The European food system and natural resources: Impacts and Options

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Paper prepared for presentation at the 148th seminar of the EAAE,

" Does Europe need a Food Policy?" , Brussels, Belgium, date as in:

30 November – 1 December, 2015

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ABSTRACT
Food systems crucially depend on natural resources, such as land, water, biodiversity, minerals and fossil fuels, not only for farming and fishing, but as well for other food system activities, such as food processing and food retailing. Food system activities (farming in particular) are also a key driver of a number of environmental impacts, such as the loss of biodiversity, soil degradation and greenhouse gas emissions. To achieve a sustainable food system, the sustainable and efficient use of natural resources is a prerequisite. In the EU this is currently however often not the case, leading degradation of natural resources, and high environmental impacts. In biophysical terms, there are many options to reduce the impact of food systems on natural resources, both at the production side, as well as on consumption side of food systems. The key question is how the various food system actors, notably powerful actors such as retailers and food companies, can enable both consumers as well as farmers and fishermen to make more sustainable and efficient use of natural resources.

Keywords: food system, sustainability, natural resources, environment, consumption

1. Introduction

To many people in the world, current food systems deliver ample and safe food on a day-to-day basis, which can be regarded as a great achievement. However, due to various reasons, in many cases food systems fail to deliver the right amount or quality of food: globally still 800 million people are hungry (FAO, IFAD, et al., 2015), while over 2 billion suffer from micronutrient deficiency[2]. Paradoxically, over 2.5 billion people are overweight or obese (Ng, Fleming, et al., 2014) and often suffer from food-related diseases due to unhealthy eating habits. Following the High Level Panel of Experts on Food Security and Nutrition of the UN Committee on World Food Security (CFS), a food system is here defined as “all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes” (HLPE, 2014). Food systems are crucially depended on natural resources, such as land, water, marine resources and minerals (nutrients). Moreover, they are a major source of emissions (as greenhouse gases, pesticides and nutrients. As a consequence of this, food systems are globally the main driver of global loss of biodiversity (PBL, 2014).

Given the present way natural resources are used in food systems, the high environmental impacts and the partially unsatisfactory outcomes in terms of food security and nutrition, one

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[1] This paper draws heavily upon the draft UNEP-IRP report Food Systems and Natural Resources: Impacts and Options (draft title), and the underlying report of the European food system

[2] WHO. *Countries vow to combat malnutrition through firm policies and actions*, <http://www.who.int/mediacentre/news/releases/2014/icn2-nutrition/en/> (2014).

can question whether current food systems are sustainable. Again following the HLPE, a sustainable food system is defined here as “a food system that ensures food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised” (HLPE, 2014).

This paper will therefore address the following questions: (i) to what extent are natural resources currently managed sustainably and efficiently in European food systems? (ii) what are the options to achieve a more sustainable and efficient use of natural resources in food systems ? and (iii) what can the various actors in the food system do to arrive at a more sustainable and efficient?

The focus of this paper is on the use of natural resources and environmental impacts, while taking social and economic effects into account. This paper is based on a study carried out in the framework of the UNEP International Resource Panel, and was mainly based on an assessment of existing literature, added by expert knowledge (UNEP, in prep). Part of the input of expert knowledge was organized in the form of regional workshops.

2. Methods and conceptual framework

2.1 Food systems

The notion that ‘food systems’ not only influence how and where food is being produced, but also people’s eating habits and diets, is gaining momentum in the literature (Ericksen, Stewart, et al., 2010, Ingram, 2011, Pinstrup-Andersen and Watson II, 2011). In contrast to the food chain concept, which perceives different actors in a more neutral way, the food system concept acknowledges that the actors influence each other, within a certain political, technological, environmental, cultural and institutional context.

A food system encompasses the interdependent sets of enterprises, institutions, activities and relationships that collectively develop and deliver material inputs to the farming sector, produce primary commodities, and subsequently handle, process, transport, market and distribute food and other agro-based products to consumers. Food systems around the globe differ regionally vastly in terms of actors involved and characteristics of their relationships and activities.
There are several ways to make the food system concept operational for analytical purposes. For instance, the agro-food system can be broken down into sub-sectors, generally by commodity or group of commodities (cereals, dairy industry, fruit and vegetables, etc.), each with own specific features of structure, institutions and relationships. A disadvantage of a focus on sub-sectors may be that the coordinating role of actors engaged in activities such as input, processing and logistics industries and retail in a food system are neglected. Moreover, a food system also has an institutional (rules and regulations) and a jurisdictional, administrative (provincial, national, intergovernmental) dimension (Ingram, Ericksen, et al., 2010). This implies that there are many aspects that should be taken into account when defining and describing a food system.

