It should be mentioned that statistics and data collection methods on the status and trends of fish populations is an area of controversy (HLPE, 2014). However, it is generally admitted that the **Aichi Biodiversity target B/6** of CBD (Convention on Biological Diversity) **will not be reached**: "*By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits*".

2.4. Fish as food

As a food, fish is distributed "live, fresh, chilled, frozen, heat-treated, fermented, dried, smoked, salted, pickled, boiled, fried, freeze-dried, minced, powdered or canned, or as a combination of two or more of these forms" (HLPE, 2014).

Fish is mainly consumed as a live/fresh/chilled product (predominantly so in developing countries) and frozen (the most common form in developed countries), followed by several forms of preparation, preservation or cure and by non-food processing (fishmeal as feed, extraction of fish-oil, medicines, food additives, cosmetics, skins, etc.).

Fish is not on top of food consumption, with about 20 kg per person per year. It is estimated that, at present, fish provides, on average, only 2% of calories and 15% of proteins from animals (Scientific Advice Mechanism, 2017) (17% of proteins from animals and 6.5% of all proteins according to HLPE, 2014) but it is a very important component of diets both in low-income countries and in advanced economies for its **nutritional value**: fish is rich in vitamins (A, B12 and D), essential aminoacids (especially lysine and methionine, Béné *et al.*, 2015), long-chain PUFA (polyunsaturated fatty acids), Omega-3 fatty acids, iron, zinc, iodine, calcium (HLPE, 2014 and Béné *et al.*, 2015). For 3.2 billion people, most of which belong to Developing Countries, fish is the source of more than 20% (in some cases more than 50%) of animal proteins in the diet.

Differences have been observed between wild and farmed fish of the same species, especially in the composition of fatty acids, as farmed fish rely increasingly on plant-source feed: omega-3 fatty acids are lower and omega-6 higher in farmed fish; some differences have been observed in micronutrients (wild fish better) (HLPE, 2014). The contentious genetic modification technique offer, at least in theory, viable solutions: for instance *Camelina sp*. was genetically modified (at Rothamsted, UK) to produce omega-3 fatty acids, to be used as ingredient of fish feed.

Processing, especially when the final product involves a good deal of work (curing, portioning, conditioning) adds a considerable value to fish. Sometimes processing is outsourced from developed to developing countries, such as crab shell removal.

Some food safety issues should be considered, connected with possible toxins contamination from algae, bacteria, viruses and chemical compounds due to **water pollution**; the latter group includes mercury, that accumulates in the body, and is thus of particular concern in long-living species and species that are at a high level in trophic chains (carnivores). Other hazards are represented by dioxins, PCBs and other aromatic chemicals.

Bacteria contamination includes *Listeria*, *Yersinia*, *Shigella*, *Salmonella* and other groups. Most hazards are reduced by strict hygiene measures in processing operations.

A growing concern has been the rapid increase in therapeutic and prophylactic usage of **antibiotics/antimicrobial agents in aquaculture** operations. Antibiotics use is now the target of restrictions in many countries due to the hazards AMR poses also to human health. Indeed, some advanced fish farming systems, such as the Norwegian salmon farming industry, have

dramatically reduced the use of antibiotics already in the early 1990s, mainly by improved management techniques (**Figure 2.7**).

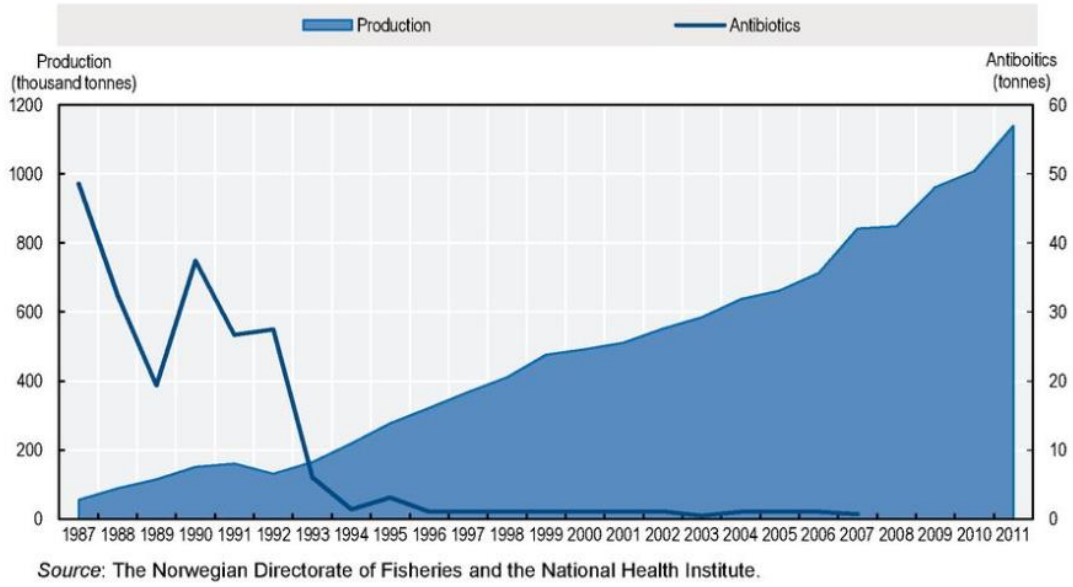

Figure 2.7 - Use of antibiotics in the Norwegian fish farming industry 1987-2011 (From OECD, 2015)

All factors considered, however, there is a widespread agreement that the health benefits form fish consumption outweigh the risks it poses (HLPE, 2014).

2.5. Fish trade

Fish and fish products represent, on a global scale, 9% of the value of "agriculture" products trade and a major source of income especially for small island states (10% according to OECD, 2016). Exports represent from 30 to 40% of production, and exports for human consumption are the lion share of all exports (around 80%). Supply and demand are increasingly global, favoured, at least so far, by the progressive removal of trade barriers.

China and the USA are respectively the largest exporter and the largest importer of fish and both rank high also in the other group (**Figure 2.8**). The international trade balance shows a **large deficit for the USA** (imports about twice the exports in value), **a large surplus for China** (the other way around). Europe has a relatively small deficit, although this masks quite different situations among the different countries.

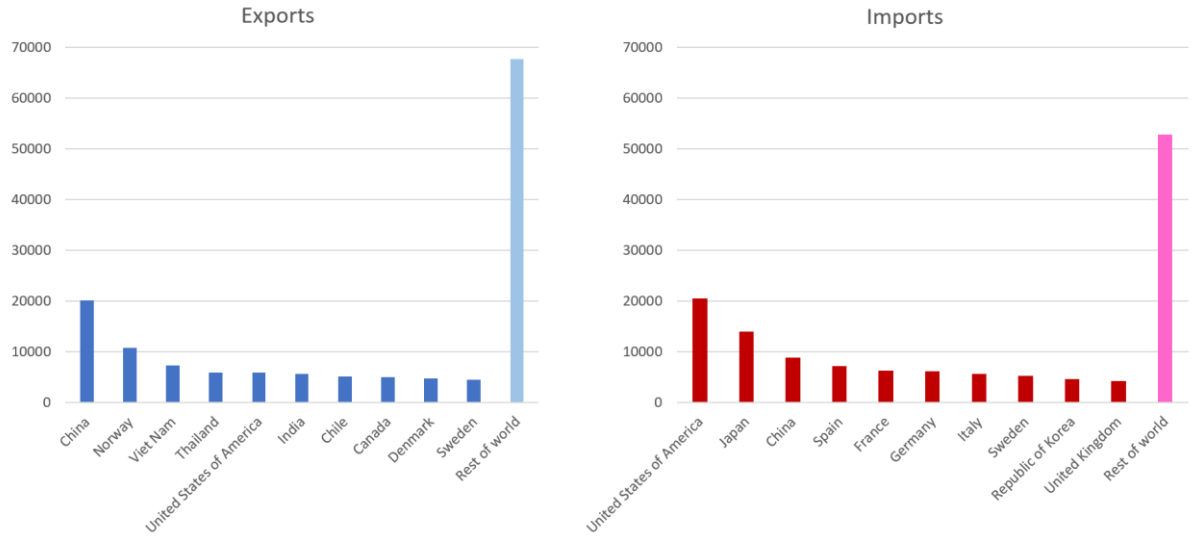

Figure 2.8 - Value of imports and exports of fish and fish product in 2016, in million of US$ (Data from FAO, 2018b)

The **European Union is the largest single market for imports**, followed by the USA and Japan. **Europe depends on imports for around 65% of its consumption** (SCAR-Fish, 2013).

Among European countries, the position of **Norway** is remarkable, ranking second in the world thanks both to a large and modern fishing fleet and to an important aquaculture sector, based especially on high value salmonids. **Norway has the world leadership in salmon farming**, followed by Chile and Scotland (Ministerial Group for Sustainable Aquaculture, 2014)

Salmons have the largest share of the market in value, although, in quantity, they lag well behind cods, hakes, haddocks and other pelagic fish. Shrimps and prawns dominate, both in quantity and in value, the market of crustaceans.

Developed countries have significantly decreased their captures after a peak in the late eighties by voluntary reduction of their fleets and imposing

effective control on their activity; this has generally favoured a rebuilding of fish stocks or at least halted their further decline.

The situation is reversed in the **developing world** where an **excessive** (and still increasing) **capacity of fishing fleets** contributes to the depletion of fish stocks; paradoxically, massive **fish imports** by developed countries, that reduced their own captures, **are fuelling overexploitation** by developing countries fleets. In addition to that, some developing countries issue fishing permits to developed countries fishing vessels (FAO, 2018b).

2.6. Certification

Ecolabelling for sustainable fisheries management is spreading, with a variety of schemes that may create confusion on the market. Most are owned by private NGOs; the FAO, upon the request of many Member States, had issued guidelines already in 2005 and 2011 (fisheries and aquaculture respectively) and more recently cooperated with the Global Sustainable Seafood Initiative to produce a benchmarking tool for ecolabelling.

Certification schemes are **used by retailers** to promote products to conscious consumers. However, criticism has been expressed on the labelling system: certification schemes may **fail to adopt a systems view** and certify unsustainable fisheries; furthermore, the costs of certification make labelling schemes **more suitable for big players**, pushing small operators into a corner (EEA, 2016).

The very sustainability consciousness of consumers is put in doubt as a factor affecting choice of products, with convenience, price, real or supposed dietary benefits probably higher up in priority.

International trade is an area of debate (as for agricultural products). On the one hand it is a source of coveted foreign currencies for developing countries (mostly exporters); on the other hand, a **massive flow of fish to wealthy countries** that can pay the price, often **deprive subsistence fishermen and local markets** of a precious share of their diet (HLPE, 2014). The above-mentioned fishing permits sold by developing countries for cash are another source of instability in the fish supply to local communities. Evidence so far is inconclusive, with positive and negative effects of trade depending much on local conditions (HLPE, 2014)

The complexity of the trade web, with multiple origins for the same species of fish, makes it difficult for the consumer to perceive the background conditions (environmental and social) of the origins of what they eat and drive fishing operations towards sustainable foundations (EEA, 2016).

2.7. Labour and the fishing fleet

The FAO (FAO, 2018b) estimates that in the reference year 2016, the total number of people employed in fisheries[12] and aquaculture (capture and primary production only) was 59.6 million, of which 40.3 million in fisheries and 19.3 million in aquaculture, quite **at odd with the amounts produced by the two sectors**. 85% of all the people employed are in Asia, that rise to 96% for aquaculture alone. Europe (with 445 thousand employed) has less than 1% of the total. The figures provided by EEA, 2016 for the **European Union** are of **129 thousand jobs in fishing** and **80 thousand jobs in aquaculture**.

If the downstream activities (industry) are concerned and the number of people dependent on the whole sector extended to include the workers' families, the global figures range between 660 and 820 million people (HLPE, 2014).

The gender balance is far from even, with women representing around 14% of the workforce in primary production. The gender balance of the workforce moves towards balance when industry is included in the counts.

The number of fishing vessels in the world is estimated at 4.6 million, 75% of which in Asia, **2.1% in Europe**. Over 60% are motorised but with a range from around 40% in Africa to 100% in Europe. Most of the boats (over 80%) are small (less than 12 m), the more so in Europe (around 87%).

[12] A fishery is defined in terms of the "people involved, species or type of fish, area of water or seabed, method of fishing, class of boats, purpose of the activities or a combination of the foregoing features" (HLPE, 2014).

2.8. Biodiversity

Marine ecosystems are extremely diverse and **rich in biodiversity**, far more than terrestrial ecosystems. The interconnection of living forms, from unicellular algae to krill to herbivore and carnivore fish, filtering molluscs, etc. makes the complex web both difficult to understand and awkward do manage.

MPA (Marine protected areas), where fishing is excluded, may play a significant role in ensuring breeding grounds for species conservation and replenishment of fish stocks; the CBD/Aichi targets as well as SDG#14 aim at 10% of marine areas protected by 2020. These measures have been proved effective within their boundaries, but the **spill-over effect outside their boundaries is not properly understood**.

In Europe, most MPAs have been designated within the framework for Natura 2000. However, they include but a fraction (1.5%) of seas and oceans and their function is primarily to protect rare or unique environments and not, specifically, to rebuild fish stocks.

Ocean management is also fraught with difficulties both in effective implementation and in the evaluation of efficacy.

The CITES convention on trade of endangered species also applies to fish, but at present only a small number of species (mainly sharks) have been included, mainly for lack of reliable data on effective populations.

An **Ecosystem approach** to fisheries and aquaculture management is gaining the attention of national and international authorities, since it was first adopted as a shared concept in the Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem in 2001. FAO's guidelines on Ecosystem approach to fisheries[13] and aquaculture[14] emphasise the need for stakeholder participation, due attention to internal and external drivers (including climate change), consideration of the tree pillars of sustainability, knowledge-based decision making (including traditional knowledge), appropriate planning and adaptive management.

According to the CFP "*Ecosystem-based approach to fisheries management means an approach ensuring that benefits from living aquatic resources are high while the direct and indirect impacts of fishing operations on marine ecosystems are low and not detrimental to the future functioning, diversity and integrity of those ecosystems*" (SCAR-Fish, 2013).

The following principles underpin the EAF/EAA approach to fisheries and aquaculture (HLPE, 2014):

- apply the precautionary approach when faced with uncertainty;
- use best available knowledge, whether scientific or traditional;
- knowledge multiple objectives and values of ecosystem services;
- embrace adaptive management;
- broaden stakeholder participation;

[13] FAO. 2003. ***Fisheries management 2. The ecosystem approach to fisheries***. FAO Technical Guidelines for Responsible Fisheries No. 4, Suppl. 2. Rome.

[14] FAO. 2010. ***Aquaculture development. 4. Ecosystem approach to aquaculture***. FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 4. Rome.

- use the full suite of management measures;
- promote sectoral integration and interdisciplinarity.

Research and state-of-the-art monitoring of marine ecosystems see a strong involvement of Norway since the years 1970s; it was recently reinforced through the new EAF-Nansen Programme launched 24 March 2017, in collaboration with FAO.

2.9. Climate change

The **effects of climate change** on aquatic environments, marine and inland, are relatively **easy to predict**. Water bodies maintain a physical/chemical relationship with the atmosphere that keep carbonic acid (H_2CO_3) in water in balance with CO_2 in the atmosphere. The more carbon dioxide in the atmosphere, the higher the concentration of carbonic acid in water.

From the point of view of the mitigation of the greenhouse effect this may sound positive, as a significant share of CO_2 emission are absorbed by the oceans, but increasing acidity puts living organisms building on carbonate salts at serious risk. This includes **coral colonies** and **shell molluscs**.

The increase of water temperature pushes fish populations towards the poles and to deeper waters, potentially depleting fishing areas that are essential for food supply in tropical and subtropical areas.

Another observed consequence is the expansion of **alien species** where they may displace native species, in a few cases facilitated by human infrastructures (e.g. from the Red Sea into the Mediterranean Sea through the Suez Canal) or, more often, transported by vessels (GO-Science, 2018).

However, actual monitoring of the effects of such changes is still limited, far from systematic and obviously difficult, due to interactions with other factors, such as pollution.

More research on species-specific responses to multiple stressors are recommended by SAM-HLG (Scientific Advice Mechanism, 2017).

On land, where most human activities are taking place, climate-change mitigation initiatives are considered (far less implemented) along with adaptation. **In fisheries and aquaculture**, that contribute only marginally to GHG emissions, **the main efforts are on adaptation** through dynamic planning and management, observation and warning systems, and diversification strategies to reduce vulnerability.

The impact of aquaculture on climate change through emissions is considerably lower than that of terrestrial animals. The main differences lies in the **conversion efficiency** (weight growth per unit weight of feed) that is considerably **higher for fish than beef and pork**; the main advantages of fish is that they are **cold-blooded** and they **float**, thus spending less energy on temperature maintenance and movement (HLPE, 2014). Nitrogen and Phosphorus emissions are also much lower than terrestrial animals.

2.10. Foresight and outlook studies

2.10.1. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals (FAO, 2018b)

Part 4 of (FAO, 2018b) is a forward-looking chapter addressing emerging issues on "Blue Growth" as a sustainable development and growth of the marine and maritime sector, inland waters and aquaculture is currently dubbed. A broad ecosystem approach to Blue Growth includes provisioning, regulating and supporting ecosystem services, as well as cultural and social aspects, including tourism. Such a broad and comprehensive approach is also advocated by the SAM-HLG of Scientific Advisors in their opinion to the EC (Scientific Advice Mechanism, 2017).

A "Blue Growth Initiative" was launched by FAO in 2013 to provide a logical framework for a coordination of policies and other actions aimed at sustainable development (**Figure 2.9**)

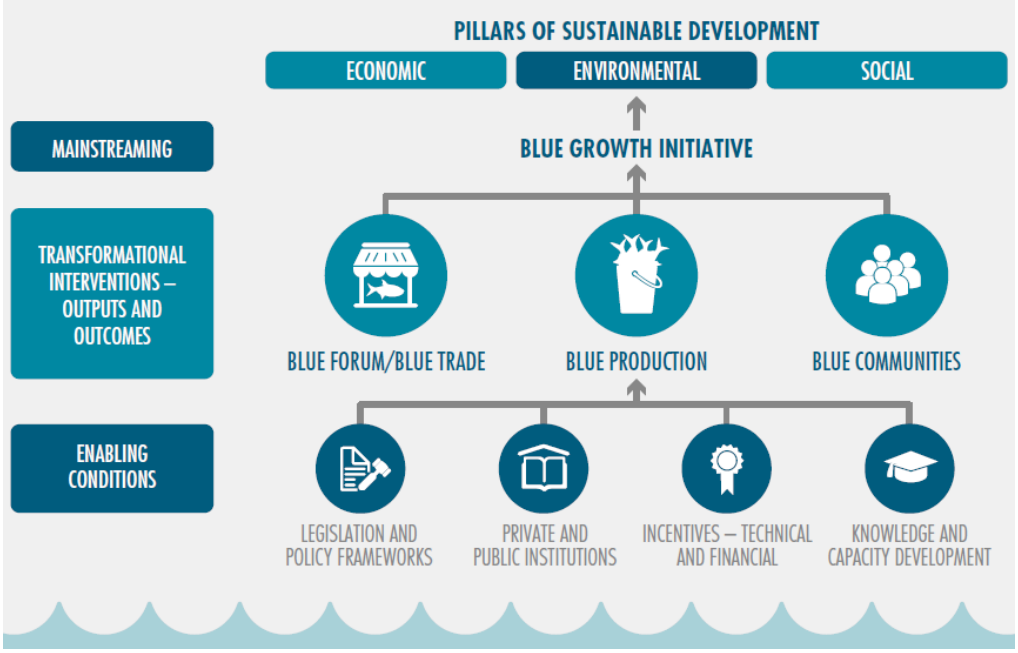

Figure 2.9 - Blue Growth framework (FAO, 2018b)

A significant role is attributed to international, regional and bilateral cooperation mechanisms in all sectors, from fisheries to aquaculture.

