Environmental degradation: impacts on agricultural production

How will environmental degradation impact food security in Europe and why we need to act now to secure food in the future

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In Europe, concerns about food security are common in political debates around agriculture policy. This was the case in 2010, when the Common Agricultural Policy was being reviewed, in part because of price surges in global food markets in 2007-2008. It is again the case in 2022 in advance of the next CAP reform, because, once again, of soaring energy and food prices. Russia's invasion of Ukraine further reinforces fears of food insecurity in Europe and globally through traded commodities. The EU depends in part on feed and fertilisers imports from Ukraine and Russia, and many low-income countries (e.g. in the middle-east) rely on them for food, in particular cereals. As a result, many key stakeholders emphasise the importance of increasing agricultural production to ensure food security, therefore supporting the status quo rather than a systemic shift of the food system that would make it more resilient and able to provide for society.

While this strategy might increase food availability in the short term, it focuses disproportionally on the food production side of the food security issue, neglecting other aspects such as food access. Indeed, according to the World Food Summit definition (1996), food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

For the FAO, food security relies on 4 pillars (FAO, 2006): the availability of sufficient quantities of food through production, distribution, and exchange (food availability), the affordability of food and the possibility for individuals to access adequate resources for acquiring appropriate foods (food access), the quantity and quality of food that reaches individuals (food utilisation) and the ability to obtain food over time (food stability). Just the availability (or increased production) of food is therefore not sufficient to ensure food security. In fact, there is consensus that the real challenge relates to food distribution and inequity in access because of poverty, rather than a shortage of production. Focusing on increasing food production is therefore unlikely to solve the problem of food insecurity.

In parallel, such a strategy has consequences in the long term, as it favours the proliferation of unsustainable farming and food systems. European food systems are responsible for 30% of the Union's GHG emissions (Crippa et al, 2021). They are also the main pressure on biodiversity (through pesticides use, landscape simplification and the destruction of habitats) and partly responsible for the physical, chemical, and biological degradation of soils and the decrease in water quantity and quality. Yet, these environmental damages will and do in turn affect food availability both now and in the future. In this regard, the recent results from the latest report from the Intergovernmental Panel on Climate Change (IPCC) are clear: climate change will threaten global food security in the coming years in many ways and some European countries will be particularly affected.

This briefing reviews existing evidence on the impact of environmental degradation on European food availability in the long run, if food systems are to remain as they are. It focuses on climate change, biodiversity loss and soil degradation, notwithstanding that other threats are also important (such as the depletion of water resources). When relevant, and when information is available, we also address impacts of environmental degradation on other aspects of food security (for example, through trade, food access, food safety and the nutritional quality of food).

1. The impact of climate change

Climate change, through changes in CO_2 and ozone concentrations, temperature, rainfall patterns, frequency of extreme weather events and increased incidence of pest and diseases[1], is already impacting global crop yields, yield stability and the quality of crops (IPCC, 2022)[2].

[1] Warming causes range expansion and alters host pathogen association of pests, diseases and weeds affecting health for European crops e.g. (Caffarra, 2012) in grapevines with high risk for contamination of cereals (Moretti, 2019)

[2] In this brief we focus on the overall or net effect of climate change. However, there is variation in impacts, for example increasing CO_2 concentrations could have a positive impact on crop production as it stimulates photosynthesis rates and biomass accumulation of C3 crops (like rice and soybean) and enhance crop water use efficiency of various crop species including C4 crops (like maize and sugarcane) (Kimball, 2016; Toreti et al, 2020). The C3 and C4 classification refers to the type of photosynthesis that a plant practices. However, large uncertainties remain, especially under water and nutrient limitations in the soil (Ciscar et al, 2018). Moreover, this effect is not always sufficient to compensate for crops losses from other changes. Increasing CO_2 concentrations could also affect the quality of food. For instance, Smith & Myers (2018) found that many food crops grown under elevated CO_2 concentration (550 ppm) have protein, iron and zinc contents that are reduced by 3–17% compared with current conditions.

These impacts differ by crops and regions. In Europe, they are mostly negative in Eastern, Western and Southern regions, while some positive effects have been observed for some crops in other areas, for instance for wheat production in Northern Europe. In most countries of Southern Europe, temperature and precipitation changes have negatively impacted the yields of wheat, barley, maize and sugar beet, leading to recent yield stagnation (Moore and Lobell, 2015).