Main elements of the food system, and their interactions with natural resources, and environmental and societal impact are depicted in a conceptual framework (Figure 1). Food systems usually can be divided into various food system activities, ranging from provision of inputs (as fertilizers and machinery), primary production (mainly by farmers and fishermen), food trading and processing (crushing of oil seeds, sugar refinery), food industry (preparation of 'food' as eaten by consumers, from bread to ready meals), retailing and food service, consumption and finally processing of food wastes. The different steps can often not be clearly separated, and also very much depending both on the types of food as well as on the regional food system. Food chains in rural areas in developing countries are often relatively short, especially in the case of subsistence farming, where most of the food production and processing (as milling and baking) is within households. In developed countries food systems are typically much more complex. Food systems necessarily depend on certain natural resources, such as land, water and minerals in the case of agriculture, or fish stocks in the case of fisheries. Due to emissions and the use (and sometimes overuse) of resources, food systems have environmental impacts. Food systems' outcomes (effect of food security and human health, farmers' income etc.) affect general social welfare. Finally, and maybe most importantly, food systems research postulates that food systems are shaped by food system actors (as farmers, food companies and retailers). These actors operate in a certain socio-economic context. The food system is therefore not a neutral logistical food chain as the food system actors have large interests, which basically shape food systems. From a societal point of view, the food system outcomes are most important: to which extent do food systems deliver satisfactory nutritional outcomes, decent incomes and are they capable of doing so not only now, but in the future as well.