The report identifies a number of potentially disruptive technologies that could change the landscape:

- Supercomputing, big data, blockchain, high speed data transmission, are ingredients of improved weather forecasts, satellite positioning systems, surveillance, real time market information sharing, traceability.
- Sensors and image analysis for fish classification improve compliance.

- Robotics, vessel monitoring systems improve safety conditions

Future projections of captures and aquaculture show a steady level (up to 2030) for the former and a further increase for the latter, albeit at a slower rate than in the recent past.

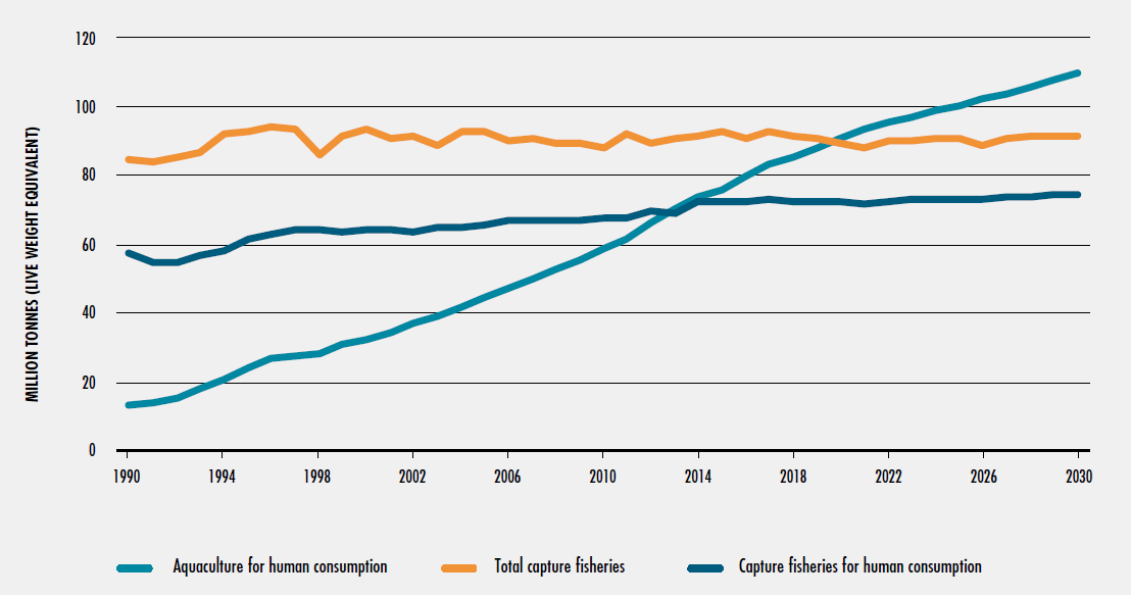

Figure 2.10 - Global capture fisheries and aquaculture production 1990-2030 (FAO, 2018b)

Consumption is expected to grow, except in Africa, where population will grow faster than the production, thus exacerbating food and nutrition insecurity in the continent (Béné *et al.*, 2015).

2.10.2. **Food from the Oceans** (Scientific Advice Mechanism, 2017)

A High Level Group of Scientific Advisors (within the Scientific Advice Mechanism) provided an opinion on the question "How can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits?".

The analysis and suggestions are limited to oceans and seas (both captures and cultures) and does not consider inland waters that are anyway relevant in large parts of the world and some European countries as well (Finland and Sweden, in particular).

The opinion includes suggestions for technical developments and policies for the implementation of sustainable food chains.

On the technical side:

- Expansion of mariculture (in an environmentally sound way)
- Shift of captures towards lower trophic levels (herbivores instead of carnivores) and to mesopelagic fish species, currently underexploited (but also insufficiently known).

- Improved management of established fisheries and more selective fishing gear that reduces discards.
- Re-direction of part of fish from the feed to the food chain (currently hampered by CFP rules of the destiny of bycatch).
- Implementation of integrated trophic systems for mariculture with finfish, filter feeders (mainly shell molluscs) and algae in closed circuits.
- Further use of feed of vegetable origin (whether from land or sea) in mariculture instead of fishmeal and/or use of krill (zooplankton).
- More research and innovation in the cultivation (genetics, harvesting) and exploitation (pharmaceuticals, feed, biomaterials) of algae.

On the policy and regulation side:

- Further integration of sustainability criteria into policies and regulations.
- Evolution of policies, regulations and international agreements along with the progress of knowledge.
- Coexistence of multiple economic activities on coastal areas (mariculture, fishing, tourism.
- Reduction or elimination of public subsidies to capture fishing or redirection towards ecologically sound practices (e.g. adoption of improved, more selective, fishing gear).
- Increased attention to small-scale fishing operations (limiting the risk of "ocean grabbing" actions by big players). The marginalisation of small-scale fishing operations that usually contribute most to food security, have the lowest discard rates and the least impact on the environment is also emphasised as a major social problem of the sector by HLPE, 2014.
- Integrate policies of fisheries and aquaculture into broader "food policies".

2.10.3. **Science in support of the European fisheries and aquaculture policy** (SCAR-Fish, 2013)

The document, produced by SCAR-Fish (a SWG of SCAR) calls on the one hand for an effective reliance of policies on evidence (from science and monitoring) and on the other hand on increasing research efforts towards the improvement of the knowledge base.

For fisheries (marine capture fishing is exclusive competence of the EU) the emphasis is on better modelling tools and data to understand, describe and assess the relevant interactions between fisheries and the ecosystem and their relationships with climate change for their use in decision processes.

According to SCAR-Fish there is a need to better understand species interactions, food-web structures, ecosystem drivers and to discriminate between exploitation and climate change.

Technological improvements are advocated to improve surveillance of fishing fleet, recording of catches, traceability, with a view to avoiding illegal, unreported and unregulated fishing and to better trace fish along the food chain.

For aquaculture, that contrary to marine capture fisheries are a competence of national or regional governments, the following areas are listed:

- Minimising and mitigating the environmental impacts of aquaculture.
- Mapping aquaculture development constraints.
- Offshore aquaculture sites, including opportunities provided by co-location with renewable energy installations.
- Development of waste product modelling capabilities to inform expansion of aquaculture sites.
- Development of integrated multi-trophic aquaculture.

An obstacle to the development of aquaculture in Europe is represented also by uncertain regulations, by the overlapping of environmental policies (on water, wildlife, landscape, …) and the consequential lack of planning at the national/regional scale.

The role of Marine Protected Areas is also a recommended topic of further research as well as methods, models and tools to determine maximum sustainable yields of fishing stocks at the highest possible scale.

2.10.4. **Aquaculture Science & Research Strategy** (Ministerial Group for Sustainable Aquaculture, 2014)

The report, although dated 2014 and clearly sectoral, is relevant for its high level expert participation, the involvement of relevant **stakeholders** (policy, regulation, industry, CSO) and for the advanced technological stage of Scottish aquaculture.

The ambition was to select key research areas that would allow doubling the mussels production and increasing finfish production by 1/3 in the decade from 2011 to 2020, firmly on the three pillars of sustainability.

The key areas identified are nutrition, stock improvement, health and welfare, food safety and hygiene, technology and engineering, wild *vs* farmed species interactions, markets, economics and social science, capacity, blue biotechnology and growth.

Within these areas, the research priorities selected are:

Finfish: effective control of sea lice on salmon farms (understanding of sea lice dynamics, between farm transmission mechanisms, farm management practices, non-chemical treatment of sea lice, breeding for resistance, relationships with wild salmon populations).

Replacement of marine-sourced components of aquaculture feeds with sustainable, alternative ingredient.

Shellfish: top priority is food safety and hygiene (norovirus detection and management, quantification and management of algal biotoxins in shellfish production).

Generic: Identifying additional areas to increase production capacity (integration of aquaculture into marine spatial plans, estimates of biological carrying capacity for fish and shellfish).

2.10.5. View on the future research of European Fisheries, Aquaculture and Seafood Processing (van Hoof, Steenbergen and Smith, 2014)

This forward-looking document on the future of research was produced by the European Fisheries and Aquaculture Research Organisation (EFARO) within the FP7 ERA-Net COFASP, with a view to providing a list of sectoral research priorities for a time span of 15 years (that is, approximately with 2030 as a target year). A scenario approach was adopted with the consultation of a broad range of stakeholders in three workshops.

For the construction of scenario, the landscape was first split into seven subsectors: **1)** Policy (EU, national, regional); **2)** Economics/market (production, distribution, consumption); **3)** Value chain; **4)** Resource use (and competition between users); **5)** Society (trends, demographics, developments, values); **6)** Natural systems (biological, physical, chemical); **7)** Knowledge (information, understanding, facts, technology, skills).

Inland freshwater systems, despite being the main source of cultured finfish, are not a central subject of the foresight, although some conclusions may be relevant to them as well.

The most important drivers were defined for each subsector, their indicators analysed for the past and projected with different hypotheses into the future. Three to five "micro-scenarios" were then developed for each sub-sector and these were combined into four internally coherent "macro-scenarios" (possible futures). Macro-scenarios, in turn, were used to determine research priorities.

A.	**POLICY**	**D.**	**RESOURCE USE**
A1	Big issues: food security, energy, fresh water	D1	Environmental health status
A2	Food safety	D2	Access, user rights and alternatives
A3	Conservation of resources	D3	Wants and needs for resources
A4	Multi-level governance	D4	Technological advancement
A5	Regionalisation		
A6	Stakeholder influence	**E.**	**SOCIETY**
A7	Political continuity	E1	Demographics
A8	Employment	E2	Population wealth
B.	**ECONOMICS/MARKET**	E3	Media and education (marine literacy)
B1	Economic climate	E4	Regional differences
B2	Economic signature	**F.**	**NATURAL SYSTEM**
B3	Globalization – competition BRICS	F1	Physical and chemical forcing
B4	Trading conditions and opportunities	F2	Species 'demographics'
B5	Access to capital (for business)	F3	Resilience of the ecosystem
C.	**VALUE CHAIN**	**G.**	**KNOWLEDGE**
C1	Consumer demand (user)	G1	Funding
C2	Certification standards and traceability	G2	Motive for generating knowledge
C3	Valorisation of raw material and co-products	G3	Reliability of knowledge
C4	Production costs	G4	Access and openness of knowledge (IP)
C5	Product development and marketing	G5	Uptake of knowledge and innovation capacity

Figure 2.11 – Drivers selected for the subsectors and for the development of "micro-scenarios" (van Hoof, Steenbergen and Smith, 2014)

The macro-scenarios were dubbed:

1. **"EUtopia"**; economic boom, high growth rates, renewed investments, a globalised economy opening new markets, shared objectives at the European level, good and effective governance at all levels, combining leadership with stakeholder involvement. World population growth has peaked and wealth is more equally distributed between and within countries. Education and responsibility drive a respectful attitude towards the environment.
2. **"It's not EU, it's me…"**. Failure of the European project, fragmentation and resurgence of nationalisms determine un-cooperative/antagonistic behaviours between MS. Long term planning is poor and politics reacts to crises, instead. Investment on environmental improvements does not pay off and is abandoned. Europe depends on imports for both food and energy. Inequality rises and creates social unrest. Marine resources are overexploited and a new "tragedy of the commons" and each state makes its own policies withdrawing from international treaties. Trade tariff and non-tariff barriers are set up.
3. **"Fortress Europe … not so splendid isolation".** Europe protects its borders and privileged economic status by fighting immigration but each State proceeds on its own way. The common market is threatened by divergent economic strategies and policies at the national level. Trade barriers are erected but a slow-growing Europe suffers the competition of younger emerging economies. Investments in research are mainly private and the research agenda is then dictated by private, often transnational, interests.
4. **"Europe takes the lead with a Moral High ground".** Sustainability dominates policies and cultures. Capture fishing is performed only at a low, local level and supply chains are short. Citizens are ethically and environmentally conscious and refrain from consumption of animal products, including fish. Even aquaculture is limited. Research is funded by public resources and strictly aimed at public interests.

Each scenario was then analysed as to its "general feeling", the likely position of fisheries, aquaculture and the food processing industry, challenges and problems, the possible role of science and the way research should be organised.

The following themes and subthemes were identified:

- Marine science in general
  - Optimal use of the seas
  - Value of use of the seas
- Environment
  - Low impact products
  - Sustainable use strategies
- Fisheries
  - Monitoring and Management
  - Adaptation strategies
  - Data use

  - Recreational Fisheries
- Aquaculture
  - Market demand
  - Organic aquaculture
  - Technology development
  - Species enhancement
- Seafood processing
  - Towards more flexible production units
  - Maximise processing efficiency
  - New products and new production technologies
- Value chain
  - Increased sustainable efficiency
  - Setting standards
  - Information in the value chain
- Governance
  - Control
  - Licence to produce
  - Participation

2.10.6. **SCAR-Fish views on COFASP Foresight paper** (SCAR-Fish, 2014)

SCAR-Fish had the opportunity to analyse a draft of the COFASP Foresight (van Hoof, Steenbergen and Smith, 2014) before its publication, so that the SWG's opinion was published almost at the time the COFASP Foresight was released.

SCAR-Fish focuses its attention on the research priorities identified by COFASP for Fisheries and Aquaculture. Seafood processing was not considered, being outside the SWG's domain.

SCAR-Fish is critical of the minimal attention given by COFASP to Marine Protected Areas and to the possible trade-off between a long term replenishment of fish stocks and a short-medium term negative impact on fishing due to the exclusion of potentially productive areas.

On Climate Change SCAR-Fish is critical on the predominantly biological approach that did not sufficiently emphasise the need to quantitatively estimate the impact on species abundance that affects fishing activities in a direct way. Both however, agree on the need to avoid rigid regulations and to keep a high degree of adaptability to evolving conditions. In particular a frequent revision of fishing zones could keep a good alignment between actual captures and estimated Maximum Sustainable Yields (MSY).

SCAR-Fish also laments the scarce attention payed by COFASP to "mixed" fishing (i.e. different species captured simultaneously) *vis-à-vis* regulations on bycatches and landing obligations.

As for research, SCAR-Fish finds that one of the four COFASP macro-scenarios foresees a decline in funds; according to SCAR-Fish this is already happening.

2.10.7. **Animal health foresight for the Mediterranean** (Bagni *et al.* 2014)

The report was produced by the FORE-Med project (*Foresight project for the Mediterranean area*) financed by the Italian Ministry of Health within the STARIDAZ FP7 project. The objective was the identification of research priorities in the field of animal health. It has relevance in our context as also aquaculture was considered.

The approach was rather standard for this type of exercises:

1) analysis of the current situation (with identification of the main drivers of change carried out with interviews, questionnaires, literature review);
2) *formulation* of possible future scenarios (arrangement of 2 main drivers, *Infectious diseases evolution* and *Environmental changes* as a Cartesian space and scenarios corresponding to the four quadrants); a fifth "desirable state" scenario was added.
3) *implementation* of strategic choices (dedicated workshop).

The four initial scenarios are displayed in **Figure 2.12**.

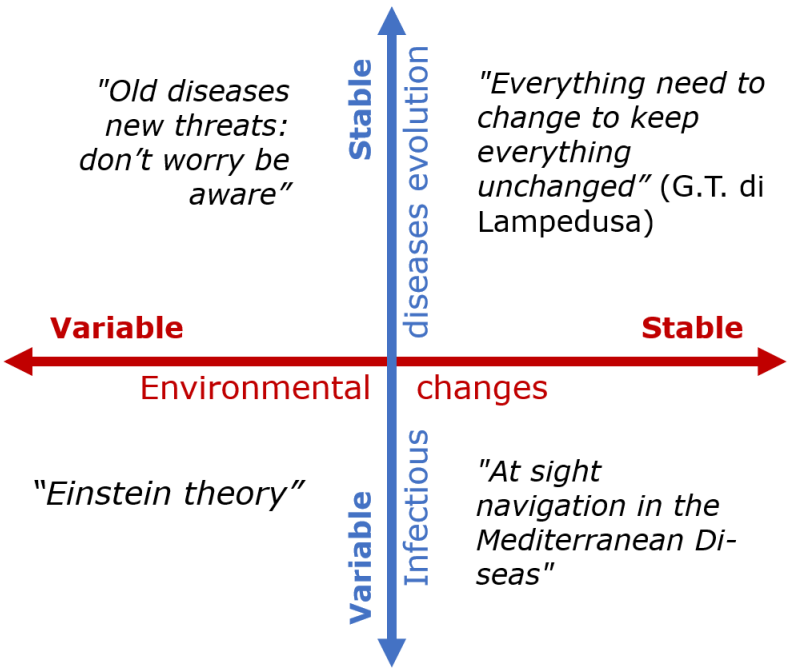

Figure 2.12 - Four main scenarios of Bagni *et al.* 2014 derived from a 2 x 2 combination of the two drivers "Environmental changes" and "Infectious diseases evolution".

Scenario 1 - "Everything need to change to keep everything unchanged"

Improved north-south cooperation, commercial agreements, increased exchanges, political stability in N.African countries leading to investments. Stronger institutions allow a better control of infectious diseases, despite higher levels of exchanges of goods and people.

Scenario 2 - "*At sight navigation in the Mediterranean Di-seas*"

Stable environmental conditions (within normal fluctuation ranges) but widespread political instability. With frequently changing governments, planning and management of animal health is very difficult and not well rooted on scientific evidence. South to North migrations (that include animals) increases the risk of introduction of new diseases. Traditional slaughtering rites evade controls. Unskilled immigrants employed in animal farms. Difficult economic situation of many countries cuts the budget of public health Institutions, weakening controls.

Scenario 3 – "Einstein theory"[15]

Climatic instability in the Mediterranean, with heat waves, droughts and storms. Pollinators in difficulty, new pests incoming. Political instability and war in surrounding areas push migrants towards Southern European countries. Emergency insecticides protect crops but kill bees and most non-harmful insects destabilising the food chains. Biodiversity falls. Big agricultural input conglomerates dominate the market. Feed is becoming too expensive or of uncertain origin and animal production falls. Surveillance systems and research under-funded.

Scenario 4 – "*Old diseases new threats: don't worry be aware*"

Efforts to overcome the economic crisis end up in a complete disregard of climate and the environment to push industrial development. The climate is changing in the Mediterranean area with heat shocks, droughts, torrential rains. Surging urbanisation leads to the abandonment of rural areas. Food imports increase. Desertification and political instability outside the Mediterranean basin stimulate immigration flows. A renewed trust in technology brings biotechnologies back on scene. Food is largely imported from third countries, but border controls are effective, international cooperation is working. Animal health is ensured by high technological standard and effective surveillance.

Scenario 5 - "Mare nostrum"

The fifth scenario derives from a combination of "plausible" and "favourable" drivers and was taken as the basis for the development of research priorities.