Since the occurrence of adverse conditions is likely to substantially increase in the 21st century (Trnka et al, 2014), these impacts on yields will intensify. In particular, with the combination of heat and drought, substantial losses in agricultural production are projected for most European areas over the 21st century and will not be offset by gains in Northern Europe. A study conducted by the EU Joint Research Center (Feyen et al, 2020), showed, based on a biophysical model, that crop yields could drop by more than -10% in Southern Europe in a 2°C warming scenario. In particular, the potential yield of grain maize could decrease by -11% and -5% on average in Southern and Northern Europe respectively. In the absence of increased irrigation, declines in maize yields of over -20% are projected for all EU countries, with crop losses up to -80% in some southern European countries (Portugal, Bulgaria, Greece and Spain). The production of wheat, which is mostly a rain-fed crop in Europe, would increase by 5% on average in Northern Europe in a 2°C warming scenario, but would be jeopardised if temperatures exceeded that limit (IPCC, 2022; Feyen et al, 2020). In Southern regions of Europe, wheat yield reductions of -12% are estimated (in some areas yields could even be halved), mostly because of the strong decrease in precipitation. Overall, food production in other continents outside Europe is predicted to be more severely affected from climate impacts (IPCC, 2022; Hasegawa et al, 2022.

While these impacts on crop yields are mostly studied for major staple crops such as wheat, rice or maize, recent results suggest similar results for vegetables, fruits, nuts and fiber products, which are essential for healthy nutrition. In particular negative impacts are expected for vegetables, leafy crops, soft fruits, tree fruits and nuts (IPCC, 2022). For instance, Scheelbeek et al (2018) showed in a meta-analysis of experimental studies that increasing temperatures, ozone concentration, salinity and water scarcity for irrigation have a negative impact on vegetable yields while the increase in atmospheric CO_2 concentration, increases yields. In a business-as-usual scenario, predicted changes in environmental exposures would thus lead to reductions in yields of vegetables globally because the positive effect of increased CO_2 concentrations does not offset the negative impacts of other factors[3]. Results are more mixed for legumes and root crops. In Portugal, Valverde et al. (2015) estimated maximum estimated yields losses for woody crops and found that they were considerably higher for almonds (-27.2%) than grapevines (-5.4%) and olives (-14.9%).

Climate variability is also a major source of variation in crop production, especially in productive regions. The increasing number and intensity of extreme climate events, such as drought or flooding, is leading to crop damage, increased pest incidence and transportation disruption,

[3] In terms of impact on nutritional quality, the results of the study are more mixed and vary greatly depending on the type of vegetable and the molecules studied (e.g., vitamin C, antioxidants, flavonoids).

reducing food production and distribution. For instance, losses for 129 crops cultivated in the EU have tripled over the last 50 years, from −2.2% between 1964 and 1990, to −7.3% in the 1991–2015 period due to drought and heat (Brás et al, 2021).

Climate change also affects livestock production in many ways. Rising temperature and increased frequency of drought in particular are increasing heat stress on animals, reducing herd mobility, productivity and increasing the incidence of vector borne diseases and parasites, as well as reducing access to water and feed. Regarding cattle in particular, Dellar et al (2018) found for instance that whilst yields in pastures will increase in some European areas (the northern region and parts of the Alpine and continental regions), their feeding quality will decrease (reductions in N concentration). Where conditions become warmer and drier (particularly southern Europe and other parts of the continental region), there will be reductions in both pastures yield and quality, which could result in nutritional stress in grazing animals and reduced meat and milk production.

These various impacts of climate change on crop and livestock productions are projected to affect the economic health of the agricultural sector in Europe. For instance, Naumann et al (2021a) showed that while droughts destroyed on average 2.58% of the annual gross value added of the agricultural sector in the EU and the United Kingdom between 1981 and 2021, this could grow to almost 7% in a 4°C warming scenario. In the Mediterranean, drought conditions at high levels of global warming could reduce agriculture economic output by more than 10% (Naumann et al 2021a; Naumann et al, 2021b).

Beyond affecting crop and livestock production, and thus food availability, climate change will also increasingly impact food access (in particular, as increasing agricultural losses worldwide will reduce production and lead to increases in global food prices), food quality and safety (e.g., because of an increased prevalence of pathogens, such as mycotoxins) and food stability (e.g., increase in the frequency of major crop failures from extreme events).

2. The impact of biodiversity loss

Food security, in particular food production, depends on the health of agroecosystems, and their provision of ecosystem services[4]. Biodiversity has a crucial role to play in pollination and biological pest control services (Dainese et al, 2019). These services are thus threatened by the continuing loss of biodiversity observed worldwide.