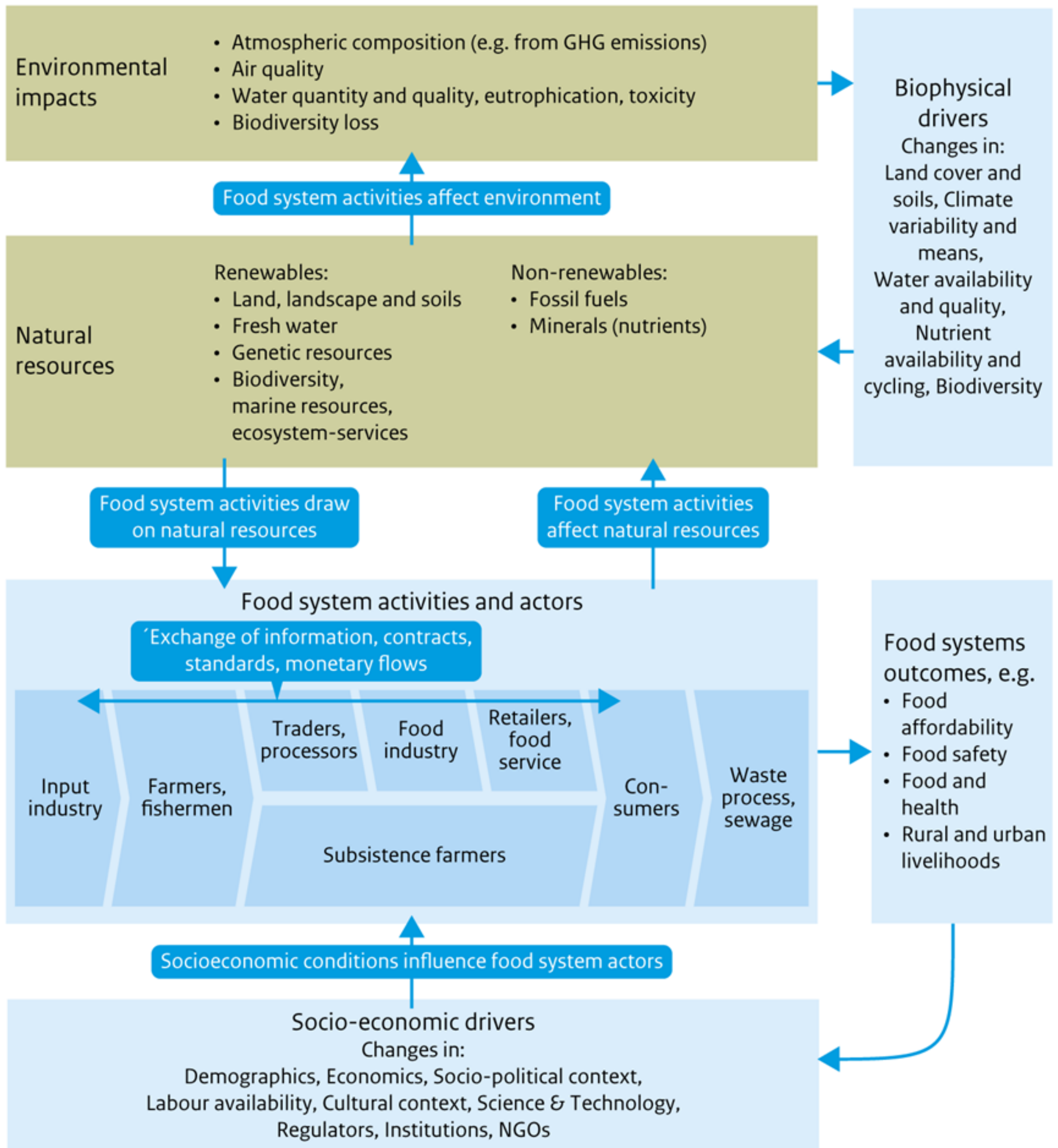

Figure 1 Conceptual framework of food system activities and natural resources

2.2 Natural resources and environmental impacts

Food systems are fundamentally underpinned by natural resources. Producing food in the form of agriculture or fisheries depends on land, biodiversity, fresh water and marine resources. Other food system activities also depend on natural resources: for instance food processing on water and packaging on paper, card and aluminium. Almost all food system activities depend on energy, which is currently mainly provided in the form of fossil fuels. Natural resources can be divided renewable and non-renewable resources (UNEP, 2010). **Renewable resources** stem from renewable natural stocks that, after exploitation, can return to their previous stock levels by natural processes of growth or replenishment, provided they have not passed a critical threshold or 'tipping point' from which regeneration is very slow (e.g. soil degradation), or impossible (e.g. species extinction). Crucial renewable resources for food systems are land, water, biodiversity (including genetic and marine resources) and ecosystem goods and services. In order to guarantee a continued supply of food for current and future generation (cf. definition of sustainable food systems') it is important that renewable natural resources are managed **sustainably.** Here we use the word sustainable in a strict sense, simply meaning that the use of the resource can continue, because the resource is not degraded or depleted beyond continued use or replenishment.

'**Non-renewable' resources** are exhaustible natural resources whose natural stocks cannot be regenerated after exploitation or that can only be regenerated or replenished by natural cycles that are relatively slow at human scales' (OECD, 2002). Crucial non-renewable resources being used in food systems are minerals (nutrients, metals and other mined resources such as lime) and fossil fuels. Although minerals (such as phosphorus) are not actually 'used' (other than fossil fuels), they often become ineffective for use in food systems, for example because they get diluted in water or fixed in soils.

Environmental impacts

All food system activities have an impact on the environment to some degree and many of these impacts are intrinsically related to the use of natural resources in food systems. For example, the use of fossil fuels leads to CO_2 emissions, while the use of minerals often leads to nutrient losses to ground and surface water. The positive side of this is that a more efficient or sustainable use of natural resources usually leads to a reduction in environmental impacts, creating many synergies. Concrete examples of these synergies are better targeted fertilization, leading to lower resource use (minerals) and as well as to lower nutrient losses, and higher fuel efficiency along the food chain, leading to lower CO_2 emissions.

The environmental impacts usually feedback on the renewable resources as needed for both food system and other, non-food system activities. An example of the first is the impact of food system activities on water quality, making water less suitable for irrigation purposes. An example of the latter is the effects of pollution from agricultural sources on drinking water quality. These feedbacks can be very local and within a short timeframe (for example water contamination), whereas in other cases the feedbacks are through global systems with a time horizon of decades (such as GHG emissions leading to climate change).

2.3 Measuring 'sustainable' and 'efficient use'

A key question is how to measure whether a certain resource is used 'sustainable' and 'efficient'. In case of a 'sustainable' use, the most important criterion is whether the state and quality of the considered resource does not deteriorate, and thus it's capacity to underpin food production. In some cases, as for example land and soils, the quality (in terms of suitability food production) can even improve as a result of human interventions. Proxies for measuring the state of resources are for example soil depth, soil organic matter, the height of groundwater

tables and fish stocks.
The question whether a resource are managed 'efficient' is more difficult to answer. Two important aspects are (i) *productivity* (output per unit of resource input) or its reciprocal value *resource intensity* (resource input per unit of output), and (ii) losses or degree of recycling. The latter aspect is notably important for minerals, where the nutrient use efficiency can be calculated over the whole food value chain. A food system can be considered more resource efficient when more food is produced and finally consumed with the same amount of resources, or when the same amount of food is produced with fewer resources (cf. (UNEP, 2011)). Higher overall resource-use efficiency can be realised in various ways: by more efficient production (also called decoupling), as well as by reducing food demand and consumption in various ways (by reducing food waste, by dietary changes towards less resource-demanding products and by reducing overconsumption of resource-intensive calories).

A complicating factor is that resource efficiency has to be evaluated for the combination of natural resources, as especially crop production is based on a large number of natural resources. For example, applying mineral (nitrogen) fertilizers will in many increase crop yield (and thus land productivity. However, at the same time the (marginal) nitrogen use efficiency decreases. From the point of view of nitrogen efficiency, less fertilizer is better, while from the point of view of land productivity more nitrogen leads to a greater productivity. This is related, but certainly not equal to the concept of total factor productivity (TFP). Two main differences are that (i) the combined resource use efficiency only assesses natural resources, where in TFP also labour and capital are included, and (ii) TFP is measured in economic terms, where the natural resource use efficiency is basically measured in physical terms. When the market price of a certain resource (for example water) is very low as certainly externalities are not included, the TFP can be high while the water use efficiency is low. The advantage of the TFP is however that all inputs and outputs are expressed in monetary terms, whereas the combined resource efficiency lacks a methodology to weigh the different natural resources.