Recovery from the 2008 crisis is slower than expected; globalisation puts European agriculture in difficulties on a globalised trade system. Climate change is hitting Southern European countries more than Northern ones. Political Instability in North-Eastern Africa and the Middle East; some terroristic episodes. Education and women's emancipation improve. New trade agreements between Mediterranean countries facilitate exchanges and dialogue. On the other and, immigrations create tensions in European countries. Increased exchanges of goods and animals and higher immigration levels makes epidemiological risks higher. Climate changes facilitates the introduction of vectors.

The following research areas were identified as priorities for aquaculture (with 2-4 topics each).

- Sustainable aquaculture
- Development of new therapeutics and antibiotic resistance

[15] "If the bee disappears from the surface of the earth, man would have no more than four years to live".

- Host-pathogen interaction
- Fish welfare
- Organic aquaculture
- Development of vaccines to reduce pathogen losses and environmental impact
- Biodiversity preservation
- Mediterranean aquatic animal health information system
- Genetic selection for disease resistance
- Climate change adaptation, to reduce production losses
- Monitoring of imported exotic fishes to decrease the risk of introduction of new pathogens

2.10.8. **Sustainable fisheries and aquaculture for food security and nutrition** (HLPE, 2014)

The report was produced by the FAO High Level Panel of Experts on food security and nutrition appointed by the Committee on World Food Security of FAO. It provides an overview of the status (in 2013) of world fisheries and aquaculture systems in relation to Food security and nutrition.

Many relevant outcomes are reported in this document and shall not be repeated here. What is worth mentioning, in this section is some of the main messages brought to the attention of the international community, national governments and international agencies.

- Recognise the role of fish for food security and nutrition and act accordingly to put the fisheries and aquaculture sectors high on the agenda. The sectors should receive more attention in policy development, effective governance systems, research, etc.
- Analyse the threats posed to fisheries and aquaculture by climate change and other factors (such as pollution) affecting fish stock abundance and health. The impact assessment should consider the consequences on the livelihoods of communities and social groups.
- Aquaculture needs a special focus as the main area of further possible development; fishmeal as feed should be reduced, genetic improvement of fish implemented, integrated trophic systems further tested and diffused.
- Priority to small-scale fishing operations instead of large-scale should be the norm both from a social and an environmental point of view.
- Pay more attention to the structure of international trade and to its consequences on the livelihood of communities in developing countries, carefully analysing trade-offs between possible income generation and local food security (for availability and access to fish resources).
- Labour conditions, safety issues, gender equity, governance.

2.10.9. **Green Growth in Fisheries and Aquaculture** (OECD, 2015)

The OECD outlook study illustrates some key conditions for putting fisheries on a pathway that allows meeting an expected increasing demand by an increasing world population in a sustainable way.

The first pillar is rebuilding wild fish stocks that are increasingly affected by overfishing. Essential to this end is the reliance on clearly defined fishing zones and surveillance of their respect by fishing fleets.

The second pillar is aquaculture systems that are more efficient (less space), rely less on other marine resources for feed, integrate with other marine activities.

In both areas the regulatory framework plays a fundamental role and research, as well as information sharing between regulatory institutions and national authorities are necessary to provide policies with the necessary evidence base. Policies should include fishing and aquaculture in a united and coherent way, and should be developed in a participatory way with all stakeholders,

The OECD advocates a Green Growth Strategy (GGS) that combines regulations and standards, support measures, economic instruments, trade measures, research and development, information sharing, education, training and advice. The combination of instruments is particularly necessary as those who bear the burden of (at least temporary) restrictions to operations are not necessarily the same that would enjoy the benefits; in any case there may be a time lag between costs and benefits. The OECD provides extensive suggestions for measures aimed at the implementation of a GGS.

A large number of complementary indicators have been proposed by the OECD to accompany and monitor the development and implementation of a GGS that combine economic, policy, physical, management and biological aspects.

The OECD recognises the efforts made by its members for a reduction of fleet overcapacity, that is responsible at the same time for excessive fishing and loss of investments. However, overcapacity is still prevalent in many developing countries where most of captures are made.

Another area that still needs considerable joint efforts is that of Illegal, Unreported and Unregulated (IUU) fishing that can take a great many forms worldwide and whose effect on stocks is, by nature, difficult to estimate.

2.10.10. **Seafood in Europe - A food system approach for sustainability** (EEA, 2016)

The EEA document advocates a "Food systems approach" as the most direct way to incorporate seafood, its production, transformation and use into a broader concept of sustainable development. Fisheries and aquaculture, therefore, should not be considered in isolation, but as components of a vast web of social, economic, environmental and technical relationships.

The pathways for change indicated by EEA, 2016 to achieve the "Food systems approach" are:

(1) "building a shared understanding of the food system and its outcomes at the EU level, namely by adopting a systems approach EU policies related to food and sustainability, and building on the EU efforts to develop the ecosystem services approach as a common language between ecosystems and human benefits;

(2) improving the knowledge base related to seafood in order to improve sustainability assessments of seafood in Europe from a food system approach;

(3) boosting efforts to implement the ecosystem approach to Europe's seas for securing the long-term availability of seafood".

2.10.11. The Ocean Economy in 2030 (OECD, 2016)

The OECD report is not limited to fisheries and aquaculture, but considers a broad range of industries: shipping, fishing, fish processing, renewable energy production, oil and gas extraction, sea-bed mining, tourism, biotechnologies. Their mutual relationships and their relationship with the environment and climate are seen as keys to the further development of a sustainable ocean economy.

Some often overlooked differences characterise oceans and land: a) the huge size of oceans (more than twice the surface of land); b) remote sensing technologies limited t the surface; c) the vertical dimension is far more relevant at sea than on land; d) the interconnection of seas and oceans; e) the unrestricted movement of fish; f) long-term persistence of pollution; g) oceans are to a large extent "commons" (with limited or absent ownership and responsibility for stewardship); h) sparse human presence.

A major problem of fisheries and aquaculture in playing a leading role in the sustainable development of the oceans economy is their marginal economic value. As can be seen in **Figure 2.13**, capture fisheries and aquaculture combined represent a negligible part of sectoral value added, although capture fisheries have the highest share of the labour force (followed by tourism).

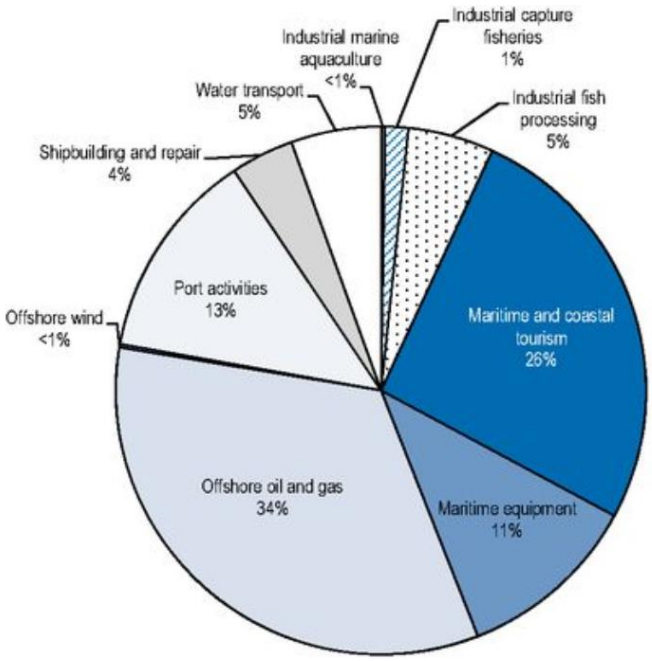

Figure 2.13 - Value added of ocean based industries in 2010 (From OECD, 2016)

A projection to 2030 is based on scenarios. The "business as usual" (baseline) scenario consists of a projection of current trends. No drastic changes are expected, except tourism taking the leadership, overcoming the oil and gas sector.

Two alternative scenarios, "sustainable" and "unsustainable" imagine respectively an environmentally conscious growth, supported by favourable public policies, and a deteriorating environment conducive to poor growth. In terms of value added, the sustainable scenario outperforms the unsustainable scenario; the BAU scenarios is half-way in between.

Among the fastest growing sectors the OECD includes marine aquaculture. The report is rather pessimistic on the possible abatement of cross-sectoral barriers to coherent regulations and policies.

The following actions are recommended to enhance the sustainable development of the Ocean economy:

- Foster greater international cooperation in maritime science and technology as a means to stimulate innovation.
- Strengthen integrated Ocean management.
- Improve the statistical and methodological base at national and international level for measuring the scale and performance of ocean-based industries and their contribution to he overall economy.
- Build more capacity for ocean industry foresight.

Science and technology are seen as key drivers of development. The OECD report takes into consideration cross-cutting innovations that are likely to impact on several sectors at the same time:

- Bioprospecting (looking for new-to-science species and understanding their economic potential for food, medicine, new chemicals, …)

- Sea-floor detailed mapping.
- Ocean health monitoring through better observation and surveillance systems and exploiting big-data, data mining and artificial intelligence.
- Development of new sensors and imaging technologies (especially satellite imaging).
- Advanced materials (for use in marine environments).
- Nanotechnology.
- Biotechnologies.
- Autonomous systems for movement control and manufacturing (e.g. 3D printing).
- Shared offshore installation for multiple use.

2.10.12. **Foresight. Future of the Sea** (GO-Science, 2018)

As for the OECD Report "**The Ocean Economy in 2030**" (OECD, 2016), this document, produced by the UK Government Office for Science takes a broad view on the many sectors that compose the marine and maritime-based economic activities with their intersections and interactions. Its declared purpose is "*to inform Government's long-term approach to the sea, and provide evidence and strategic thinking to inform relevant activities by all sectors*".

The study pays particular attention to factors that affect in a cross-cutting way the economic and social lives of citizens. The first priority is the oceans' environment, as it affects climate (by buffering anthropogenic emissions and the temperature increase that they provoke), it holds a largely unexplored biodiversity, it provides a broad range of ecosystem services, it impacts on health and wellbeing.

Fishing, aquaculture and fish processing, despite being among the major players in Europe, are certainly not in the forefront in UK marine and maritime economy, dwarfed by oil & gas extraction, ports and tourism in terms of value added and by tourism, shipping and ports in terms of employment. As a consequence, fishing, aquaculture and food processing need to come to term with the stronger sectors when planning for their further development.

The report provides recommendations on various fronts: we here report those related to research:

- **Prioritise key research needs:**
  - Improved modelling of sea level rise and coastal flooding to inform planning of infrastructure and reduce uncertainty for coastal communities
  - Technologies to enable modern communication at sea, and improve data transfer and battery power
  - The interactions between different stressors, e.g. ocean warming and ocean acidification, and their cumulative impact on the marine environment
  - The 'tipping points' at which marine ecosystems will be unable to recover from projected damage

- **Ensure international scientific collaboration.**
- **Enable big data to be a driver of innovation**
- **Improve our understanding of the sea**

2.10.13. BLUEMED Strategic Research and Innovation Agenda (BLUEMED, 2018)

The BLUEMED SRIA is the outcome of a series of coordinated initiatives carried out within a H2020 CSA aimed at reinforcing cooperation for marine and maritime research in the Mediterranean area and at proposing a research agenda for the future.

The BLUEMED subject area, much as the Blue Growth component of Horizon 2020 Societal Challenge 2 under which it was developed, covers a broad range of marine and maritime sectors and disciplines. Out of a detailed list of research, innovation and governance priorities we have here selected those that the SRIA declares relevant for fisheries and aquaculture and the linked food domain.

Despite being developed specifically for the Mediterranean region, the priorities are relevant for other areas as well.

- Innovative blue growth trajectories
  - Exploring the potential of blue-biotech
  - Support solutions for sustainable food production
  - Exploiting the Deep Sea
- Innovative businesses based on marine bio-resources [in the Mediterranean]
- Ecosystem-based management of [Mediterranean] aquaculture and fisheries
  - Develop optimal fishing strategies, technologies and practices
  - Develop optimal aquaculture strategies, technologies and practices
- Governance of maritime space and marine resources [in the Mediterranean]
  - Strengthen synergies among science, industry, policymakers and society
  - Effective maritime spatial planning in the Mediterranean

2.10.14. Strengthening fish welfare research through a gap analysis study (Manfrin *et al.*, 2018)

The study is based on the premises that concerns over the welfare of farmed animals by consumers may represent an obstacle to the development of a sector that is otherwise considered essential to provide the world with fish in the future.

Welfare issues display a widespread lack of scientific data due to various reasons: **a)** the huge number of fish species involved; **b)** the variety of production methods and **c)** limited research funding. Furthermore, the sector often displays resistance in the adoption of innovation backed by recent scientific developments.

The aim of the joint SCAR Fish/SCAR AHW working groups was to detect gaps in research and facilitate a dialogue with stakeholders of the aquaculture industry on research priorities.

The work included literature review, expert panel work, a survey and a focus group between stakeholders and researchers leading to a consensus on research priorities.

The list of priorities was made separately per **Production phase (**Breeding stock, Early life, Rearing, Transport and Slaughtering) and per **Fish species** (Atlantic salmon /Rainbow trout, Carps, Sea bass/bream, Turbot/Sole, Eel and Sturgeon).

2.10.15. **Rethinking Innovation for a Sustainable Ocean Economy** (OECD, 2019)

Oceans and seas are fundamental assets for future development, but the current development pathways are putting the marine environment under a growing strain from pollution, increasing temperatures, overexploitation of fish stocks etc., thus undermining the very development that is advocated. This acknowledgement led the OECD to the undertake a forward-looking exercise to devise new ways towards a sustainable economic development that preserves the natural capital while supporting human activities and wellbeing.

The report presents four case studies:

1. Ballast water treatment in ships, to combat the spread of (alien) marine species;
2. Floating offshore wind power;
3. Innovations in the marine aquaculture sector;
4. Conversion of decommissioned oil and gas rigs and energy renewables platforms into artificial reefs.

The third one is the most directly connected to the theme of our analysis and will be considered in detail, but the first and fourth ones have at least some interesting connections with the fisheries and aquaculture themes.

The OECD anticipates that the combined effect of innovations in the aquaculture sector would guarantee a 5% growth of gross value added per year to 2030, even without considering upstream (suppliers) and downstream (food processing and retail) sectors. The main avenue for the future of aquaculture, according to the OECD, is the development of offshore operations where a theoretical area of over 11 million square kilometres could be available for finfish and 1.5 million square kilometres for bivalves. Such surfaces could produce 15 billion tonnes of finfish a year, that is almost 100 times the current global consumption of seafood.

However, at present there is little experience on offshore aquaculture that would face huge technical and operational obstacles. This is indeed the main area of innovation suggested by the OECD report.

One fundamental field of research and innovation that provides an evidence base for all forms of sustainable development is the acquisition and analysis

of observational data, an area in which satellites, sensors, big data, artificial intelligence and other emerging technologies will contribute. The OECD study proposes interesting approaches in this field.

The report also mentions areas of incremental technology that hold a high cross-sectoral innovation potential for marine and maritime development:

- Advanced materials (for stronger, lighter and more durable structures)
- Nanotechnology (self-diagnostic, self-healing and self-cleaning materials)
- Biotechnology (breeding of species, vaccines, food and feed, new biochemicals, pharmaceuticals, cosmetics)
- Subsea engineering and technology
- Sensors and imaging for measurement of the marine environment.
- Satellite technologies (optics, imagery, sensors, satellite
- Computerisation and big data analytics
- Autonomous systems for surface and underwater vehicles

The OECD study advocates a strong collaboration between actors of the marine and maritime sectors and the establishment, or reinforcement, of networks that bring together public research organisations, enterprises (large and SMEs), universities and public agencies into comprehensive innovation efforts.

One area of standardisation and further research, according to the OECD, is that of economic statistics, currently fragmented in national or regional systems that make them incomparable and therefore of limited use to measure development. Providing economic value to ecosystem services and social benefits would allow a better appreciation of their contribution to society.

Innovation in marine aquaculture. One of the four case studies proposed by the OECD, the development of marine aquaculture, is motivated by the observed slowing down of the rate of growth of the aquaculture sector, constrained by growing concerns about environmental footprint, impact on human health (from antibiotic use), impact on wild fish population, competition with other activities for coastal space, limited availability of feed.

Moving offshore, however, is not straightforward. There is a need for infrastructures (cages) that can withstand harsh physical conditions, facilitate access and operations of labour forces, monitor health and welfare of fish stocks, etc.

One area of research and innovation is observation technologies for the selection and mapping of appropriate sites, monitoring environmental conditions, detection of algal blooms, etc. Combinations of high resolution satellite imagery, big data analytics and GIS-mapping/modelling could provide the knowledge necessary for significant improvements.

Genetics (supported by genome mapping) can support breeding programmes that are already proving profitable from an economic point of view. However, there is a need to move from fast growth, that was the main objective so far, to resistance to diseases, more efficient conversion of feed to flesh (thus

reducing pollution and eutrophication from excretions), increased resilience to stress factors.

Advancements in feed technology are also anticipated. Less fish and more fish-processing by-products will be employed in the future, as well as novel sources of proteins and oils, from insects or maritime/terrestrial plants, micro-algae, etc.

Integrated multi-trophic aquaculture holds the best promises for the solution of pollution associated with fish farming. Different trophic levels are combined: fed fish are associated with bivalves, that feed on so that on fish excretions an with algae that absorb the excess nitrogen and phosphorus, thus closing the circle and returning water to a clean state.

Progress is expected also in protection of farmed fish stocks from diseases by a combination of measures: genetic resistance (see above), prevention (vaccines and management improvements), monitoring and detection, treatment (least use of antibiotics, development of "natural" products).

2.11. List of documents

Bagni M, Zilli R, Messori S, Mariano V. 2014. **Animal health foresight for the Mediterranean**. RORE-MED Report

The report is an output of the FORE-Med project, (*Foresight project for the Mediterranean area*) aimed at the identification of animal health challenges and priorities for research, including Aquaculture. The exercise was carried out within the activities coordinated by the STARIDAZ FP7 project and is linked to the SCAR CWG on Animal Health and Welfare and to the ERA-Net EMIDA.

Béné C, Barange M, Subasinghe R, Pinstrup-Andersen P, Merino G, Hemre GI, Williams M. 2015. **Feeding 9 billion by 2050 – Putting fish back on the menu.** Food Security, March 2015.

The purpose of the paper is to advocate a clear inclusion of fish in the debate and policy development on food security and nutrition. Controversies and debates on fisheries and aquaculture are exposed with a view to understanding and clarifying their role in ensuring adequate nourishment to the almost 10 billion inhabitants of the Earth in 2050.

BLUEMED. 2018. **Strategic Research and Innovation Agenda (SRIA)** - Updated version 2018. Coordination and Support Action Horizon 2020 - BG-13-2016 Grant Agreement 727453

Research and Innovation Agenda developed by the BLUEMED initiative supported by a CSA of the Horizon 2020 SC2 WP 2016-17.

EEA. 2016, **Seafood in Europe - A food system approach for sustainability**. 56 pp. doi:10.2800/06589

The EEA observes that, despite a growing concern about the food needs of a growing word population, a coherent approach to food systems is lacking in Europe. In particular, it advocates a broad view that combines technical, social, economic, environmental issues not only at the European scale but at the world scale. Europe imports more than 55% (in 2013) of the seafood it consumes and therefore also what happens in the lands and oceans of origin ow hat we eat should be of our concern. Obstacles to the implementation of an Ecosystem Based Management system in Europe is often hampered by conflicts between goals linked to the three pillars of sustainability, by a plethora of regulations and policies and by the difficulties in agreeing on crucial issues as the observation of Maximum Sustainable Yields.