In Europe in particular, biodiversity has been declining at an alarming rate. The assessments of the species and habitats protected by the EU Habitats Directive reveal a predominantly unfavorable conservation status (60% for species and 77% for habitats). This loss of species abundance is not confined to rare and threatened species. According to the IUCN Red List, 9% of bee and butterfly species are threatened and populations are declining for 37% of bees and 31% of butterflies. Losses are particularly concerning in agroecosystems, with long-term

[4] Ecosystem services are the many and varied benefits to humans provided by the natural environment and from healthy ecosystems.

monitoring showing continued downward trends in farmland birds (32% between 1990 and 2016) and grassland butterflies (39%, between 1990 and 2017) populations (EEA, 2019).

So far, Europe has remained food secure through food production and trade, despite this continuing decline in biodiversity and the degradation of several of nature's regulating contributions (IPBES, 2018). However, if these trends continue, they could threaten food security, particularly in the area of agricultural production.

2.1 Pollination

Pollination[5] is fundamental to the reproduction and persistence of flowering plants. Most flowering plants depend on vectors for pollination, such as animal pollinators, wind, or water (IPBES, 2016). Globally, over 300,000 species (87.5%) of the world's flowering plants have been estimated to be pollinated by animals (Ollerton, Winfree and Tarrant, 2011). Food crops are particularly concerned as 85% of the leading types of global food crops rely to some extent on animal pollination for yield and/or quality (Klein et al, 2007). It mostly includes fruits and vegetable crops, that are cultivated on small areas and have relatively low yields compared to cereal crops for example, which account for the bulk of the amount of food crops produced. As a result, globally, animal pollination has been estimated to be directly responsible for between 3 and 8 per cent of total current agricultural production by volume[6] (i.e., this amount of production would be lost if there were no pollinators) (Aizen 2009). Moreover, it contributes to the production of crops that supply major proportions of micronutrients in global human diets, such as vitamin A, iron and folate (Chaplin-Kramer et al, 2014). However, the importance of animal pollination varies substantially among crops, and therefore affects regional crop economies differently.

In Europe, some estimates show that pollinators increase the productivity of around 85% of 264 crops cultivated (Williams, 1994) and that 12% of the total EU cropland area is dependent on pollinators for optimal agricultural production (Schulp, Lautenbach and Verburg, 2014). Moreover, this dependance increased substantially between 1961 and 2016 (Aizen et al, 2019). According to study by the JRC, the absence of insect pollination would result in a reduction of between -25% and -32% of the total production of crops which are partially dependent on insect pollination in the EU, depending on the source of the data used for the assessment (Zulian, Maes and Paracchini, 2013). However, it varies strongly between countries, the most vulnerable country being Slovenia, with a reduction estimated around -57%. The total loss of pollinators in Europe would also decrease Europe's capacity to produce enough fruits and vegetables for its own consumption (Gallai et al, 2009).

[5] Pollination occurs when animals move viable pollen grains from anthers (the male part of a flower) to receptive and compatible stigmas (the female part of a flower) of flowering plants. When followed by fertilization, it usually results in fruit and seed production.

[6] Representing an annual market value of $235 billion-$577 billion (in 2015 US$) worldwide.

2.2 Biological/natural pest control

Species present in agroecosystems, in particular arthropod predators and parasitoids, insectivorous birds and bats, and microbial pathogens, also provide a biological control service as they act as natural enemies to agricultural pests (Power, 2010; Tscharntke et al, 2005). Through this service, they actively prevent crop losses from pests, therefore contributing to food availability. For instance, Östman, Ekbom and Bengtsson (2003) showed, through a predator removal experiment, that the presence of natural enemies in ten farms in central Sweden increased barley yields by 303 kg/ha, preventing 52% of yield loss due to aphids while Letourneau et al. (2009), in a meta-analytic synthesis, found that increases in natural enemy species richness generally yield to greater suppression of arthropod herbivores. However, evaluating the contribution of natural enemies of pests to food production remains complex (both in terms of production quantities and economic value) because of the widespread use of pesticides and the resulting impossibility of isolating the contribution of natural enemies (Kremen and Chaplin-Kramer, 2007). Yet, some studies have used the cost of the efforts to replace natural pest control services as a proxy of the value of this service. For instance, Losey and Vaughan (2006) estimated that the value of native pest control by ecosystems to be approximately $13.60 billion each year in the USA.