3. Current state and developments

3.1 The European food system

In a simplified model, food systems around the globe can be categorized as 'modern' and 'traditional' food systems (Ericksen, 2008). Modern food systems are characterized by longer, more consolidated supply chains, specialized, market-oriented farmers and fishermen and more processed food. Food is typically bought in supermarkets, or out-of-home (restaurants, food service and catering). 'Traditional' food systems, as still dominant in rural areas in developing countries have a relatively short supply chain, with several activities concentrated at the farm: producing crops and animal products, processing them in-house, and trading the raw and/or processed products. Commercial relationships largely take place on a spot or cash market. Many farmers and fishermen are simultaneously producer, processor and trader of their produce. The European (EU) food system can be largely characterized as a 'modern' food system. The EU food system can be seen as one system, or as an agglomerate of many national or even local food systems. Within the EU, there are large differences in terms of farm size, products being consumed and share of supermarkets in food retail. In poorer, rural areas the food system still has characteristics of a 'traditional' food system, whereas the urban areas are truly 'modern' food systems.

In the European Union there are currently around 12 million farms with wide variation in structure and scale of operation (European Commission, 2013). Small family farms can particularly be found in Romania, Italy and Poland together accounting for around 60% of all small family farms. There are also family farms that are relatively large such as in the UK (with an average of 70,3 ha agricultural land per holding), Luxembourg, Denmark, Czech Republic and Germany.
The food and drink industry is EU's largest manufacturing sector in terms of economic turnover and employment (Underwood, Baldock, et al., 2013). With a global market share of 17%, the European Union is together with the US the main food exporter in the world. These export consist mainly of processed foods such as beverages, essential oils, food preparations and meat and dairy products. In 2010 food and drink companies in the EU accounted for 15% of the direct employment with 'bakery and farinaceous products' ranking as the first in terms of value added, employment and number of companies, followed by the subsectors meat, dairy and drinks (Table 1).

It should be noted that the European food system and the European agricultural and fisheries system largely overlap, but certainly not completely. This implies that natural resources (especially land and water) outside the EU are being used to produce food for the EU, but at the same time also natural resources within the EU are being used to provide food consumed elsewhere. The European Union is both the world largest importer of agricultural commodities (with a total value of €120 billion in 2013), as well as by far the world's biggest importer of agricultural goods, with imports at €101.5 billion (EC, 2014). The EU has thus an agri-food trade surplus of €18.6 billion. Final products for direct consumption account for around two thirds of EU agricultural exports. The share of final products in imports is lower, with a higher share of basic commodities and intermediate products. Main imported products are tropical fruits, oil cakes (mainly soy bean meal), coffee and tea, fats and oil and soybeans. This indicates that the net balance in term of land use is probably negative for the EU: it uses more land abroad (especially for the production of soy beans and palm oil), than the amount of land needed to produce food for export. For many important products, as meat, dairy and cereals the rate of self-suffiency is around 90-110% (EC, 2014, FEFAC, 2015, Westhoek, Rood, et al., 2011). The trade balance for fisheries is negative, with a self-suffiency level of the EU of around 45%.

3.2 Natural resources and environmental impacts

The key question is whether the natural resources as currently used for the European food system are currently managed sustainably and efficiently. This question will be mainly addressed for the European agricultural system.

In case of the resource **land and soils**, agriculture is the dominant land use, covering 176 million hectares, which is around 40 per cent of the total territory (Eurostat, 2015). It is difficult to make a pan-European assessment to determine whether land and soils in the EU currently managed sustainably, as soil and land surveys are generally quite old, and there is no provision for systematic collection of soil data. It is therefore hard to give an exact estimate of soil erosion and other forms of land degradation. The JRC has estimated by means of a model that the area affected in the EU is 130 million hectares (JRC, 2012). This involves all land in Europe, not only agricultural land. The uncertainty of modelled erosion risk is high, especially at local level. The answer is thus that a significant share of the EU agricultural soils are currently not managed sustainably, but that exact data are lacking.

Are land and soils in the EU currently managed efficiently? Crop yields per hectare are generally high in the EU, especially in the prime agricultural areas, indicating a largely efficient use of agricultural land. Nevertheless, there are marked differences in crop yields between regions, partially reflecting growing conditions (as climatic and soil conditions), but some of the differences are due to farm management and use of technologies. In North Western Europe, crop yields are generally close to the current maximum attainable yields, while these are typically below attainable yields in parts of Southern and Eastern Europe (Mueller, Gerber, et al., 2012, Neumann, Verburg, et al., 2010).

In Northern Europe, crop production is mainly **rainfed**, whereas in Southern Europe crops (especially high value crops as fruits and vegetables) are often irrigated by **ground or surface water** to produce adequate yields. This is expressed in the large differences average irrigation demand. Across the EU, 24% of abstracted water is used in agriculture. Agricultural water use across Europe has increased over the last two decades. Water scarcity is particularly expected to increase in the Mediterranean countries (also as a result of climate change) which could negatively affect agricultural production in the EU (EEA, 2012, EEA, 2012). In many cases, water resources are not managed sustainably (EEA, 2009). Overextraction of groundwater supplies will lead to lowering of groundwater tables. For example in Spain, more than 50% of the hydrological units are overexploited. Also large-scale interventions in hydrological regimes in favour of agriculture and energy production lead to ecological damage, and thus can be regarded as unsustainable, as rivers require a sufficient amount of water, in order to maintain healthy aquatic ecosystems. In many cases, water is still being used inefficiently in the EU, especially in case of traditional gravity systems. The share of pressured systems (such as drip irrigation) which are generally more efficient, has increased over the last decades.