FAO. 2018. **FAO yearbook. Fishery and Aquaculture Statistics 2016**. Rome

The FAO yearbook provides statistics on fisheries and aquaculture updated to the year 2016. They are meant to contribute to the achievement of the 2030 UN Agenda SDGs by providing support to effective knowledge-based policies and practices.

FAO. 2018. **The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals**. Rome

The report provides a comprehensive description of the status and trends of fisheries and aquaculture at the global level. The FAO is the recognised authority for the production of official statistics that are mainly (not exclusively) based on data produced by Member Countries. As such, they are not perfect, probably affected by lack of figures on illegal unreported and unregulated (IUU) fishing but represent the best source of data available. All developments are seen through the lens of the sustainable development goals of the UN 2030 Agenda.

GO-Science. 2018. **Foresight. Future of the Sea**. – A Report from the Government Chief Science Advisor.

This is a UK report that addresses all the interconnected sectors of seas and oceans economies with a national focus and provides analyses and recommendations for the policies to be developed by the UK Government and its Departments and Agencies, as well as for a better targeted research activity.

HLPE. 2014. **Sustainable fisheries and aquaculture 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 2014.

"The report presents a synthesis of existing evidence regarding the complex pathways between fisheries and aquaculture and food and nutrition security, including the environmental, economic and social dimensions, as well as issues related to governance. It provides insights on what needs to be done to achieve sustainable fisheries and aquaculture in order to strengthen their positive impact on food and nutrition security" (from the Foreword).

Manfrin A, Messori S, Arcangeli G. 2018. **Strengthening fish welfare research through a gap analysis study**. SCAR FISH & SCAR CWG AHW

The document was produced jointly by members of two SCAR Working Groups, the SWG SCAR Fish (Fisheries and Aquaculture Research) and CWG AHW (Animal Health and Welfare). The aim was to detect gaps in existing knowledge on health and welfare issues of farmed fish in order to facilitate progress of the aquaculture sector towards increasing concerns of citizens.

Ministerial Group for Sustainable Aquaculture. 2014. **Aquaculture Science & Research Strategy**. 85 pp.

This research strategy and requirements document was produced by the Scottish Government's Ministerial Group for Sustainable Aquaculture – Science and Research Working Group (MGSA-S&R WG) in 2014 in order to provide research priorities to public authorities. The work was carried out by experts interacting with relevant stakeholders of the aquaculture sector, with an ambitious sustainable development goal: increasing finfish production by 1/3 and mussel production by 1/2 between 2011 and 2020. The main topic areas for research are; Nutrition, Stock Improvement, Health and Welfare, Food Safety and Hygiene, Technology and Engineering, Wild-Farmed Interactions,

Markets, Economics and Social Science, Capacity, Blue Biotechnology and Growth.

OECD. 2015. **Green Growth in Fisheries and Aquaculture**. OECD Green Growth Studies. OECD Publishing. Paris. http://dx.doi.org/10.1787/9789264232143-en

The OECD report provides a comprehensive approach to the design and implementation of policies aimed at the sustainable development and management of fisheries in their two main domains: capture fishing and aquaculture. It emphasises the need for sound knowledge, as provided by research efforts, a participatory and inclusive approach to policy development, a comprehensive and coherent palette of actions in regulation, incentives, technical support. It estimates a possible increase of fish productions of 13% by the year 2030 if green growth principles are adopted.

OECD. 2016. **The Ocean Economy in 2030**. OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264251724-en

The OECD Ocean Economy in 2030 provides a perspective view of the future economic and social development of oceans and seas in a landscape framed by the global challenges. A broad range of industries is considered (shipping, fishing, fish processing, renewable energy production, oil and gas extraction, sea-bed mining, tourism, biotechnologies, etc.) and their relationships with the natural environment and climate. Indeed, the health state of the oceans (pollution, fish stock depletion, increasing temperatures, acidification) is seen as a major obstacle to the further development of the ocean economy. Among the fastest growing sectors the OECD includes marine aquaculture. The report is rather pessimistic on the possible abatement of cross-sectoral barriers to coherent regulations and policies.

OECD. 2019. **Rethinking Innovation for a Sustainable Ocean Economy**. OECD Publishing, Paris. https://doi.org/10.1787/9789264311053-en

The OECD report places science-driven innovation at the heart of the sustainable development of the marine and maritime economic sectors. Innovation networks should bring together different types of operators (PRO, Universities, large-medium-small enterprises, regulatory agencies) and different subsectors that interact and often, at the moment, compete for space and resources. Emerging and enabling technologies, cross-cutting in nature, should underpin and boost innovation: remote observation, data handling, bio- and nano-technology. One of the key areas of development is aquaculture and, specifically, the still limited offshore aquaculture that holds promises of almost "unlimited" space, but is fraught with technical obstacles..

SCAR-Fish. 2013. **Science in support of the European fisheries and aquaculture policy**. Brussels

The report was prepared as an input to H2020 programming and was based on a preliminary foresight exercise. The European research system is of high quality but fragmented and fails to provide the evidence required for effective management of fisheries and aquaculture. The Common Fisheries Policy is criticised for lack of a sound evidence base.

SCAR-Fish. 2014. **SCAR-Fish views on COFASP Foresight paper – View on the future research of European Fisheries, Aquaculture and Seafood Processing**, Brussels

SCAR-Fish opinion on the COFASP Foresight (van Hoof, Steenbergen and Smith, 2014) exposes a substantial agreement with the COFASP conclusions, albeit with some differences on priorities. SCAR-Fish criticises the lack of interest placed by the COFASP document on Marine Protected Areas that, however positive in the medium-long term for the replenishment of fish stock, have a considerable short-term effect on fisheries. Also the approach to Climate Change is seen as mostly directed on its biological effects by COFASP and on its impact on fisheries by SCAR-Fish. Other non-fundamental differences are discussed.

Scientific Advice Mechanism. 2017. **Food from the Oceans - How can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits?** High Level Group of Scientific Advisors. Scientific Opinion No. 3/2017. EC/RTD.01 – SAM, Brussels

The document is the scientific opinion expressed by the Scientific Advice Mechanism – High Level Group of Scientific Advisors upon request by the EC. The question posed to the SAM-HLG was: "How can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits?". The main suggestions were an expansion of aquaculture (especially mariculture) in an environmentally sound way, the shift of captures towards lower trophic levels (herbivores instead of carnivores), combined culture systems with finfish, filter feeders (mainly shell molluscs) and algae in closed trophic circles and the further use of feed of vegetable origin (whether from land or sea). Measures aimed at a further integration of sustainability criteria into policies and regulations are also advocated.

van Hoof L, Fabi G, Johansen V, Steenbergen J, Irigoien X, Smith S, Lisbjerg D *et al.* 2019. **Food from the ocean; towards a research agenda for sustainable use of our oceans' natural resources**. Marine Policy, **105**: 44-51

This recent paper, published in a peer-reviewd Journal represents a partially revised version of van Hoof, Steenbergen and Smith, 2014.

van Hoof L, Steenbergen J, Smith S. 2014. **View on the future research of European Fisheries, Aquaculture and Seafood Processing**. Report produced for the FP7 ERANET COFASP

This forward-looking document on the future of research was produced by the European Fisheries and Aquaculture Research Organisation (EFARO) within the FP7 ERA-Net COFASP, with a view to providing a list of sectoral research priorities for a time span of 15 years (that is, approximately with 2030 as a target year). A scenario approach was adopted with the consultation of a broad range of stakeholders in three workshops. Scenarios (possible futures) were used for the development of research priorities.

3. Forestry

3.1. Setting the scene

The latest global figures on the extent of forests, their types, functions and dynamics are provided by the Global Forest Resources Assessment "FRA-2015" (FAO, 2016), the most recent of a series of reports that the FAO regularly updates every five years. The next issue is expected in 2020.

According to FRA-2015 (FAO, 2016), forests represent the second largest type of use of land: **3.999 M ha or 30.6% of land** (excluding Antarctica and Greenland). The first is agriculture.

Forests differ greatly around the world and have a broad range of functions at the global and local scale, depending on climate, demography, social and economic contexts (HLPE, 2017).

The general definition of a forest adopted by the FAO both in recent FRA and for the next report of 2020 (FAO, 2018a) is of "*land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use*". The definition includes tree plantations where the trees themselves represent the main focus of land use (e.g. Eucalypts, Pines, Poplars for timber or pulp/paper production) but *"excludes tree stands in agricultural production systems, such as fruit tree plantations, oil palm plantations, olive orchards and agroforestry systems* [with some exceptions] *when crops are grown under tree cover".*

Another substantial part of the world land (1204 M ha, or little less than 1/3 the surface of forests) is classified as "Other wooded land", where either the degree of canopy cover is less than 10% or the height of trees (at maturity) is less than 5 metres.

All the rest, land devoted to agriculture, urban settlements, infrastructures is classified as "*other land*", although part of it includes trees.

However, the FRA is based on statistics provided by countries with limitations due to uneven quality of data. Estimates that made use of satellite images "discovered" around 467 M ha of "hidden forest" that had not been reported (HLPE, 2017).

The majority of forests (more than 90% of surface) are classified as "naturally regenerated", including both "primary" forests and "secondary" forests depending on the degree of human influence.

Whereas the area of primary forests is expected to follow a progressive reduction, the total forest area is expected to rise from 2020 onwards; more rapidly so in OECD countries, followed by BRIICS and, at a later date (2030) by the rest of the world (OECD, 2012).

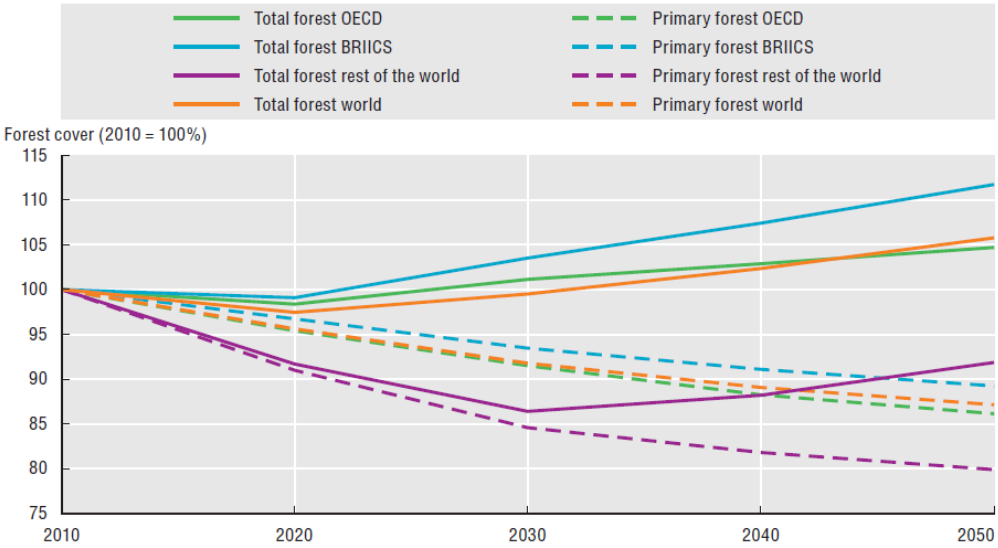

Figure 3.1 - Global forest area change according to the baseline OECD (2012) projections over the period 2010-2050.

Table 3.1 - Natural and planted forests in the world (Million hectares; data from FAO, 2016)

Continent	Natural Forests	Planted Forests
Africa	600	16
Asia	462	129
Europe	929	83
N. & C.America	707	43
S.America	817	15
Oceania	169	4,4

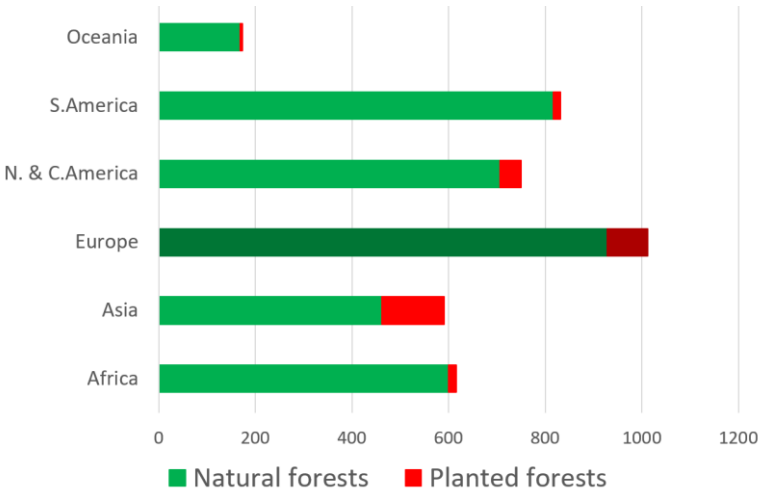

Figure 3.2 - Natural and planted forests in the world (Million hectares; data from FAO, 2016)

The area of **planted forests** is increasing in all continents at an annual expansion rate between 1.11% (Europe) and 2.55% (North and Central America). Despite the low share of land (around **7%**), forest plantations provide around **45% of roundwood for industrial uses** (HLPE, 2017). There is a broadly shared conviction that plantations contribute to decrease "pressure" on forests for the provision of industrial roundwood; however, dissenting voices are also heard, claiming that the high profitability of forest plantations is a driver of further de-forestation, for conversion to plantations (an effect of "Jevons paradox"[16]).

The global forest area decreased steadily since 1990, although at a slower annual rate in the last decade than in previous years (**Table 3.2**).

Table 3.2 - Global forest area change, 1990–2015 (FAO, 2016)

Year	Forest area (thousand ha)	Period	Net change (thousand ha)	Annual change rate (%)
1990	4 128 269			
2000	4 055 602	1990–2000	-7 267	-0.18
2005	4 032 743	2000–2005	-4 572	-0.11
2010	4 015 673	2005–2010	-3 414	-0.08
2015	3 999 134	2010–2015	-3 308	-0.08

The overall figures, however, mask a significant diversity across the world with ten countries (from S.America, Tropical Asia and Africa) leading the loss of forest (**Table 3.3**)

Deforestation rates are declining; this trend is expected to continue; significant is the case of China where a contraction of agriculture on the most productive areas and chronic shortage of wood has led to a significant increase in forest cover (OECD-2012)

Table 3.3 - First ten countries ranked for net forest loss in the period 2010 to 2015 in absolute figures; Nigeria displays the highest annual rate of forest loss at 5% per year, compared to Brazil at 0.2% (FAO, 2016)

Country	Net forest loss 2010-2015 (thousand hectares)
Brazil	**984**
Indonesia	684
Myanmar	546
Nigeria	**410**
Tanzania	372
Paraguay	325
Zimbabwe	312
D.R of the Congo	311
Argentina	297
Bolivia	289

[16] https://en.wikipedia.org/wiki/Jevons_paradox

… and ten countries (also from S.America, Asia and Africa, but also N.America and Europe) expressing the highest net gains of forest area, with China by far the leader of the group.

Table 3.4 - First ten countries ranked for net forest gain in the period 2010 to 2015 in absolute figures; The Philippines display the highest annual rate of forest gain at 3.3% per year, compared to China at 0.8% (FAO, 2016)

Country	Net forest gain 2010-2015 (thousand hectares)
China	**1542**
Australia	308
Chile	301
United States of America	275
Philippines	**240**
Gabon	200
Laos	189
India	178
Viet Nam	129
France	113

Two more aspects deserve consideration: the first is that, consistently over the last three decades, **the forests expand in the temperate regions of the world and decrease in the tropical regions**, with boreal forests (mainly N.Europe and Canada) and subtropical forests almost stable over the same period.

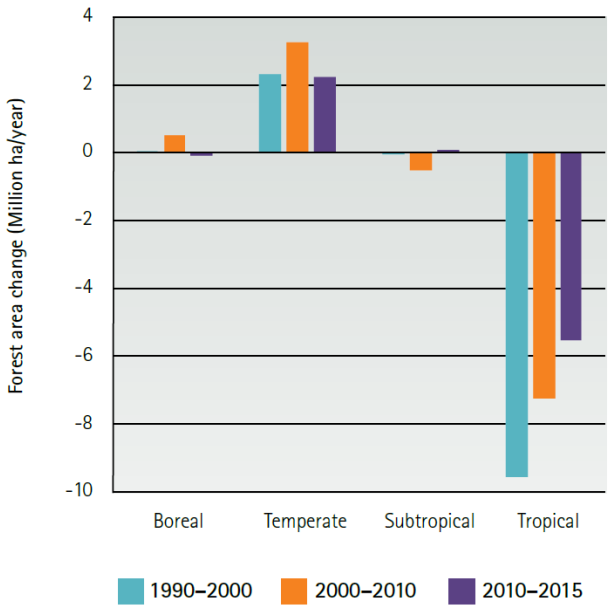

Figure 3.3 - Annual forest area net change by climatic domain, 1990–2015 (FAO, 2016).

The second remarkable point is that **net forest loss is inversely correlated with income** (i.e. the poorer the country, the highest the loss).

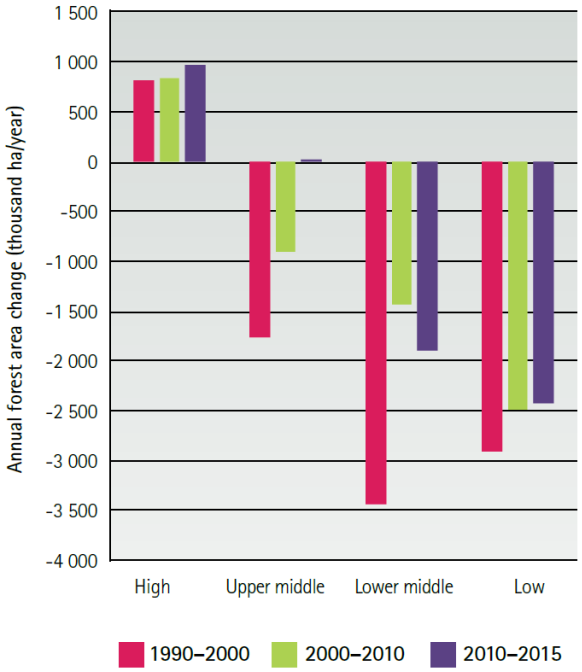

Figure 3.4 - Annual forest area change by income category, 1990–2015 (FAO, 2016)

Again with obvious *caveats* about the risk of generalisations, and with remarkable exceptions (e.g. Laos), forest loss is associated with poverty, hunger, population growth and the related pressure on agricultural expansion. Indeed, **conversion to agriculture is the first global cause of forest loss** and, indirectly, the main reason for the **contribution of agriculture to net GHG emissions** leading to climate change.

Partial Canopy Cover Loss, a symptom of forest degradation often leading to deforestation and conversion to agriculture is also concentrated in tropical areas of South America, South and Southeast Asia and Western and Central Africa.

On a global scale, deforestation, forest degradation, fires and other damages contribute to around 10% of carbon emissions but the **sink effect** (growth minus emissions from losses) **offsets around 30% of the total emissions** with temperate and boreal forests of the Northern hemisphere playing the major role (UNECE/FAO, 2015).

Data about source and sink effects, however, are fraught with uncertainties; and discordances can be observed, for instance, between the data provided by FAO's Forest Resources Assessments and by the UNFCCC (UNECE/FAO, 2015).