Although it is difficult to assess the value of this service, its impact on food production is without doubt. Thus, Dainese et al (2019) have shown that the richness and abundance of species present in the agro-ecosystem positively influences the provision of the biological control service, which in turns impacts agricultural yields positively. The continuing decline in agroecosystems diversity could therefore impact yields negatively by reducing natural pest control.

3. The impact of soil degradation

Soils also contribute to food security by providing the necessary substrate for crop growth, as well as nutrients and water. Nevertheless, soil functions are threatened by a wide range of processes. The FAO and the IPTS (2015) identified ten soil threats globally: soil erosion, loss of soil organic matter and carbon, nutrient imbalance, acidification, contamination, waterlogging, compaction, sealing, salinisation and loss of soil biodiversity. Amongst these threats, many impact food security negatively by decreasing agricultural productivity and yields, through a reduction of the land area available for food production, or via contamination. However, while the potential impacts of some of these degradations on food production are well documented and quantified (for example, soil erosion), others remain relatively less known due to a lack of data. This is the case, for example, for soil biodiversity, for which the status and trends are poorly known in Europe and the impact on yields have been little quantified (Orgiazzi et al, 2016; FAO, 2020).

In the EU, it has been estimated that about 60 to 70% of EU soils are not healthy because of unsustainable land-use management practices, overexploitation and emissions of pollutants (Veerman et al, 2020). In particular, 25-30% of all EU soils are currently either losing organic carbon, receiving more nutrients than they need, are eroding or are compacted or suffer secondary salinization, or are facing some combination of these threats, all of them occurring on agricultural land (Veerman et al, 2020). This would mean that between 61% and 73% of agricultural soils are affected by these phenomena[7].

Soil sealing, which happens when urban expansion consumes soils by physical removal or covering them with impermeable artificial material for housing, roads or other construction work, leads to a reduction in the area available for agriculture (Gardi et al, 2015). Moreover, it often occurs on productive soils, which further reduces the ability of the agricultural sector to produce food. In 2012, 2.43% of the total EU-28 land area was sealed, with important variations according to regions, small countries with high population densities being particularly vulnerable (EEA, 2019). While in almost all EU-27 countries the rate of soil sealing has been slowing down between 2012 and 2015, total sealed area still continued to increase in this period, with an additional 639 km^2 sealed, corresponding to an annual average increase of 213 km^2. Austria and Belgium account for 24 and 19% of this increase, respectively. Gardi et al, (2015) estimated the loss of potential agricultural production following soil sealing in 19 EU countries between 1990 and 2006 to be around -6 million tons of wheat. While this only represents a total loss of -0.81% of the total potential agricultural production over the period, areas near large cities in Central and Western Europe and coasts of Southern Europe were particularly affected, some of them losing more than 10% of their agricultural production potential.

Other soil threats, including erosion, loss of soil organic carbon and matter, decline of soil biodiversity, compaction, salinisation, acidification, and desertification, affect food production by reducing yields and agricultural productivity. For example, erosion by water, by wind and by harvest losses impacts soil function and fertility and leads to the transfer of materials and pollutants into water systems, affecting water availability and quality for agriculture and human consumption. In the EU, recent estimates show that a quarter of European land is subject to unsustainable soil loss rates (of over 2t/ha/year in 2016), and that more than 6.6% of agricultural lands suffer from severe erosion (>11t/ha/year) (Panagos et al, 2020). Additionally, in a significant number of countries, the trend in soil loss is worsening rather than improving; between 2010 and 2016 soil loss increased in eight countries, most of which were already highly exposed (e.g., Greece, Spain, Italy or Slovenia). This trend has been mainly attributed to a decrease in conservation tillage. On the basis of a literature review, Panagos et al (2018) estimated that crop productivity decreases by -8% in agricultural fields that have been intensively cultivated and where erosion rates are high (>11 t/ha/year). Using 2010 data, they further estimated that almost 3 million tonnes of wheat and 0.6 million tonnes of maize are being lost annually due to severe erosion in the EU. The highest productivity losses are found for rice and wheat because they are the dominant crops in the most eroded areas of

[7] As there are 4,233,255 km^2 of land area in the EU, we estimate that between 0,25* 4,233,255 km^2 = 1 058 313,75 km^2 and 0,3* 4,233,255 km^2 = 1 269 976,5 km^2 of the EU land areas are affected by those events. If these are all agricultural soils, and since we know the total area of agricultural soils is about 1,730,000 km2, we can estimate that between 61% and 73% of agricultural soils are degraded.