Agriculture and fisheries are critically depending on **biodiversity** (such as **genetic resources** and **fish stocks**) and **ecosystem services** (such as pollination and water regulation). At the same time, both agriculture and fisheries have a large, generally negative impact on biodiversity and ecosystem services, although there are certainly exceptions. High Nature Value farmlands are an example of the positive impact of especially low-intensity forms of agriculture. Of Europe's farmland area, around 32% is estimated to be HNV farmland (Paracchini, Petersen, et al., 2008).

As a result of the intensive use of land, as well the emissions of nitrogen, phosphorus and pesticides, agriculture is one of the main drivers within Europe of biodiversity loss. Such areas are under threat, however, from both the intensification of farming and land abandonment. The impact of agriculture on biodiversity is illustrated by the fact that common farmland birds declined by 30% over the period 1990-2012 (EEA, 2015). Agriculture plays a key role in the fragmentation of land, affecting the connectivity and health of ecosystems and their ability to provide services as well as viable habitats for species. Over the last 50 years, Europe has witnessed a decline in genetic diversity in crops and livestock, due to a focus on productivity, and the concentration of breeding within a few firms. Over the last 10 years, this topic has gained more policy interest.

A comprehensive assessment of the state and trends of Europe's ecosystems and related services is still missing, but over the last years important progress has been made towards a better mapping(Egoh, Dunbar, et al., 2012). While agricultural production is already profiting from many ecosystem services, this use could still be significantly expanded, for example in the form of biological pest control. Also a better understanding of soil processes could help the increase crop yields, while lowering external effects. In this way, food production could make more efficient use of biodiversity and ecosystem services.

Capture fisheries are largely depending on **marine resources**. Fishing pressure has been decreasing since 2007 in EU Atlantic and Baltic waters. The number of assessed stocks fished above their maximum sustainable yield (MSY) has fallen from 94 % in 2007 to 39 % in 2013. In 2013, 59 % of assessed stocks had climbed back to safe biological limits (EEA, 2014). However, 88 % of the assessed stocks in the Mediterranean and Black Seas were still overfished (EEA, 2014). The EU balance of trade in fishery products in terms of value has shown a negative trend since 2001. This was caused by the increasing imports of fresh, frozen and prepared and preserved products between 2004 and 2007 [3]. EU self-sufficiency for seafood was stable at around 45% between 2008 and 2011. While the EU covers fully its needs for flatfish and small pelagics (and even produces surpluses) it is increasingly and highly dependent on external sourcing for groundfish, salmonids and tuna. Because of the fish quota system, a significant amount of fish was discarded. The new CFP tries to end this inefficient practice of discarding through the introduction of a landing obligation.

There are about 15-18 **minerals** (in some cases, depending on their function, referred to as minerals) which are essential for crop production, livestock as well as humans. Minerals are in fact the only natural resource transported through the food system. Compared to other regions in the world, the use of mineral fertilisers per ha is relatively high, especially in a number of western European countries. In addition, the EU imports nutrients in the form of products, mainly in the form of soy beans and soy bean meal (Westhoek, Lesschen, et al., 2014, Withers,

[3] http://ec.europa.eu/fisheries/market-observatory/documents/10157/bf18cf2c-1b33-440d-8870-e05b2644b58b

van Dijk, et al., 2015). This high input of minerals facilitates on one hand high crop yields, on the other hand it is one of the factors contributing to high nutrient losses to the environment. In another consequence is that of all the N and P input into the agricultural system, only around 18% to 25% (for P) ends up at the consumers end of the food system (Westhoek, Lesschen, et al., 2014, Withers, van Dijk, et al., 2015). On other essential minerals (K, Mg, S, Zn etc) there is much less information. The surplus either is stocked in soils (mainly relevant for P), or is lost in various forms to the environment (mainly relevant for N). Of all the nutrients ending up in household, a large share ends up in either solid waste, as well as in sewage sludge from waste water treatments. A unknown (but probably not very high) fraction of these nutrients are recycled into agriculture.

Due to various policies (such as dairy quota, Nitrate Directive) and other developments (like the fall of communism, but also awareness raising) nutrients surpluses in most European countries have declined significantly in the period 1985-2005 (OECD, 2008). There all however still large differences both between as well as within countries in nitrogen surplus. This is mainly due to the concentrated livestock production in certain regions, as well as to intensive arable farming in certain regions (EEA and JRC, 2010).