3.2. Forests in Europe

The European forest area is clearly dominated by the **Russian Federation**, with almost 815 Million hectares (of course on a huge territory). Excluding the Russian Federation, **European forests cover an area of 215 Mha**, or 33% of its territory (Forest Europe, 2015), with Sweden (28.1 Mha), Finland (22.2), Spain (18.4) and France (17,0) in the lead. For the rest of Europe, see **Figure 3.5**.

Finland (first) and Sweden (second) also display the highest proportion of forest area with respect to total country surface.

European **forests are expanding in all countries** with very few exceptions. **Figure 3.6** and **Figure 3.7** report the rate of forest gain/loss between 2010 and 2015 and the absolute variation of forest area in the same period, respectively.

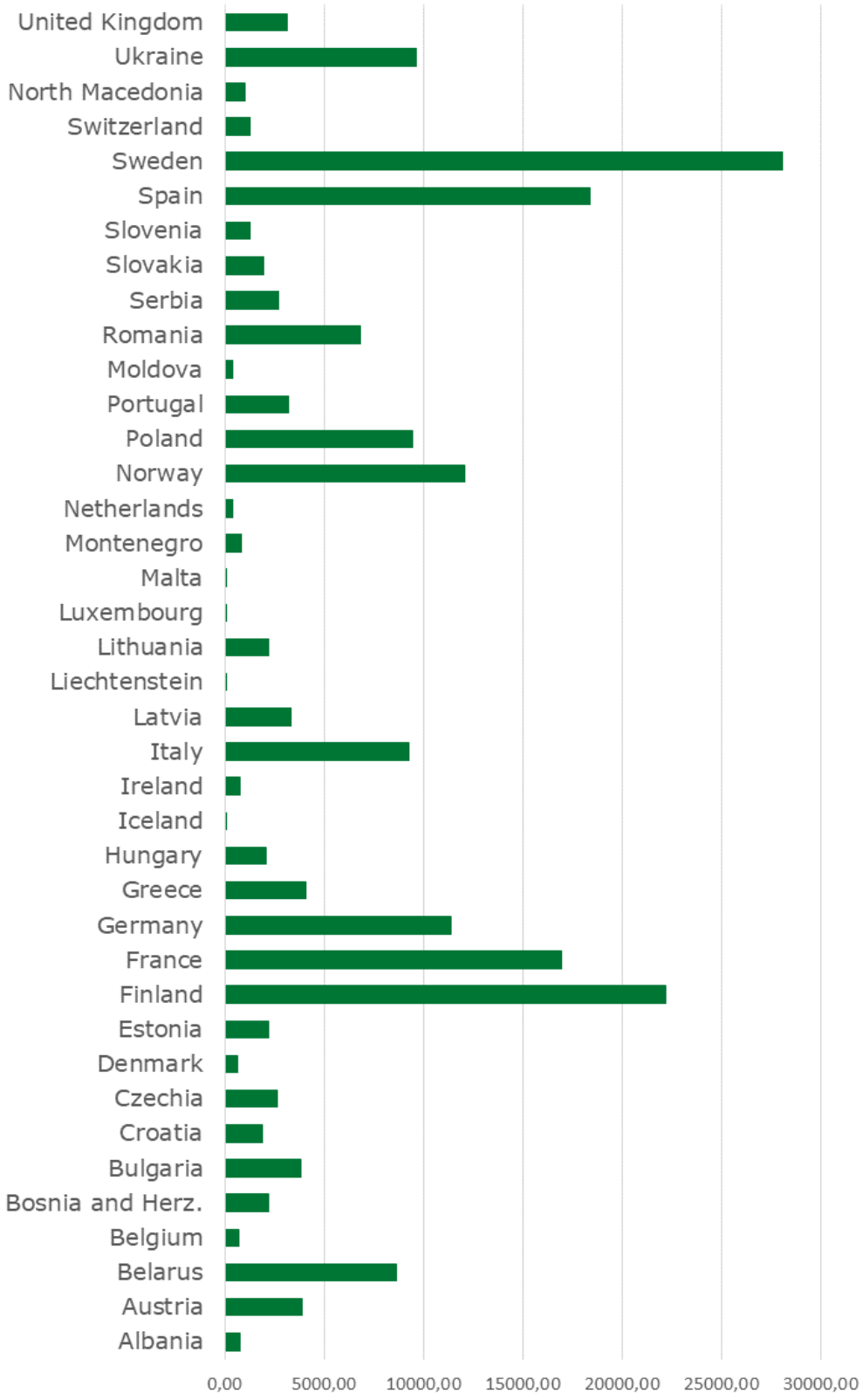

Figure 3.5 - Forest area of European countries in 2015 (thousands of hectares), excluding the Russian Federation (815 Mha) for reasons of scale (Data from FAO, 2016)

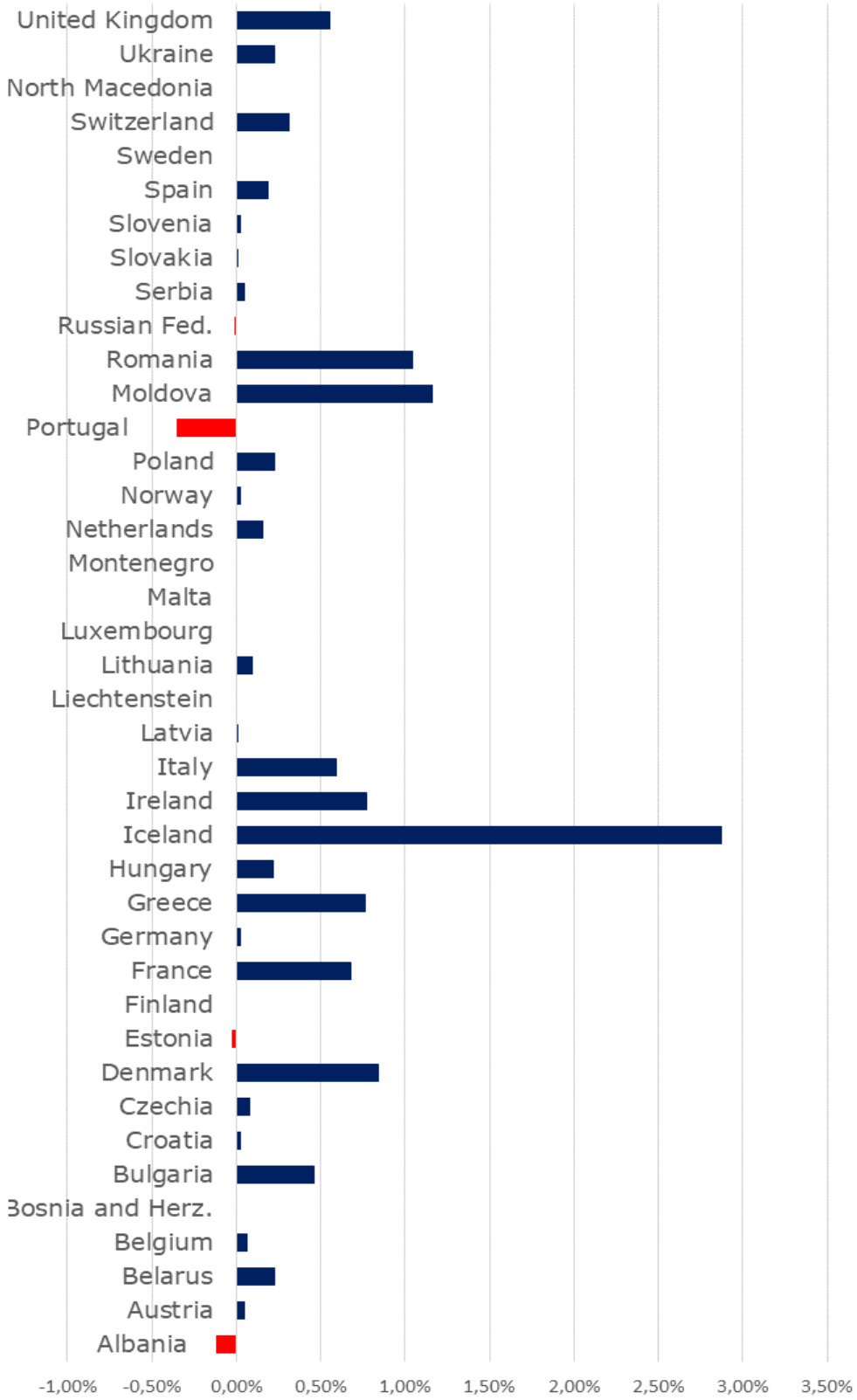

Figure 3.6 - Change of forest area of European countries between 2010 and 2015 (in %) (Data from FAO, 2016)

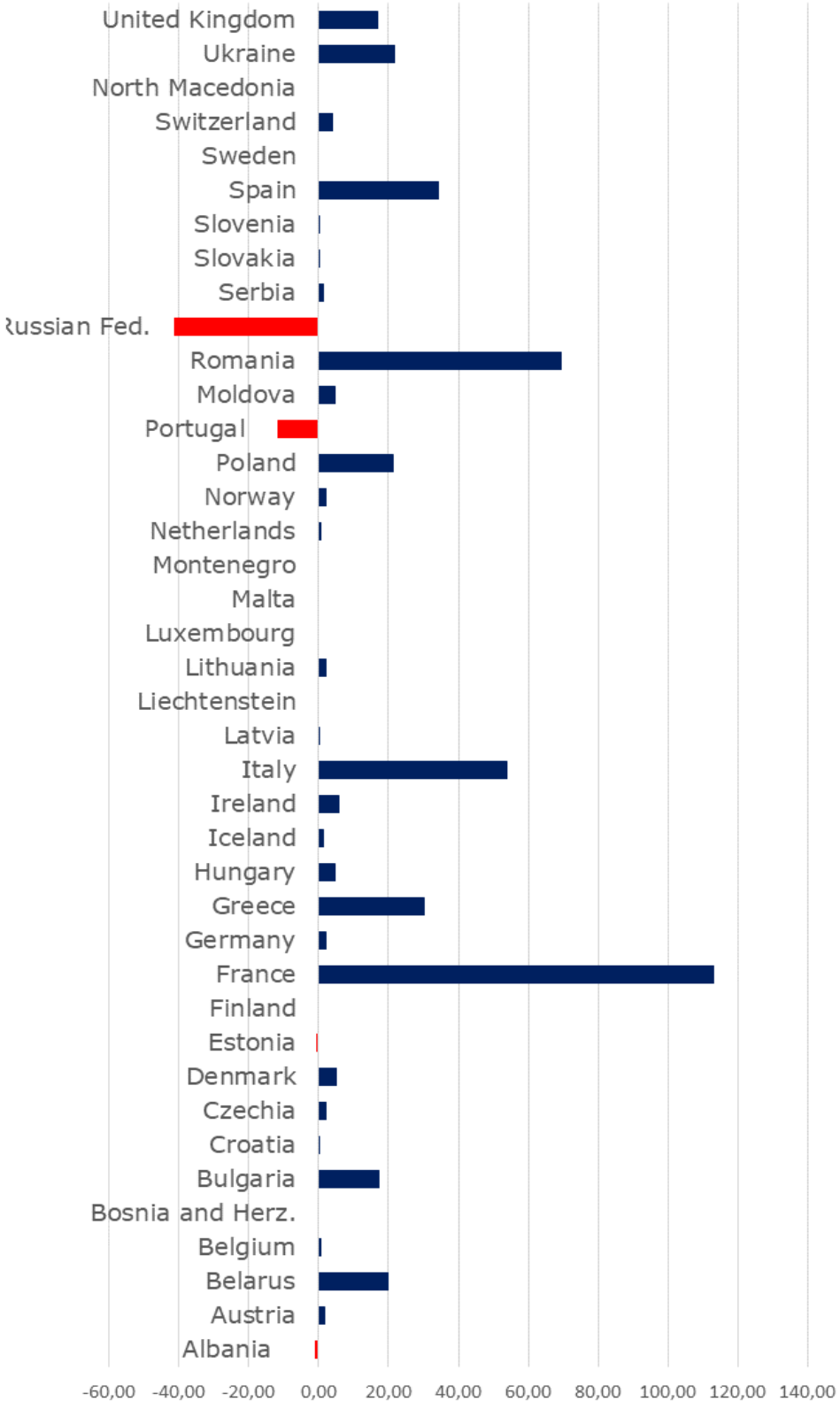

Figure 3.7 - Change of forest area of European countries (thousands of hectares) between 2010 and 2015 (Data from FAO, 2016)

3.3. Functions of forests

Forests, probably even more than agriculture, display a broad range of functions and services, typically simultaneously in the same area, that depend on the local climatic, ecological, demographic/ethnographic, social, and economic situation. The main functions will be briefly mentioned here.

3.3.1. Wood for the industry

Pulp and paper, constructions, packaging and furniture make large use of wood of different species and provenances. The utilisation of forests for production of industrial roundwood is favoured where **access with operational machines** is easier.

According to the FRA-2015 (FAO, 2016), **high income countries** of the world have the **highest share of forests designed for production**, as a primary objective, or for multiple use: approximately, little more than 600 Mha for each category, together about 2/3 of all forests. In upper middle income countries that share is 1/3, in lower middle income countries or low income countries the share of production forests plus multiple use forests is around one half.

The contribution of forestry and logging to GDP (not considering downstream industrial transformation) is low; **the higher the national income, the lower its share** (**Figure 3.8**).

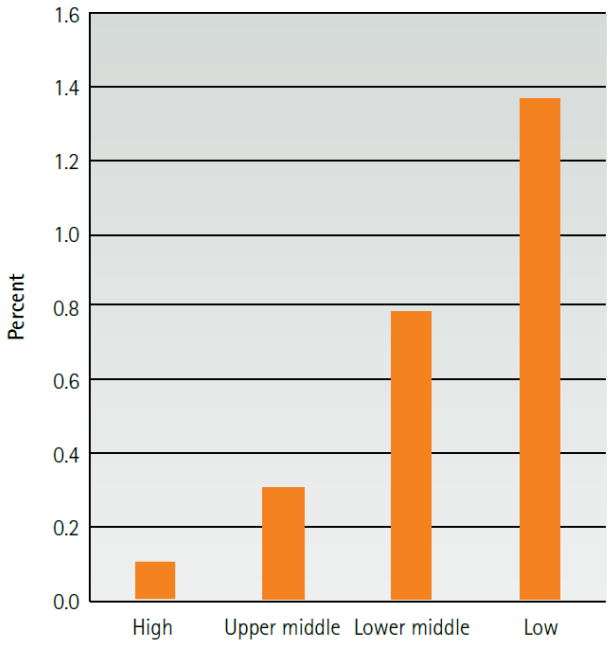

Figure 3.8 - Contribution of forestry and logging to GDP (%) (from FAO, 2016).

The value added by forestry and logging, on the other hand, is highest in high income countries (41% of the total) and lowest in low income countries (5%) (FAO, 2016).

Employment in forestry and logging parallels GDP: **lowest in high income countries** (largely due to mechanisation), higher in lower income countries: the perspectives are of further decline in developed countries; stable where most harvesting is focused on fuelwood.

In Europe the **wood production** component of forest economies amounts to at least **135 G€ of annual gross value added** (EEA, 2016), with the **pulp and paper** sector representing about 40% of that amount and the solid wood sector the other 60%. The contribution to GDP is on average low: about 1%, with a downward trend (Forest Europe, 2015), a fact that often makes the forest sector to be considered marginal in most economies; notable exceptions are Latvia (6.5%), Finland and Estonia (4.3%), Sweden (2.9%) and Slovakia (2.4%)(UNECE/FAO, 2015). However, when the **downstream industrial sectors** depending on wood source material are considered, the figures rise considerably. If the US estimates can be extrapolated to Europe, the contribution of the enlarged forest-dependent sector to national economies is around **ten times** that of the primary sector (EEA, 2016).

The same can be said of employment, where forestry accounts for around one sixth of the whole forest sector (**Figure 3.9**).

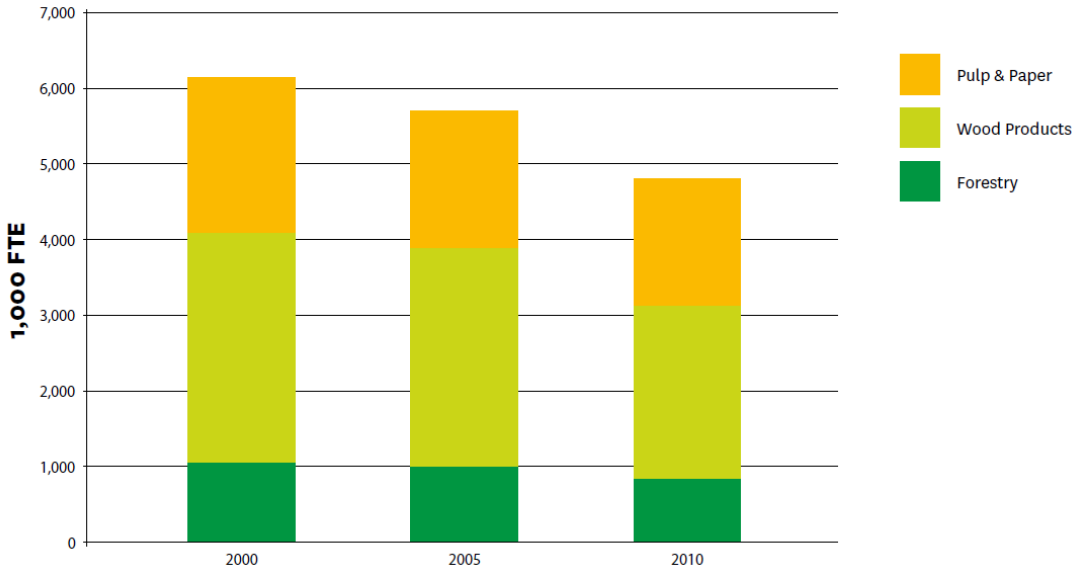

Figure 3.9 - Employment in the forest sector 200-2010 in Europe, including forestry, the wood products industry and the pulp and paper industry (UNECE/FAO, 2015).

The main trends observed in the international market of forest products is of an increase of sawn wood and panels *vs* roundwood, a **decrease** of the printing **paper** sector offset by an **increase** of **cardboard** for packaging. The market of wood chips for the production of energy is still volatile, as no clear position is so far broadly accepted on the role of forests as sources of renewable feedstock for biomass power plants (Viitanen J and Mutanen A Ed. 2017).

The amount of wood harvested expressed as a ratio to annual increment is on average around 60% in Europe (UNECE/FAO, 2015). However not in itself the ultimate index of a good forest management and with the caution that is

recommended when average data are used, it shows that, in general, European forests are not subject to an impoverishment of its living biomass resources, but, rather, that they are progressively accumulating wood (**Figure 3.10**).