Mediterranean countries (Italy, Spain, and Greece) and the most affected countries are Italy and Slovenia.

Industrial activities, waste disposal and intensive land management practices have led to the dispersal of contaminants in the environment, including in soils. These contaminants include residues of pesticides, industrial emissions, fertilisers, pharmaceutical products or heavy metals, as well as emerging pollutants such as microplastics, endocrine disruptors and antibiotics (EEA, 2019). Depending on soil properties and concentrations they can then enter the food chain, threatening soil ecosystems functioning, food safety and thus human health (Peralta-Videa et al, 2009). For instance, Tóth et al (2016) found that 137,000 km^2 of EU agricultural land has high concentrations of heavy metals, representing almost 8% of the total agricultural area. The accumulation of pesticide residues in soils is also a source of increasing concern. Researchers from Wageningen University measured residues in soils from 11 European Union member states and found that over 80% of these soils contained pesticide residues, glyphosate and its metabolites, as well as some broad-spectrum fungicides, being the most frequently present pesticides and at the highest concentrations (up to 2.87 mg/kg) (Silva et al, 2019). While these various pollutants do not directly affect food supply, they impact the quality of the food produced, therefore also threatening food security.

Conclusion

Climate change, biodiversity loss and soil degradation are already affecting food production, in the EU and worldwide. These impacts will intensify in the future and affect our capacity to feed an increasing global population. In Europe, Southern countries (especially Mediterranean ones) will face multiple threats, as they are particularly vulnerable to climate change and some types of soil degradation (such as erosion, salinisation) and are highly reliant on pollinator-dependent crops. Moreover, some threats remain relatively less well known than others (for example, the expansion of pests and diseases versus increased temperatures) and further cross-cutting effects are likely to reinforce these negative impacts. For instance, climate change will reduce the effectiveness of pollinator agents as species will be lost from certain areas, or the coordination of pollinator activity and flower receptiveness will be disrupted in some regions (IPCC, 2022). Furthermore, other aspects of food security are also impacted either directly or indirectly, including food access (due to high food prices), food quality and safety (for example because of the loss of nutrients in food or the development of pathogens) and food stability (because of the increased frequency of extreme weather events that will disrupt production and distribution).

Actions should therefore be implemented now to limit environmental degradation and its impacts, which are, for the most part, the result of unsustainable human systems, not least food systems. European food systems are responsible for 30% of the union’s GHG emissions. Land use is the primary driver of biodiversity loss in Europe (IPBES, 2018) and is partially or fully responsible for various types of soil degradation, for example soil erosion. These actions should therefore target the main sectors responsible for environmental degradation. They include i) reducing GHG emissions in all sectors; ii) reducing water and soil pollution from industries; iii) reducing soil sealing, land take, and contamination from urban areas; as well as specific actions in the agricultural sector to iv) reduce pesticides and fertiliser use, v) increase landscape complexity, vi) improve water efficiency and adopt agro-ecological practices (such as reduced tillage and catch/cover crops). Only with those changes to key sectors will it be possible to secure food availability in the long term.

To accompany this transition, the EU will also have to rethink its consumption patterns. Cutting down food waste, reducing the production of crop-based biofuels and shifting to more plant-based diets would also allow to decrease the ecological footprint of European food consumption in Europe and in third countries, freeing up land for production and ecosystem protection everywhere. Additional measures will also be needed to address impacts on the other aspects of food security (food access, food quality and stability). For instance, closing yield gaps in the Global South would help ensuring food availability at the global level, therefore limiting increases in food prices, and improving food affordability.

Recent papers have shown that such a transition, supported by an ambitious green deal at the European level, will have a high cost in the short term (Barreiro Hurle, J et al, 2021) leading to reduced production capacity and higher food prices. However, these analyses do not account for future threats to food production, and therefore do not provide a full picture of the costs and benefits of implementing the green deal and limiting threats to agricultural and food systems.

In addition, such high cost will hit some stakeholders more than others, in particular poor people and some types of farmers. The EU should therefore focus on supporting them primarily, using redistributive and social policies aiming at reducing poverty, and promoting a change in the sharing of added value along the chain to help farmers support associated costs.

The ecological and social transition of European food systems is therefore crucial. If it is successful, the impacts could be felt beyond the issues of food security, for example in improvements to the quality of life and the physical and mental health of European citizens (Filipova T., et al, 2021).

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