Environmental impacts

Many food system activities lead to environmental impacts, ranging from affecting water quality to greenhouse gas emissions. **Water quality** can be impacted by agricultural activities, mainly due to diffuse pollution. Pollution from agricultural point sources (as stables, silage silo etc.) has largely been successfully addressed by national and EU policies. Also industrial food processing can result in the discharge of organic and inorganic pollution of water bodies.

Within the EU, agriculture is the largest contributor of nitrogen pollution. Although nitrogen losses from agriculture have been reduced, still more than half of the river and lake water bodies in Europe are reported to be in less than good ecological status or potential. Water quality is affected further by emissions of pesticides.

Greenhouse gas emissions from agriculture (which include emissions related to manure and fertilizer application on soils and methane emissions in livestock) make up around 12% of the EU’s total greenhouse gas emissions (Westhoek, Rood, et al., 2011). At primary production, the main source of emissions are the manufacturing and use of N-fertilizers, methane from cattle enteric fermentation and manure (Ingram, 2014). The food sector is one of the largest user of energy in the economy as a whole, of which most is used in processing and wholesale, followed by food preparation and consumption in households and the catering sector. A smaller proportion of the energy use goes into agricultural production, packaging and transport.

Consumption side aspects

In the EU, around 90 million tonnes of food is annually wasted and without action this amount is expected to rise to 126 million tonnes by 2020 if no additional prevention strategies are taken

(European Commission, 2014). According to Eurostat, in back in 2006 the manufacturing industry accounted for 39% of total food wastes, food service and catering for 14% while households accounted for 42% of total food waste.

European diets can be characterized as relative resource demanding, especially because the intake of animal proteins is high, compared to the average global intake(Westhoek, Rood, et al., 2011). Compared to plant based alternatives, the production of animal proteins require more land and lead to higher GHG emissions (Nijdam, Rood, et al., 2012), and also lead to higher nitrogen losses (Leip, Weiss, et al., 2014).

Food system outcomes
While undernutrition is much less a problem in the EU compared to the rest of the world, still a number of EU countries (notably Romania and Bulgaria) score much lower in terms of affordability, availability of food and micronutrient availability (EUI, 2014). In terms of varied diets and micronutrient availability, five European countries are in the global top 10 (France, Portugal, Greece, Ireland and Italy) (EUI, 2014). Over the past two decades, the obesity rate has doubled in European countries. According to the latest available data, 52% of the adult population in the European Union is overweight or obese (and an average 17% of the adult population is obese) showing little difference between men and women. These rates do however vary largely among countries, with low rates in Romania (around 8%) and high in Hungary and the United Kingdom (over 25%) (OECD, 2012).

4. Options to arrive at a more sustainable and efficient use of natural resources

In biophysical terms, there are options to enhance the sustainable management and efficient use of natural resources, at all stages of the food chain. In most cases, this will also lead to lower environmental impacts, for example by reducing nutrient losses (in the case of the more efficient use of fertilizers), or by lower GHG emissions in the case of a more efficient use of fossil fuels. Options to attain a **sustainable** use of renewable natural resources (land, soils, water and ecosystem services) are largely in the hand of farmers and fishermen, as they are typically the main users of these resources. Important options to enhance the sustainable use are good land and soil management, to keep the soil covered and by using soil amendments such as compost, controlled water use to prevent depletion of aquifers and the promotion of biodiversity in agricultural landscapes. An important measure for fisheries is balancing fish catches with the ecological carrying capacity.

Options to achieve a more efficient use of natural resources are distributed over the various food system activities. In agriculture, crop yields could be increased, especially in region with a yield gap. Concrete measures to achieve this include integrated nutrient management, improved crop varieties, smart irrigation, precision agriculture using sensors and remote sensing, or improving the utilization of rainwater. The choice of the most effective measure is very site-specific. Other important ways to improve resource efficiency at the farm level are better water management (both of rainwater and irrigation water), a more effective use of ecosystem services (for example for pest and disease management, which could reduce the use of pesticides), and better nutrient management. An substantial route to improve nutrient efficiency is the closing of the crop-feed-manure-crop loop. Currently, this cycle is often broken due to the spatial segregation of crop and livestock production.

In pig and poultry production, opportunities exist to increase feed efficiencies, for example through improved livestock management or precision feeding). When increasing feed conversion, trade-offs with animal welfare should be avoided. Finally, even in the EU post-harvest food losses occur, which could be reduced.

Also upstream and downstream in the food chain there are major options to arrive at a more efficient use. These include the production of fertilizers (lower energy use) and more efficient transport or in some cases less transport by eating more seasonal fruits and vegetables. Also less or more efficient packaging is an important option, although in some cases packaging can avoid food wastes. More public refilling station in for example schools and train stations can lower the use of plastic bottles. Lower food waste as well as less resource-intensive diets also important routes to lower resource use.

5. Actors and drivers

As is clear from the overview of options, farmers and fishermen on the one hand, and consumers on the other hand, have in theory the largest potential to arrive at a more sustainable and efficient use of natural resources. In many cases, mainly driven by short-term economic considerations, farmers and fishermen have indeed taken action, for example by increasing crop yields and feed efficiencies, and reducing on-farm energy use and nutrient losses. In other cases, economic incentives are lacking, as for example many externalities are not priced. Given the ‘price-squeeze’ in which farmers and fishers have to operate, they often lack the means to adopt other practices.