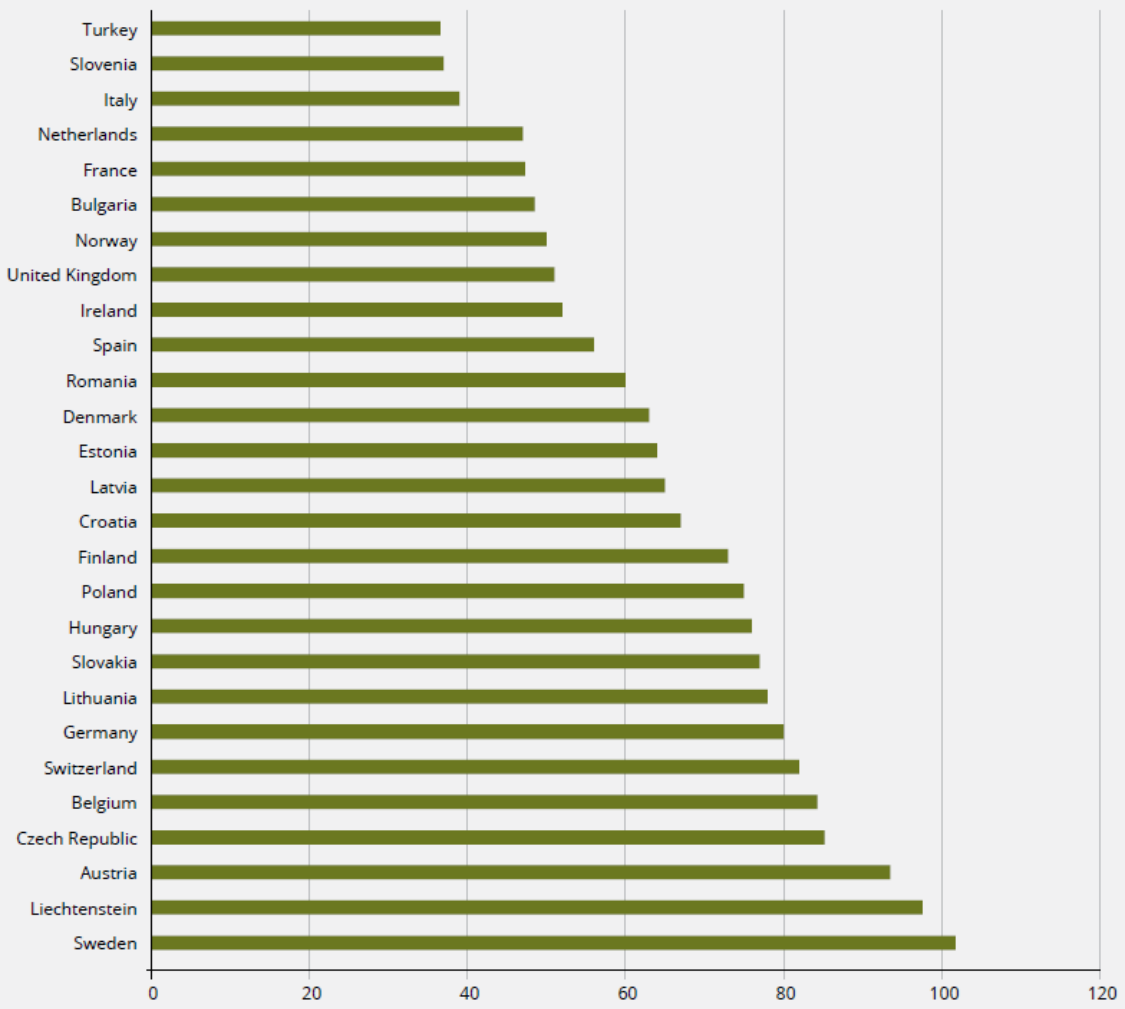

Figure 3.10 - Rate of utilisation of European forests in 2010 (from EEA, 2016)

3.3.2. Provision of energy

Cooking, heating, water sterilisation still largely depend on fuelwood and charcoal in large parts of the world, affecting about one third of the world population (FAO, 2018b). Consumption of fuelwood for these traditional uses is estimated at 1.9 billion m^3, with Asia, South America and Africa the main users. Charcoal, common in urban centres in developing countries, increased by 2% per year since 2010, reaching 52 Mt in 2015 (REN21, 2017).

It is estimated that **wood represents around 6% of total energy supply** (or **40% of all renewable energy**), with a share of up to 27% in Africa (FAO, 2014). In parts of Africa (e.g. Ethiopia) virtually all wood removals from forest are fuelwood, compared to Canada on the other extreme (2.5%). Wood for heating and, to a lesser extent, for cooking, is also important in high

income countries: most of coppice forests of central and southern Europe produce fuelwood for private heating.

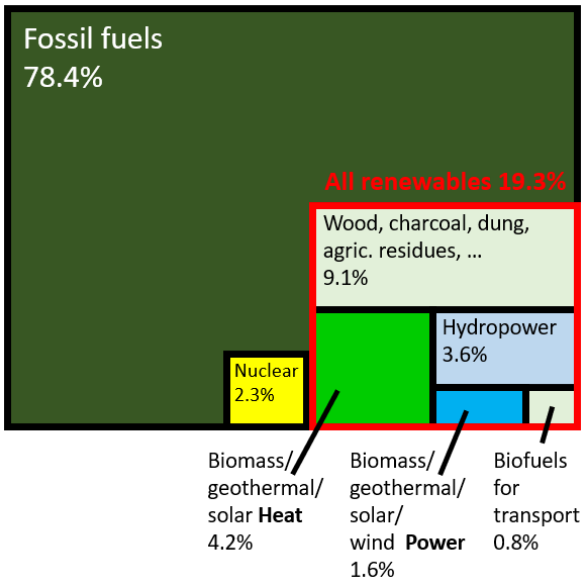

Figure 3.11 - Estimated renewable energy share of total final energy consumption, 2015 (from REN21, 2017[17]: modified; for sources of data see note 12, pages 224-5).

Europe has seen a slow but steady increase in the production of fuelwood since 1990 and a dramatic increase of imports that have exceeded internal production since 2011 (EEA, 2016).

3.3.3. Provision of food

The degree of dependence of populations living in or near to forests on food collected in the forests depends greatly on the circumstances. In tropical/subtropical regions, forest is often a regular or occasional source of **vegetable and animal food**, integrating and improving the quality of diets. In high income countries, such as in Europe, non-wood forest products (NWFP) are locally important for economic, cultural and recreational purposes. The collection of mushrooms and berries is often regulated in Europe, with rules, norms, habits, customs varying across states and often locally.

Bushmeat is an important source of high quality proteins in many developing countries, and often finds its way to markets in cities (especially in Africa and Asia). In the affluent countries hunting is considered more a recreational activity, although its indirect economic dimension may be considerable.

Plant/mushroom collection, hunting and bee products are the main sources of non-wood revenues in European forests. Hunting is also a source of income to forest owners and public administration in the form of licences.

[17] http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf

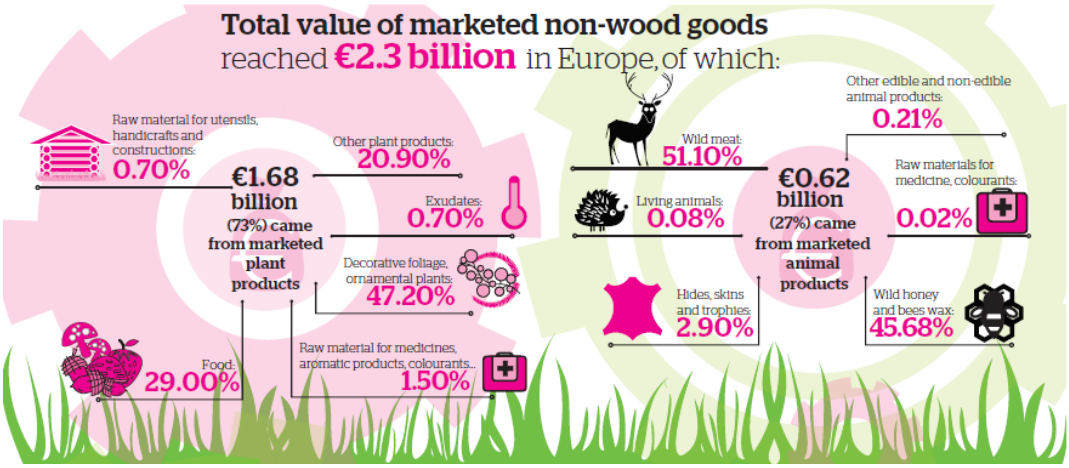

Figure 3.12 - Value of non-wood marketed products in Europe (Forest Europe, 2015)

3.3.4. Ecosystem services

Water regulation, erosion control, soil protection, nutrient circulation, are all actions performed by forests in various degrees. The importance of forests for the preservation of fundamental ecosystem functionality has been remarked by Steffen *et al.* (2015) who proposed **"Land-system Change"** as **one of the planetary boundaries**, with an indicator being the area of forested land as % of potential forest in different biomes. The proposed thresholds (and their uncertainty zones) are 50% (50–30%) for temperate regions and 85% (85–60%) for boreal regions.

There is a widespread debate about the possible "payment for ecosystem services" (PES), that is some sort of scheme or agreement whereby users of a service pay providers (OECD, 2012). However reasonable the idea may appear, there are a number of difficulties in its application. For many ecosystem services establishing a value or a price is not straightforward as **there is not a market**; some services are inherent in the very existence of a forest, so that a compensation could be conceivable only in case of onerous but discretionary management decisions. There is a need for research that enable on the one hand an evaluation of the economic value of services and on the other hand the costs (better, cost opportunities) of different management decisions, with the added difficulty that both are likely to differ considerably in different environments as well as the categories that would benefit from the services and should therefore be the subjects who pay for the services (EEA, 2016).

3.3.5. Climate change mitigation

The subject of carbon sequestration is open to debate. A typically mature forest where a balance between carbon captured by vegetation growth and its release by decaying biomass is **most likely neutral**, unless more biomass can be permanently added to the soil in stable form than is released. Harvesting of logs (especially from plantations) has the potential to return the carbon to the atmosphere, albeit with a **delay** depending on use (construction and furniture are usually ways to achieve long term locking of

carbon). In construction, wood can often replace concrete and steel, both energy intensive materials. However the **substitution effect** is difficult to quantify in the real world (UNECE/FAO, 2015).

More delicate is the issue of first-generation energy production by burning woody biomass; a zero-balance between carbon captured by growing trees and carbon released can never be reached due to energy employed or lost in the conversion; however, a **"substitution"** concept can be invoked, meaning that the alternative **"fossil" energy** would be significantly **more negative** in terms of net CO_2 emissions.

FAO Forest Resources Assessment 2015 (FAO, 2016) estimates at 296 Gt the stock of carbon (1085 Gt CO_2) in forest vegetation and soil (approximately one half each) or about 74 t/ha (271 t CO_2). The overall trend is towards a diminishment of the above stock, mainly due to conversion of forest land to agriculture. Since 1990 the loss of carbon has been estimated at 11,1 Gt of carbon (or 40,7 Gt CO_2).

The situation, however, is very diverse in the different regions, with some contributing significantly to an increase of carbon stocks (Europe leading the way) and others to its depletions (South America and South and Southeast Asia *in primis*) (see **Figure 3.13**).

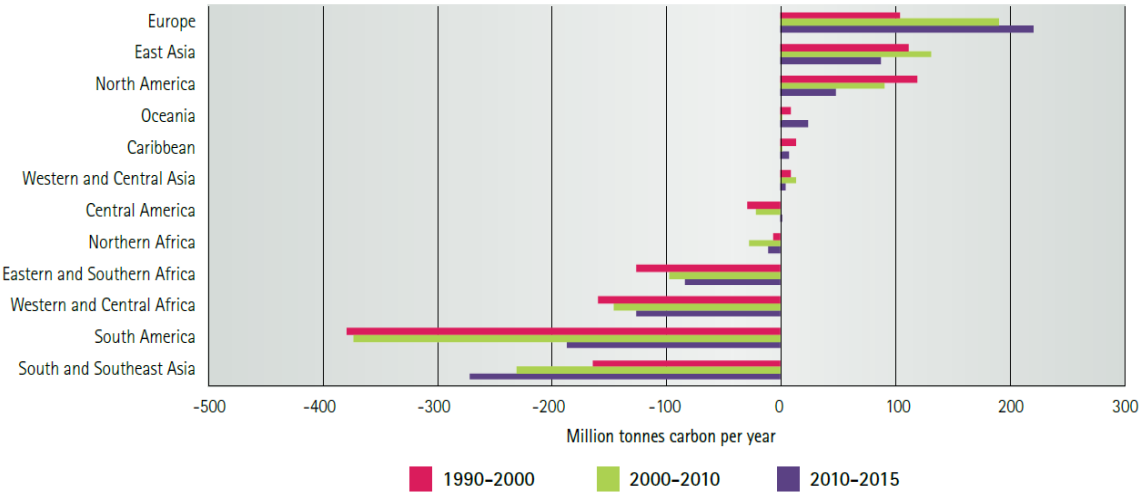

Figure 3.13 - Changes in carbon stock in forest biomass, 1990–2015 (FAO, 2016)

The highest contribution of forests to the mitigation of climate change would come from a limitation of deforestation, more than from any other initiative aimed at increasing carbon storage.

3.3.6. Preservation of biodiversity

Forests are by far the land environments richest in species of all *phyla* when compared to agricultural ecosystems of the same climatic regions. The conservation of biodiversity is essential for maintaining stability of the environment, preserving the ability of species to evolve. In the world, about

13% of forest land is affected by legal provisions expressly designed at keeping biodiversity; Brazil and the USA have the largest areas (FAO, 2016). Biodiversity preservation often includes the protection of pollinators, essential for most agricultural crops.

In **Europe**, in 2015, more than **30 Mha of forests were protected** with the main objective to conserve biodiversity (and the trend is still pointing upwards); more than half a million ha of forests were managed primarily for genetic conservation and over a million ha for seed production (Forest Europe, 2015).

An issue closely related to the preservation of biodiversity is that of Invasive Alien Species (IAA). To remain within the area of forest trees, some were deliberately introduced by man in the past, sometimes as ornamentals or for use in specific environments (e.g. *Robinia*, *Ailanthus*), more frequently for deliberate use in forests and plantations: Sitka spruce, Lodgepole pine, Douglas fir, Western hemlock, Eucalypts, Poplars, Red oak. Whereas the preference for **autochthonous species** is nowadays sometimes a **matter of principle**, there is a tendency towards the avoidance of non-native species where seminatural habitats are desired and to employ them only in the context of intensively managed plantations.

3.3.7. Culture, Recreation, Amenity

Forests have a cultural, often religious, value in many traditional cultures and a fundamental role also in more secular cultures as key elements of landscapes, areas of choice for recreational activities, sport and tourism.

The recreational function of forests is particularly important in **Europe** where around **90%** of their area is **accessible to the public** (Forest Europe, 2015). It has been estimated that around 60% of Europeans live in or close to forests (EEA, 2016).

3.3.8. Stakeholders' expectations

A variety of functions means a complex interaction of rights and expectations by different groups of stakeholders.

Ownership of forests in the world varies considerably, from almost entirely public to almost entirely private. The same occurs in Europe, with most of the countries of the former Eastern bloc having the largest proportion of public forest.

However, on the one hand both public and private ownerships have a range of types of owners (state, region, community, publicly owned institutions; individuals, families, cooperatives, for-profit or not-for-profit organisations) with different objectives and priorities; on the other hand, only rarely has the owner exclusive rights on its property; most frequently **a range of users have legal or customary rights** of access, collection of mushrooms and berries, collection of dead wood and litter, hunting, foraging. Rules and rights vary considerably from country to country.

Whereas in Europe and other developed countries rights are usually well established and documented, in many developing countries where customary

rights are more frequent than legally determined rights, indigenous populations are frequent victims of deals that states strike with private logging companies awarding concessions on areas previously accessible on the basis of tradition.

Several conventions, mostly non legally binding, try to protect the rights of indigenous people, but enforcement is weak.

3.3.9. Forests in a circular economy

Wood has attracted a great interest in the context of a circular approach to manufacturing, as it may keep most of its structural properties through a long chain of **recycling**. In line with a "cascading" principle, the first use of wood would be in the residential housing products that have typically a long life; subsequent steps could include reconstituted panels, then recovered and recycled to produce the interior core of industrial furniture, then pallets or other products with a short life. The final stage could be the direct (burning) or indirect (through pellets) transformation into energy.

This long cycle would **extend the duration of carbon storage** (contributing to climate change mitigation) and act as a multiplier of industrial jobs, while decreasing the cost of feedstock for the downstream sectors (EEA, 2016).

Research initiatives are expected to broaden the range of possible pathways considerably.

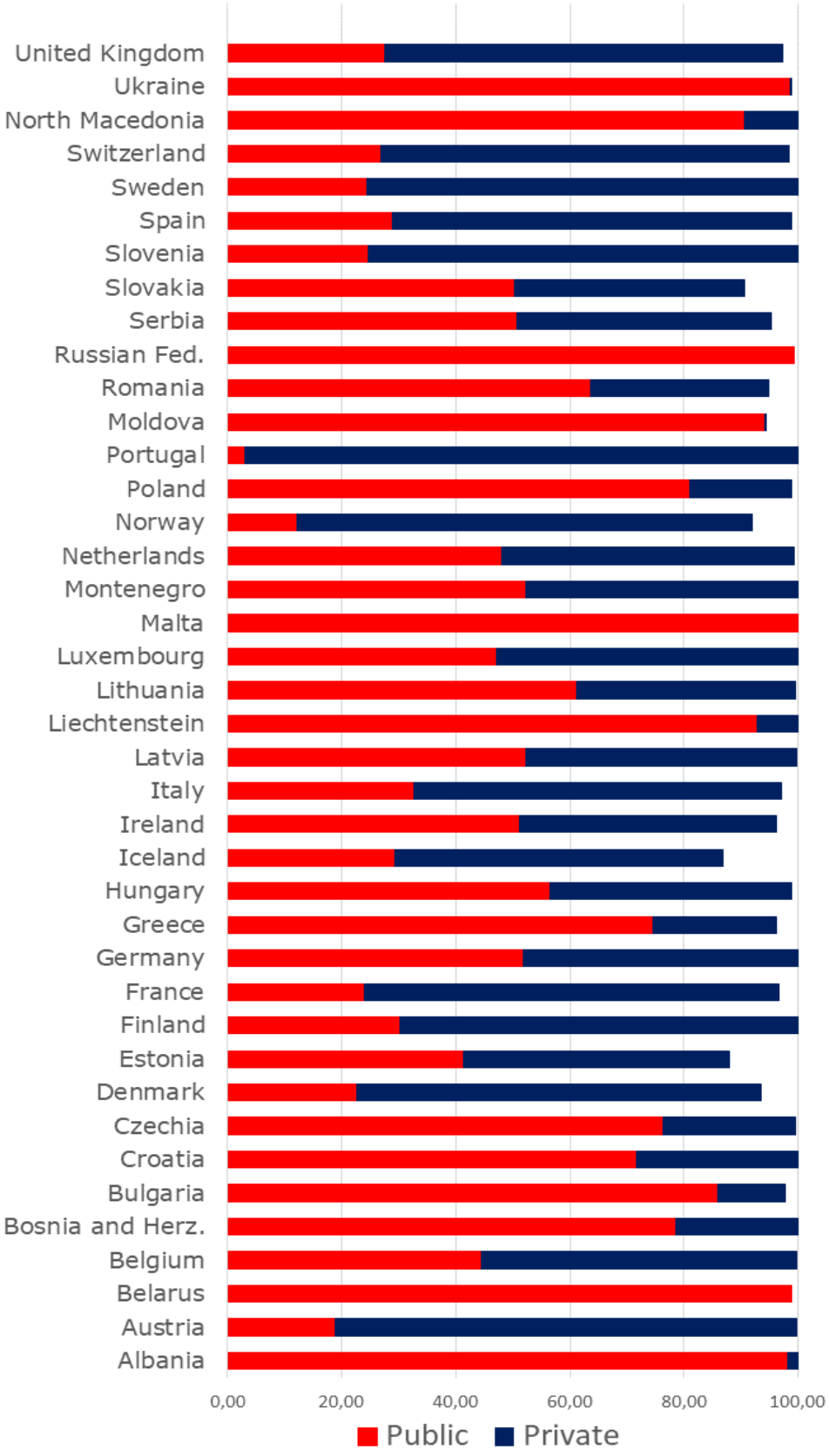

Figure 3.14 - Share of public and private forests in European countries. Where the sum does not add up to 100, the difference is due to areas of unknown ownership (data from FAO, 2016)

3.4. Forests and climate change

The effect of climate change on forest ecosystems has been a matter of speculation rather than of conclusive evidence.

There is a possible benefit to biomass production from increased CO_2 concentration in the atmosphere, as photosynthesis uses CO_2 as input for the production of carbohydrates. Higher average temperatures might extend the growing season by an earlier spring initiation and later autumn cessation of annual growth.

However, evidence is inconclusive and such positive effects would certainly depend on latitude, with Northern forests the most likely beneficiaries.

On the other hand, **shifting climatic zones** towards higher latitudes and altitudes **threaten the ability of forest ecosystems to follow the trend**, as the colonisation process of long living organisms might be slower than the climatic shift, depending also on the specific mechanisms of seed dispersion and the degree of genetic diversity, essential for evolution.

On the southern fringes of forest species ranges, the conditions might become inhospitable before any genetic adaptation can become effective.

The main threats from climate change, however, are probably not progressive changes of average conditions but a higher frequency of **extreme climatic events**, from prolonged droughts to floods and windstorms.

On the biotic side, **attacks from new pests** from lower latitudes that find viable conditions to invade more northern areas have already be observed. Native pests may have **more generations per year**, **reduced winter mortality**, and thus provoke damages rarely seen in the past (EEA, 2016).

3.5. Future of forests

3.5.1. Sustainable Forest Management

There are a range of instruments aimed at a sustainable management of forest resources: laws and regulations, incentives, market instruments. Remarkable is the REDD+ initiative (https://redd.unfccc.int/), launched by the UNFCCC Conference of the Parties to share efforts, knowledge and resources to reduce emissions from deforestation and forest degradation in developing countries.

Forest Europe[18] (formerly the Ministerial Conference on the Protection of Forests in Europe) defined SFM as the "*stewardship and use of forest lands in a way, and at a rate that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national and global levels and that does not cause damage to other ecosystems*". This definition, obviously generic, echoes the principle of sustainable development as proposed in the "Bruntland report" (Our Common Future) of 1992.

There is not universal agreement on the idea that SFM incorporates the concept of Ecosystem Based Management (EBM) of Forests, that emphasises the focus on the preservation of biodiversity, the functionality of ecosystems and the provision of ecosystem services (or vice-versa, that EBM incorporates SFM)(EEA, 2016).

At the local level voluntary, private **certification schemes of sustainable forest management** (SFM) are spreading. The most common are **FSC** (Forest Stewardship Council, supported by environmental NGOs) and **PEFC** (Programme for the Endorsement of Forest Certification, with a strong base in forest owners). Both aim at the dialogue between the different stakeholders in the definition of forest management plans. FSC has a top-down approach, with basic principles that have to be applied in all circumstances, however adapted to local situations; PEFC has a more bottom-up approach aiming at an agreement on objectives locally shared by the stakeholders.

The rationale of the certification schemes, both verified in their actual application by independent parties, is to achieve a better **price or share of the market** where **environmentally and socially concerned citizens** give preference to products of environmentally and socially sound provenance. With that objective, products complying with the scheme principles may be labelled accordingly to be recognised by consumers.

In practice, certification schemes proved more effective in the relationship between **forest owners and public administration** that often accept third party certification of SFM as a demonstration of compliance with environmental rules, labour laws, social norms.

Pressure on forest owners towards certification usually comes from the wood industry and the pulp and paper industry where these adopt a chain-of-custody SFM certification (UNECE/FAO, 2015). In such cases they need to

[18] FOREST EUROPE is the "brand name" of the Ministerial Conference on the Protection of Forests in Europe, a pan-European voluntary high-level political process for dialogue and cooperation on forest policies in Europe. Its members are 46 European countries and the European Union.

acquire feedstock from certified forests and, if the relative weight of the industry on the market is high, forest owners may find certification as necessary to stay on the market, even without a positive differential price for certified material.

The European forest area under sustainable management, however, is certainly broader than that certified by FSC or PEFC (sometimes by both, simultaneously). Failure to certify a forest property may depend on lack of perceivable benefits for the owners or on purely economic inability to cover the costs of the certification process, especially by small private owners (UNECE/FAO, 2015).

Forest Management Plans, i.e. periodically revised plans documenting the intended use of forest land, are an essential component of SFM and are being gradually applied around the world. **Europe**, where the tradition of rational forest management was first developed, is leading, with **94% of forests managed according to a formal plan**. South America (15%) and Africa (22%) are still far behind (FAO, 2016).

3.5.2. Health of European Forests

Most European Forests (over 90%) are ecosystems modified by man and subject to active management, but still displaying a high level of diversity and thus possessing the ability to function as viable diverse ecosystems. **Two thirds** (68%) **regenerate naturally**; the rest are generally **replanted after wood harvesting operations** (especially in Nordic countries). **Figure 3.15** (from EEA, 2016, based on data from Forest Europe, 2015) shows a positive image of the state of health of European Forests, with a very small fraction of its surface displaying critical disturbances. There is however a disagreement between this rosy picture and the reports that Member States produce in agreement with the Habitats Directive that around three quarters of forests have 'unfavourable conservation status'. However, the apparent incoherence may reflect different evaluation criteria and different perspectives.

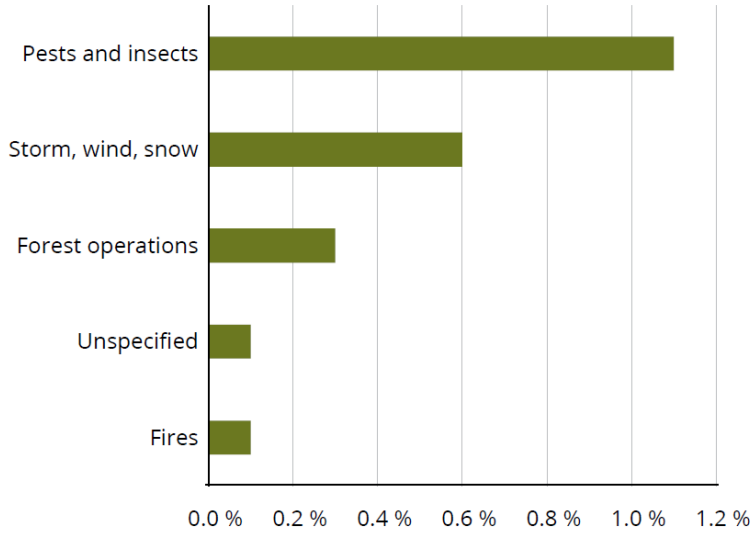

Figure 3.15 - Relative areas of forest affected by different types of disturbance (from EEA, 2016; data from Forest Europe, 2015).

3.6. Foresights, Scenarios, Forecasts and other forward-looking studies

Specific forward-looking studies are not particularly abundant in the Forest sector, although relevant information can be found in documents with a broader scope: land use, environment, climate, energy.

We have therefore analysed also relatively dated documents when still relevant for at least part of their contents.

3.6.1. **EFI Review of Forest Foresights** (Pelli, 2008)

This EFI (European Forest Institute) technical paper compares approaches and methods adopted by different institutions for the deployment of five Foresights developed in the previous ten years, including the first SCAR Foresight Exercise.

We here report only elements that could be relevant today as well. In particular the definitions of scenarios and "dimensions" that were considered to describe possible future landscapes:

The UNECE European Forest Sector Outlook Study (2005) considers a BaU scenario and two alternatives: a) a future in which environmental issues will have a growing influence on forest management; b) an increased integration of international markets.

Prospective: la fôret, sa filière e leur liens au territoire (developed by INRA in 1998), describes possible futures with the combination of two axes: **a)** wood would or would not remain the main focus of forest management; **b)** supply sector (forest owners) and industry would or would not reach a closer vertical integration (with suppliers' management decisions based largely on users' demand).

The UNECE study of 2005 was updated in 2011 (see below). Also updated was another document analysed by Pelli (2008): the Vision paper of the Forest Based Industry European Technology Platform. The fourth one, a Finnish Forest Sector Perspective study, we did not consider, taking the more recent "Finnish Forest Sector Economic Outlook 2017–2018" as a reference (see below).

3.6.2. **Future Forests Scenarios 2050 – Possible Futures, Future Possibilities** (Moen *et al.*, 2012)

The Future Forests Scenarios 2050 (Moen *et al.*, 2012) considers a future landscape developing along combinations of two possible axes: **a)** the role of renewable energy sources and bioenergy; **b)** the role of strong political institutions and transnational agreements on climate mitigation and forest use. The first reflects the strong expected impact of energy policies on wood production and use as a renewable source of energy; the second is remarkably similar to a key "dimension" of other general foresights or foresights connected with food and agriculture, i.e. the weight of multilateral or global governance mechanisms.

The combinations leads to four scenarios described in **Figure 3.16**. In the discussion with stakeholders on the four scenarios, the Authors observed a clear tendency of participants to rank scenarios according to the specific interests of the group they belonged to.

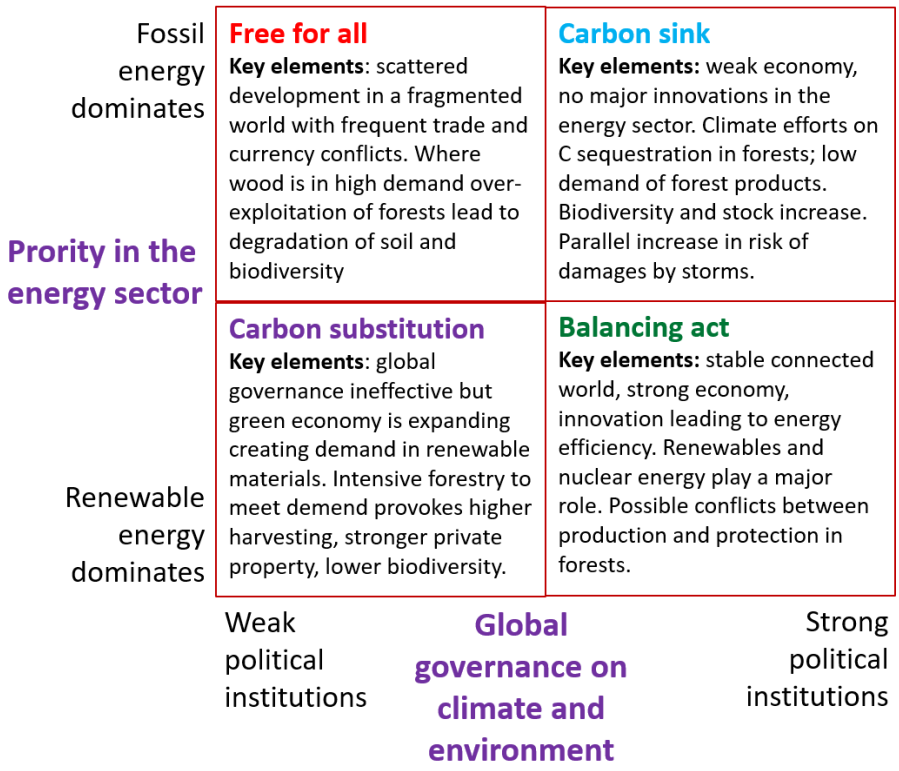

Figure 3.16 - Four scenarios derived from the combination of contrasting directions along two axes in the Future Forests Scenarios 2050 (Moen *et al.*, 2012).

3.6.3. **Foresight on Future Demand for Forest-based Products and Services** (Pelli and den Herder, 2013)

The study reports the outcomes of a series of COST workshops on Forest sector Foresights that involved key stakeholders under the coordination of EFI. The work started with a discussion of the relevance of drivers divided in categories according to the STEEPV[19] frame:

- **Social [Demographic]** (population growth, ageing, migration, urbanisation) with due attention to regional differences.
- **Technological**: bio-, nano-, gene-technologies, ICT, AI, big data, robotics, enabling new products, solutions and social interaction models (e.g. off-grid, prosumers, self-sufficiency).
- **Economic**: power shifts (unipolar *vs* multipolar; west *vs* east; globalisation *vs* deglobalisation of trade; free *vs* protectionist economies; role of finance).
- **Environmental**: scarcity of natural resources, accelerating climate change, biodiversity, ecosystem services.

[19] https://connections.etf.europa.eu/wikis/home?lang=it-it#!/wiki/Waf3b410daf0b_49f0_9a8e_897181655904/page/STEEPV

- **Political:** international governance mechanisms; roles of public and private sectors; citizens participation.
- **Values [Cultural]:** Attitude towards natural resources; global vs local lifestyles; value of quality of life and wellbeing vs wealth; value of traditional knowledge; metrics for wealth and success.

The main findings following workshops and internet surveys were:

- A widespread trust in technological solutions
- A prevalence of believers in an expansion of free trade *vs* the emergence of barriers, but leading to increased divergences between the rich and the poor and to recurrent economic/financial crises.

On other topics opinions expressed differed significantly: global vs local governance of natural resources, global vs segmented customers, the benefits of zoning (segregation of functions) vs multifunctionality of forests, open or restricted access to forests.

A **technological "optimism"** is also prevalent as far as innovation in forest industry products is concerned and the focus of European Forest Industries on a quality-oriented market. Innovation is seen, specifically, in connection with the development of emerging bioeconomy sectors, such as biomaterials.

As for climate change, there is a broad (but not complete) agreement on the risks that climate changes may pose to forests (modified ecological conditions, failure of adaptation, higher threats from pests and diseases), but also expectations that a climate consciousness will increase the demand of wood products and therefore open new business opportunities.

3.6.4. **European Forest Sector Outlook Study II** (UNECE/FAO, 2011)

The **European Forest Sector Outlook Study II**, although published in 2011, was conceived with a perspective of 20 years (2030). Its purpose was to explore the effect of seven major "challenges" on the European forest sector:

1. Mitigating climate change
2. Supplying renewable energy
3. Adapting to climate change and protecting forests
4. Protecting and enhancing biodiversity
5. Supplying renewable and competitive forest products
6. Achieving and demonstrating sustainability
7. Developing appropriate policies and institutions

Climate changes are considered from the points of view of **(1)** mitigation (what role can forests play) and **(3)** adaptation (how to cope with changes) and, indirectly, as the pressure on forests to provide renewable products **(2, 5)**(energy, biofuels, materials). Concern is expressed on the functionality of ecosystems, with particular regard to biodiversity **(4)**, sustainability as a comprehensive concept **(6)** and the capacity to translate analyses and priorities in effective policy measures **(7)**.

Five scenarios are created according to four different priorities that give more or less weight on the above mentioned challenges:

0) Business as usual (current trends and policies remain unchanged)

1) Maximising biomass carbon (forests as carbon sinks)

2) Priority to biodiversity (functional and healthy ecosystems)

3) Promoting wood energy (exploitation of forests to provide renewable substitutes to fossil fuels)

4) Fostering innovation and competitiveness (technological innovation, new markets)

The scenarios are analysed in a quantitative way with the use of several simulation models developed specifically for the forest sector.

The main findings are that in the BaU scenario, the demand of forest products will steadily increase, including of wood residues for energy production.

Maximising biomass carbon needs a compromise between the provision of wood and energy and to increase the stock of living biomass by the application of longer rotations and an increased reliance on thinnings as sources of wood. However, this can work until a natural limit to the stocking capacity is reached. From then on, the main contribution to carbon sequestration would be to incorporate wood into products with a long life.

Should wood energy become an overarching priority, pressure on forests would become heavy, with serious risks of overexploitation and forest degradation. The removal of deadwood, stumps and branches from forests for bioenergy purposes can alter the biological and biogeochemical cycles that return nutrients to soil, with a significant risk of fertility loss (EEA, 2016).

At present the largest source of wood for energy in Europe is industrial residues, that are employed either directly in the industries themselves (e.g. for kilns) or for the production of pellets[20] or as feedstock for biomass-fuelled power and heat plants.

There is a growing interest on cellulosic ethanol, with the United States, Italy and Finland the leaders in technology, expanding their activity worldwide through joint ventures and licensing (Brazil, China, India, Thailand). It must be mentioned, however, that wood is one, and not the major source of cellulosic biomass as feedstock (REN21, 2017).

The alternative of short rotation coppices in agricultural land would likely create conflicts with food and feed production.

An emphasis on biodiversity and ecosystem complexity would reduce both roundwood and energy production with the consequences of increased wood imports (for forest-rich countries reduced exports) or substitution with SRF (controversial as competing with agriculture).

There is a significant degree of confidence on innovation in products, management systems, development of alternative supply chains (e.g. wood

[20] In 2016 Europe accounted for 70% of global demand for pellets for heating, led by Italy, Germany, Sweden and France. Big powerplants (e.g. in Denmark, UK, Japan, S.Korea) are converting from coal to pellets as they represent a viable alternative due to their high energy intensity. The US, Canada and, in Europe, the Baltic countries, are the main producers and exporters (REN21, 2017).

from maintenance of urban spaces), new strategies to favour adaptations (genetics), ICT for decision support systems, etc.

Policies should strive for an optimal combination of measures: better management systems based on effective monitoring, balancing carbon sequestration with substitution of fossil resources, preventing losses by fires, storms pests and diseases, applying the best knowledge to forest adaptation (e.g. guided species migration), improving wood and wood-based product recycling.

The needs of the energy sector, but also of the traditional wood industries should be balanced with a scientifically sound evaluation of the "carrying capacity" of forest ecosystems in order to avoid loss of fertility and a long term degradation of forests.

Research and knowledge sharing are fundamental. Top priority should be given to forest soil as carbon sink, strategies for forest tree adaptation to climate change (based on an understanding of their physiology), trends and limitations of wood supply, and non-forest wood provision (SRF, rural, urban).

3.6.5. SUMFOREST "Emerging Issues in European Forest-Based Sector and Research Priorities" (Foresight Panel and Workshop) (Hetemäki L and Lovrić N., 2015)

The report was developed within the FP7 ERA-Net "SUMFOREST" to explore the perception of the scientific community with regard to the most relevant issues for the future of forests. The focus was mainly on Europe, but with a broader view for themes that were considered relevant in other continents as well.

The experts involved were mainly researchers: this might be a weakness of the exercise, as it failed to capture the positions of other stakeholders, forest owners and forest industries in the first place but, on the other hand, provided a view that was not biased by economic interests.

With a stepwise selection process, ten emerging themes were selected and prioritised:

- **Climate change and trade-offs between carbon sequestration and material or energy substitution**
- **Future of bioeconomy and forest-based sector**
- **Management of changes, risks and uncertainties in forestry**
- The impact of forest- and non-forest policies to forest-based sector and governance, and their better coordination
- The increasing demand for bioenergy and how to provide enough and sustainably forest biomass for this purpose
- Better understanding of the forest ecosystem services role and their development
- The future role of community-based, state and private forests in the provision of public and private goods
- Land use, resource competition and scarcity

- Urban forests and forest environmental services in cities
- Preventing the spread of pests and pathogens caused by the plant trade, and compensating for the possible damages caused by it.