Consumers could also have a large role in changing food systems and reducing the pressure on natural resources. Although some consumers indeed take action, for example by reducing food waste or eating less meat, for many consumers it is hard to really change their behavior. Food choices are largely determined aspects such as culture and habits, price, availability and by what is called the ‘food environment’ (Story, Kaphingst, et al., 2008). This leaves a large role for governments as well as for the private sector. On certain aspects governments definitely have an important role, such as for example the legal framework, tenure and property rights, and environmental regulation. Yet, many governments feel themselves constraint to take firmer action, for example due to the felt need to create a ‘level playing field’ for their farmers in an international context. EU legislation can at least partly overcome this, as has been shown in the case of environmental legislation (e.g. the Nitrate Directive) and animal welfare (e.g. the ban on cages for laying hens). Another barrier is that many food items are imported, which implies that the production circumstances cannot be directly influenced.

The private actors in the middle of the food system thus have, at least in potential a large role to play. These actors can work with farmers and fishermen to change management practices. This can be on a voluntary bases, or, if needed, using a 'stick' approach (exclusion criteria) or by a 'carrot' approach by rewarding farmers or fishermen for extra performances. Well-known examples of these are certification schemes, for example for certain commodities (soy bean, palm oil) or ways of production (such as organic production). There are examples where certification schemes have led to significant changes in management practices, such as different fishery techniques related to MSC certification schemes. Also civil society (mainly in the form of NGOs) have played a large role in developing these kind of schemes.

The most adequate opportunities may be leveraged by identifying the key actors of change in specific regional food systems. When considering these actions, the interests of the different key actors should be understood. These interests are often the key to understanding the way the current food system operates, and why certain societal undesired outcomes occur.

6. Conclusion

Currently, many natural resources are not being used sustainably or efficiently in the European food system, leading to a significant environmental impacts (such as greenhouse gas emissions and water pollution) as well to risks for future food provision, for example in the case of land degradation and depletion of marine resources. These inefficiencies not only occur at the production level, but also at the consumption side, for example in case of food waste and resource-intensive diets. In a biophysical sense, there are many options for improvement. Currently, not all of these are options are put in practice, for example because farmers are operating at small margins. The food systems approach facilitates consideration of the perspectives of all different actors in the food system, and thus the identification of improvement opportunities leading to enhanced resource efficiency, as well as potentially to other societal desired outcomes, such as appropriate farmers' incomes and healthy diets.

7. References

EC. 2014. Monitoring Agri-trade Policy. Agricultural trade in 2013: EU gains in commodity exports. European Commission, DG Agriculture & Rural Development, Brussels.

EEA. 2009. Water resources across Europe - confronting water scarcity and drought. EEA Report No 2/2009. European Environment Agency, Copenhagen.

EEA. 2012. European Waters – Current Status and Future Challenges: Synthesis. EEA Report No 9/2012. The European Environment Agency, Kopenhagen.

EEA. 2012. Water Resources in Europe in the Context of Vulnerability. EEA 2012 State of Water Assessment. EEA Report No 11/2012. The European Environment Agency, Kopenhagen.

EEA. 2014. Presentation at the UNEP-IRP Workshop 'Natural resource use and environmental impacts of food systems in Europe' held in The Hague, The Netherlands on 17-18 September 2014 European Environment Agency.

EEA. 2015. Abundance and distribution of selected species (SEBI 001). The European Environment AgencyAssessment published online Feb 2015 http://www.eea.europa.eu/data-and-maps/indicators/abundance-and-distribution-of-selected-species/abundance-and-distribution-of-selected-2.

EEA and JRC. 2010. The European environment: State and outlook 2010. Thematic assessment Soil. European Environment Agency, Luxembourg.