Although the ranking in an order of priority differed between the participants in a workshop and a foresight panel, the three topics in bold character emerged in both cases.

The **dilemma** between the function of forest as **carbon sinks or as source of renewable raw materials** is clearly dominant; more or less connected with this is a question mark on the development of the Bioeconomy (the EU Bioeconomy strategy had been published recently at the time of the survey) and its implication on forests, seen as provider of feedstock for a range of "new" end products (fuels, fine chemicals, bioplastics), but also for more traditional and well established ones (pulp, paper, sawn wood, panels) and the possible integration of the "old" with the "new".

3.6.6. Forests in the ECE Region[21] - Trends and Challenges in Achieving the Global Objectives on Forests (UNECE/FAO, 2015)

The UNECE/FAO report draws data and analyses from three other outlook studies (one for the US, one for Russia and, for Europe, the already cited UNECE/FAO, 2011) and provides some general consideration for the future of the European forest sector:

- **Europe**, as a whole, is going to be **self sufficient in forest products** for decades, due to a slow growth of demand and well-established forest management practices. This, however, masks an **intense exchange** of roundwood, wood products and pulp and paper **within Europe**.
- **Climate change** is likely to become the main cause of concern for forest ecosystems by the combined effects of altered weather patterns, destructive meteorological events, forest fires and the combined action of pests and diseases.
- The future of European forests with regard to **renewable energy** supply remains **open to debate**; the conundrum of substitution of fossil fuels vs the risk of forest degradation from overexploitation is far from resolved and may lead to drastically different policy decisions in different regions.
- Similar concerns regard the potential storage of carbon in forests (above-ground and below-ground biomass) *vis-à-vis* the storage in long-living wood products; an efficient reuse/recycle approach in line with a circular economy concept is likely to be the optimum compromise.
- Asia, with faster growing economies than most Western countries, is going to become dominant in the wood sector as it is already in many agricultural commodities[22].

[21] The United Nations Economic Commission for Europe (ECE) is is composed of 56 Member States, most of which are based in Europe, as well as a few outside of Europe (USA, Canada and several Central Asia countries.

[22] Buyers from China have won several auctions of roundwood put on sale in Northern Italy in 2019 after extensive forest destructions by the wind storms of 29 October 2019.

- Measures to halt or reduce illegal logging within the European region (a practice still relevant especially in some Eastern European countries) and in international trade will be enforced (FLEGT[23]).
- **Employment** will likely **decrease further** due to increased level of mechanisation; poorer areas, especially those characterised by small-scale forest ownerships and difficulties of access will be the hardest affected.

The following actions have been identified by UNECE/FAO (2015) as the main challenges, and at the same time opportunities for Europe in the coming decades:

1. Protect the forests.
2. Contribute to climate change mitigation through carbon sequestration and storage in forests and products, and through substitution.
3. Mobilise significantly more wood for energy, on a sustainable basis.
4. Exclude all unsustainably produced forest products from ECE Region markets, while helping countries outside the Region to fight illegal logging and other unsustainable practices.
5. Promote the consumption of sustainably produced forest products.
6. Take the lead in developing the green economy, sharing experience, with other sectors, and learning from them.
7. Put the forest work force on a sustainable basis, dramatically improving safety and health of forest workers, and providing necessary skills for a changing world.
8. Continue to help countries in other regions achieve sustainable forest management skills for a changing world.
9. Seek mechanisms to finance forest functions on a fair and sustainable basis, for example through valuation of forest ecosystem services and payment for forest ecosystem services.
10. Build capacity throughout the ECE Region.
11. Develop a culture of innovation, in the face of structural change.
12. Address the social and economic problems of forest dependent people in the ECE Region – remote rural communities, indigenous peoples and forest owners.
13. Maintain and improve forest biodiversity, through protected areas and active management.

3.6.7. Forest-based Sector Technology Platform (FTP) - Vision 2040 (FTP, 2018)

The technology platform FTP, as all European TPs, is an initiative led by the Industry with the participation of research institutions and other sectoral

[23] "Forest Law Enforcement, Governance and Trade": the EU produced its Action Plan in 2003 to reduce illegal logging by strengthening sustainable and legal forest management, improving governance and promoting trade in legally produced timber.

stakeholders. The four shareholders[24] are the European **State Forest** Association (EUSTAFOR), the Confederation of European **Paper Industries** (CEPI), the Confederation of European **Forest Owners** (CEPF), and the European Confederation of **Woodworking Industries** (CEI-Bois).

The following objectives or areas of research and innovation have been identified as priorities for the next twenty years:

1. Sustainable forest management, biodiversity and resilience to climate change.
2. Increased, sustainable wood production and mobilization.
3. More added value from non-wood ecosystem services.
4. Towards a zero-waste, circular society.
5. Efficient use of natural resources.
6. Diversification of production technologies and logistics.
7. Purposeful, safe jobs and links between rural and urban regions.
8. Renewable building materials for healthier living.
9. New fibre-based products and 80 per cent lower CO_2 emissions.
10. Renewable energy for society.

3.6.8. The State of the World's Forests 2018 - Forest pathways to sustainable development (FAO, 2018b)

The FAO (FAO, 2018b) provides a list of the SDGs most directly connected with forests' role and functions:

- **SDG1**. End poverty in all its forms everywhere. Forests provide income both directly (wood and non-wood forest products) and indirectly, by delivering ecosystem services to farmers. This is true at all latitudes and degrees of development. Poverty is strongly correlated with people's dependency on forests for their living. It has been calculated (OECD, 2012) that 90% of the world 1.2 billion poor are somehow dependent on forest resources.
- **SDG2.** End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Forests are sources of fruit, vegetables, nuts, berries and meat. For populations of the tropical/subtropical regions forests are essential at providing a nutritionally balanced diet, otherwise inaccessible and access to forest food is particularly important due to a large prevalence of poor people among forest dwellers.
- **SDG5.** Achieve gender equality and empower all women and girls. There is still a long way to go to achieve gender equality in the forest sector. In the poor regions of the world women role in forests is mainly as collectors of wood and food; logging operations and forest management are still predominantly male, also in advanced economies.

[24] The current legal form of FTP is of *Societé privée à responsabilité limitée* established under the Belgian law.

- **SDG6.** Ensure availability and sustainable management of water and sanitation for all. Generally speaking, a forest cover improves the water cycle both in terms of quantity made available in aquifers and springs (reducing runoff) and in terms of quality, due to the filtering capacity of canopies and healthy soils.
- **SDG7.** Ensure access to affordable, reliable, sustainable and modern energy for all. Of the role of forest and trees in providing energy we have discussed earlier; the challenge will be to shift from burning wood and charcoal, often associated with respiratory diseases, with more efficient sources of renewable energy.
- **SDG8.** Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. There is a broad range of productive employment opportunities linked with forests, from the traditional wood harvesting and logging operations, all the way to tourism. There is often a problem of safety at work due to the inherent characteristics of the forest environment.
- **SDG11.** Make cities and human settlements inclusive, safe, resilient and sustainable. There is a role for forests around or in cities for improving the quality of life of citizens, despite the relative "domestication" of many such habitats. Urban forests and parks become essential recreational grounds for a large (and increasing) urban population.
- **SDG12**. Ensure sustainable consumption and production patterns. The forest sector and the forest-based industries are at the forefront of innovation in many emerging sectors (e.g. new materials and fine chemicals from wood or residues or sidestreams) and in novel engineered versions of wood products (e.g. with a faster increase of industrially produced panels with respect to the quantity of roundwood that provides the raw material; which implies a higher value incorporated into the same amount of wood). Also recycling both of wood and paper is usually performed at a very high level of efficiency, often comparable to metal and glass.
- **SDG13**. Take urgent action to combat climate change and its impacts. Of the role of forests in the mitigation of climate change we have discussed in chapter 3.4. There is a still a potential for carbon sink capacity in young forests and in forest soils. However, the most urgent thing is to stop deforestation for conversion to agriculture and livestock production, still occurring at unacceptable levels.

  In the European Region, the stock of carbon of the forest aboveground biomass amounts to 64 Gt and the carbon sequestered each year amounts to 255 Mt of carbon per year between 2005 and 2010. The European forests are thus a major carbon sink, although precise figures are difficult to produce. Forest management is deemed essential to maintain such a positive flow through timely and scientifically determined withdrawals (UNECE/FAO, 2015)

  The ECE forests are a significant carbon sink although there is uncertainty over the exact size of the sink, and its underlying causes. Forest management has the possibility to continuously maintain a carbon stock over larger forest estates, while at the same time sustainably producing

wood products and biomass for bioenergy. There is a risk of unintended carbon emissions through fire, insects, wind etc.

- **SDG15.** Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Forests are biodiversity hubs, always richer than surrounding agricultural in number of species; their preservation is therefore essential for achieving the overarching goal of preserving or restoring biodiversity. Sustainable management is spreading, albeit unevenly across the world.

3.7. List of documents

EEA. 2016. **European forest ecosystems — State and trends.** European Environment Agency. 123 pp.

Comprehensive report on European forests covering both the physical and biological state and economic, social and management aspects. It is the result of a broad collaboration of experts from all over Europe. In a forward-looking perspective, the report emphasises the need for an integration of all the different perspectives into an ecosystem based management supported by such mechanisms of shared governance as the Sustainable Forest Management third-party certification mechanisms.

FAO. 2016. **Global Forest Resources Assessment 2015 - How are the world's forests changing?** Second edition. FAO. Rome

The Forest Resource Assessment is a periodical report published by FAO based on structured statistics contributed by Countries. It provides by far the most comprehensive picture of the state of forests in the world in terms of surfaces (and its trends), type, productivity and social aspects.

FAO. 2018a. **Terms and Definitions - FRA 2020**. FAO Working Paper.

The paper is meant as a support to the collection of homogeneous statistics for the Forest Resources Assessment of FAO. It provides precise definitions of facts and figures that National Correspondents have to apply when submitting national data, in order to ensure uniformity

FAO. 2018b. **The State of the World's Forests 2018 - Forest pathways to sustainable development**. Rome.

The State of the World's Forests 2018 analyses the contribution of forests to the achievement of ten out of the seventeen Sustainable Development Goals of Agenda 2030, with specific focus on 28 targets (out of the global 169). It emerges a picture that clearly demonstrate the fundamental role of forests on sustainable development.

Forest Europe. 2015. **State of Europe's Forests 2015**. Ministerial Conference on the Protection of Forests in Europe. Madrid

The report is the fourth in a series started in 2003 to provide policy makers and stakeholders with information on the status of forests and trends towards their sustainable management. Forest Europe offices in Spain collaborated with FAO, EFI, JRC and the University of Hamburg (UHH). The report covers the 46 Forest Europe signatory countries and the EU and is divided into two parts.; the first one provides general information about the way in which forests are governed through policies, institutions and instruments for SFM; the second one provides information on the current status and changes in European forests and the progress achieved in SFM. The Russian Federation is not included, in order to provide consistency and comparability with previous editions of the report.

Forest-based Sector Technology Platform. 2018. **Vision 2040**. Brussels

The Vision document reports the views of the Forest-based Sector European Technology Platform with the year 2040 as a time target. It emphasises the importance of sustainable and multifunctional forest management to provide for raw material production, as well as ecosystem services (climate change mitigation, biodiversity conservation, water supply). It anticipates a possible increase by 30% of withdrawals from forests without compromising ecosystem functionality. A well-managed forest will produce revenues from multiple sources, in addition to wood: tourism, food, services. A circular economy approach would become pervasive, leading to a full re-use and re-cycle of almost all wood materials and products. New technologies (ICT, AI, automation, digitization) would boost the efficiency at all stages of production and for SME as well as big industries. The future of the wood sector is bright, as a widespread concern of citizens about climate and the environment would shift preferences to products based on renewable materials. Thanks to the full use of residues and side-streams of the wood industry, to efficient logistics and, likely, a diminished energy demand (at least in Europe), wood is expected to remain the first source of green electricity and biofuels in Europe.

Hetemäki L, Lovrić N. 2015. **Emerging Issues in European Forest-Based Sector and Research Priorities**. Foresight Panel and Foresight Workshop Results. EC FP7 ERA-Net SUMFOREST

This foresight exercise for the forest sector was part of the FP7 ERA-Net Sumforest and is based on the expert opinion of the scientific community about "*emerging issues with high policy relevance related to the forest-based sector"*. The final objective was the delivery of a list of research priorities. Limitation to the scientific community may be a weak point of the exercise, but the argument produced by the Authors is that scientists often proved to be ahead of the industry and of policy makers in the identification of key issues that prove relevant at a later date.

HLPE. 2017. **Sustainable forestry 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

The HLPE, appointed by FAO/CFS, has produced a series of sectoral analyses connected to Food Security and Nutrition. Forests are the subject of this report as they fulfil a hey role, both directly (providing food) and indirectly (income generation, energy, ecosystem services that make food production possible) in the food system. The application of sustainable forest management (SFM) principles, balancing multiple uses of forests and trees and competing rights and expectations of stakeholders is key to the preservation of forests as well as their sound exploitation. Particularly critical, on a world scale, is the consideration for the rights and legitimate expectations of indigenous peoples.

Hujala T Ed. (Forthcoming). **Special Issue "Foresight for Forest Bioeconomy"**. Forests MDPI

This special issue of the journal "Forests" (ISSN 1999-4907) has been announced but is not yet available. Editor's note: "*Forest bioeconomy may be seen as a concept bridging current forest-based businesses and policies and visionary thinking on sustainable and inclusive biosociety. To further towards*

operable societal transformation, we need better understanding of the trends and drivers within the operational environment of forest bioeconomy. Not only are technological advances prevalent, but also economic, social, political, and environmental aspects of future developments deserve attention. In particular, exploring weak signals, potential game changers and disruptors, transformative tipping points and their possible timing may meaningfully add to existing literature on forest bioeconomy foresight. For this Special Issue, authors are encouraged to submit studies that look at futures of forest bioeconomy from the viewpoints of new bio-based forest products and their markets, services and business concepts, policies and governance, discourses, practices and consumer behaviour, as well as measures to understand and influence the transformation towards biosociety".

Moen J, Nordin A, Larsson S. 2012. **Future Forests Scenarios 2050 – Possible Futures, Future Possibilities.** EFP Brief No. 209.

This is a foresight exercise with the Swedish Forest sector as the main focus. It acknowledges the need of forest management to fully account for multiple, sometimes conflicting, services from the traditional wood production (essential for a lively wood-based industry) to recreational functions and the need to preserve the functional viability of a natural environment. Interdisciplinary research and stakeholder participation are felt as a necessity to deal with typically complex problems, build trust, and prevent divergent interests from becoming open conflicts.

OECD. 2012. **OECD Environmental Outlook to 2050**, OECD Publishing. http://dx.doi.org/10.1787/9789264122246-en

The document covers a broad range of perspectives on the future of the earth environment with 2050 as the target year. As far as forests are concerned, the main points analysed are the role of forests in climate change mitigation, the evolution of biodiversity, the contribution of forests to the provision of renewable energy. Under a baseline scenario, forest cover is predicted to grow after 2020-2030 but with a steady decline of "natural" (pristine) forests and an expansion of managed forests, under the pressure of an increased demand of forest products, both traditional and novel; the degree of utilisation of forests for the production of renewable energy (through direct combustion or advanced transformation of biomass) is expected to have a major influence on the future status of forests.

Pelli P, den Herder M. 2013. **Foresight on Future Demand for Forest-based Products and Services**. EFI, Technical Report 87, 2013. Joensuu

Description of objectives and methods of several foresight (or similar) exercises carried out at the international, regional or national level in the forest domain, as well as in other sectors (energy, environment, trade, …)

Pelli P. 2008. **Review on Forest Sector Foresight Studies and Exercises**. EFI, Technical Report 29, 2008. Joensuu

The paper provides a review of methods adopted for foresight exercises applied to the forest sector. It is more valuable for its description of different approaches than for the development of specific sectoral perspectives

REN21. 2017. **Renewables 2017 Global Status Report**. Paris (REN21 Secretariat)

The report provides an updated picture of the complex sector of renewable energy. In this study the main areas of interest were those dedicated to biomass as energy source. REN21 is a multi-stakeholder network that connects a wide range of key actors of global renewable energy. It facilitates knowledge exchange, policy development and joint action towards a global transition to renewable energy.

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

The paper is an update of a previous publication (J. Rockström *et al.*, 2009. Planetary boundaries: Exploring the safe operating space for humanity. Ecol. Soc. 14, 32) that had introduced the concept of Planetary Boundaries. Some boundaries (climate, ozone, ocean acidification) have seen little modification; for others (biosphere integrity, biogeochemical flows, land use change and freshwater use an effort to define them at a regional level has been initiated. Climate change and biosphere integrity are considered "core" planetary boundaries for their global effects and strategic importance for the future of humanity.

UNECE/FAO. 2011. **European Forest Sector Outlook Study II**. Geneva. 111 pp.

EFSOS II is a co-production of FAO and UN-ECE that provides policy makers with an objective analysis of the current status and future perspectives of the Forest sector in Europe on which to build sound decisions. The study is based on scenarios spanning the period 2010-2030 and covering both forest resources and forest products. A BaU scenario is based on current projections with no significant changes in policies. Four policy scenarios are based on the hypothesis of different policy priorities: a) maximising biomass carbon; b) priority to biodiversity; c) promoting wood energy, and d) fostering innovation and competitiveness. The BaU scenario and the wood energy scenario describe a future in which the environmental viability of forests could be seriously impaired due to overexploitation and a consequential loss of fertility. Longer rotations (and more wood from thinnings) would be the consequence of having carbon storage as a priority; short rotation forestry as a supplier of biomass could be an option to spare forest resources but runs the risk of conflicting with agricultural production. Europe would remain a net exporter of wood and forest products under all scenarios, with prices rising, due to increasing global demand and to scarcity in various regions of the world.

UNECE/FAO. 2015. **Forests in the ECE Region - Trends and Challenges in Achieving the Global Objectives on Forests**. ECE/TIM/SP/37. 212 pp.

"ABSTRACT - This study is the contribution of the ECE Region to the Eleventh Session of the United Nations Forum on Forests. Using the best available data, it examines progress of the forest sector in the ECE Region towards the achievement of the four Global Objectives on Forests, adopted by the United Nations General Assembly in 2007. On the basis of this assessment as well as the forest sector outlooks and policy commitments by ECE member States, thirteen major challenges for the forest sector in the region are identified and

analysed. The study provides policy recommendations for consideration in the discussions by UNFF".

Viitanen J and Mutanen A Ed. 2017. **Finnish Forest Sector Economic Outlook 2017–2018.** Luke (Natural Resources Institute). Natural resources and bioeconomy studies 71/2017. Helsinki

Executive summary (in English) of a Finnish outlook exercise about forest sector perspectives for the year 2018. No long term vision.

Vv.Aa. 2015. **Changes in Global Forest Resources from 1990 to 2015.** Special issue of Forest Ecology and Management **352,** 1–145

This special issue of the journal Forest Ecology and Management was dedicated to the analysis of different parts and aspects of FRA-2015