Egoh, B., M.B. Dunbar, J. Maes, L. Willemen and E.G. Drakou. 2012. Indicators for mapping ecosystem services: a reviewPublications Office.
Ericksen, P., B. Stewart, J. Dixon, D. Barling, P. Loring, A. M., et al. 2010. The Value of a Food System Approach. In: J. Ingram, P. Ericksen and D. Leverman, editors, Food security and global environmental change. Earthscan, London. p. 25-45.
Ericksen, P.J. 2008. Conceptualizing food systems for global environmental change research. Global Environ. Change 18: 234-245.
EUI. 2014. Global Food Security Index.The Economist Intelligence Unit.
European Commission. 2013. The common agricultural policy (CAP) and agriculture in Europe - frequently asked questions http://ec.europa.eu/agriculture/faq/index_en.htm European Commission Brussels
European Commission. 2014 Sustainable Food http://ec.europa.eu/environment/eussd/food.htm Last accessed on 28-01-2015
Eurostat. 2015. Farm structure statistics. Data from April 2015, last retrieved on 7 April 2015 http://ec.europa.eu/eurostat/statistics-explained/index.php/Farm_structure_statistics. Eurostat, Europan Commission
FAO, IFAD and WFP. 2015. The state of food insecurity in the world - Meeting the 2015 international hunger targets: taking stock of uneven progress. Food And Agriculture Organization of The United Nations, Rome.
FEFAC. 2015. Feed & Food Statistical Yearbook 2013. In: E. f. m. association, editor Brussels.
HLPE. 2014. Food losses and waste in the context of sustainable food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome.
Ingram, J. 2011. A food systems approach to researching food security and its interactions with global environmental change. Food Security 3: 417-431.
Ingram, J. 2014. Presentation at the UNEP-IRP Workshop ‘Natural resource use and environmental impacts of food systems in Europe’ held in The Hague, The Netherlands on 17-18 September 2014.
Ingram, J.S.I., P.J. Ericksen and D.M.e. Liverman. 2010. Food security and global environmental changeEarthscan, London
JRC. 2012. The state of soil in europe-a contribution of the jrc to the european environment agency’s environment state and outlook report–SOER 2010. Joint Research Center, Europe, Luxembourg.
Leip, A., F. Weiss, J.P. Lesschen and H. Westhoek. 2014. The nitrogen footprint of food products in the European Union. The Journal of Agricultural Science 152: 20-33. doi:doi:10.1017/S0021859613000786.
Mueller, N.D., J.S. Gerber, M. Johnston, D.K. Ray, N. Ramankutty and J.A. Foley. 2012. Closing yield gaps through nutrient and water management. Nature advance online publication. doi:http://www.nature.com/nature/journal/vaop/ncurrent/abs/nature11420.html#supplementary-information.
Neumann, K., P.H. Verburg, E. Stehfest and C. Müller. 2010. The yield gap of global grain production: A spatial analysis. Agricult. Sys. 103: 316-326.
Ng, M., T. Fleming, M. Robinson, B. Thomson, N. Graetz, C. Margono, et al. 2014. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. The Lancet 384: 766-781.
Nijdam, D., T. Rood and H. Westhoek. 2012. The price of protein: Review of land use and carbon footprints from life cycle assessments of animal food products and their substitutes. Food Policy 37: 760-770. doi:10.1016/j.foodpol.2012.08.002.
OECD. 2002. Measuring material flows and resource productivity. Volume 1. The OECD Guide Glossary. OECD, Paris.
OECD. 2008. Environmental Performance of Agriculture in OECD Countries Since 1990OECD Publishing, Paris.
OECD. 2012. Health at a Glance: Europe 2012. OECD Publishing.
Paracchini, M.L., J.-E. Petersen, Y. Y.Hoogeveen, C. Bamps, I. Burfield and C. van Swaay. 2008. High Nature Value Farmland in Europe - An estimate of the distribution patterns on the basis of land cover and biodiversity data. Joint Research Centre, Institute for Environment and Sustainability, Ispra.
PBL. 2014. How sectors can contribute to sustainable use and conservation of biodiversity. In: M. Kok and R. Alkemade, editors, PBL & CBD, The Hague.
Pinstrup-Andersen, P. and D.D. Watson II. 2011. Food policy for developing countries: The role of government in global, national, and local food systemsCornell University Press, Ithaca and London.

Story, M., K.M. Kaphingst, R. Robinson-O'Brien and K. Glanz. 2008. Creating healthy food and eating environments: policy and environmental approaches. Annu. Rev. Public Health 29: 253-272.
Underwood, E., D. Baldock, H. Aiking, A. Buckwell, E. Dooley, A. Frelih-Larsen, et al. 2013. Technology options for feeding 10 billion people. Synthesis report: Options for sustainable food and agriculture in the EU. Science and Technology Options Assessment (STOA), European Parliament Brussels
UNEP. 2010. Assessing the environmental impacts of consumption and production: priority products and materials. A report of the Working Group on the environmental impacts of products and materials to the International Panel for Sustainable Resource Management. Hertwich, E., van der Voet, E., Suh, S., Tukker, A., Huijbregts M., Kazmierczyk, P., Lenzen, M., McNeely, J., Moriguchi, Y.
UNEP. 2011. Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. UNEP International Resource Panel, Paris.
Westhoek, H., J.P. Lesschen, T. Rood, S. Wagner, A. De Marco, D. Murphy-Bokern, et al. 2014. Food choices, health and environment: Effects of cutting Europe's meat and dairy intake. Global Environ. Change. doi:10.1016/j.gloenvcha.2014.02.004.
Westhoek, H., T. Rood, M.v.d. Berg, J. Janse, D. Nijdam, M.A. Reudink, et al. 2011. The protein puzzle : the consumption and production of meat, dairy and fish in the European UnionPBL (Netherlands Environmental Assessment Agency), The Hague / Bilthoven.
Withers, P.J., K.C. van Dijk, T.-S.S. Neset, T. Nesme, O. Oenema, G.H. Rubæk, et al. 2015. Stewardship to tackle global phosphorus inefficiency: The case of Europe. Ambio 44: 193-206.