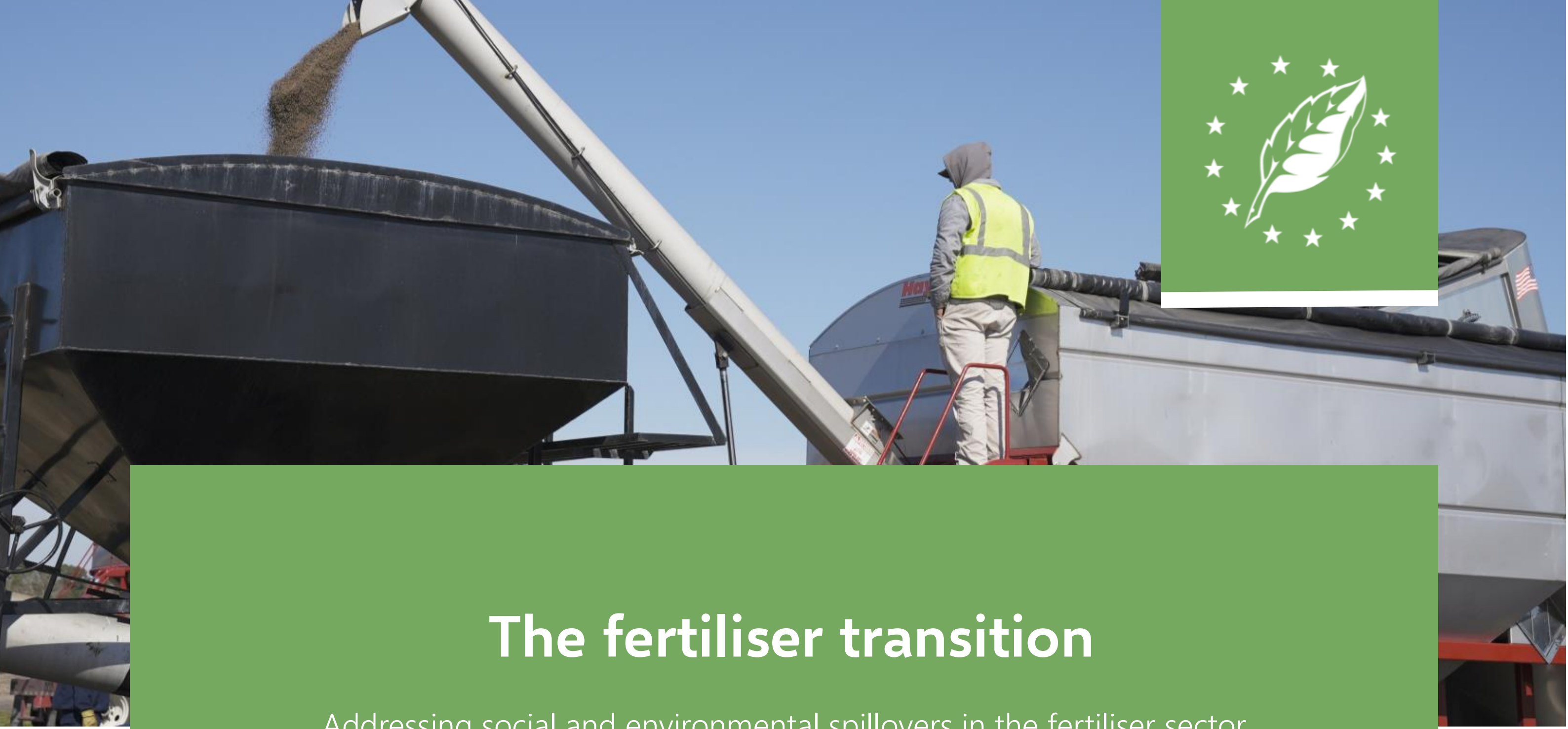

The fertiliser transition

Addressing social and environmental spillovers in the fertiliser sector

This briefing is one of a series assessing spillovers associated with the EU's circular transition. Sections 1 summarises the material flows of fertilisers and addresses the particular impact of the Russian invasion of Ukraine for the sector and section 2 provides an overview of the environmental and social impacts of these material flows. Section 3 review the EU policy landscape associated with the use of fertilisers for food production and how they could be mobilised for more circularity. Sections 4 and 5 map the potential positive and negative environmental and social spillovers, respectively, both inside and outside the EU of a circular transition for fertilisers use. Section 6 concludes with some initial policy recommendations.

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The European Green Deal (EGD) was adopted on 11 December 2019 and aims to make Europe the first climate-neutral continent by 2050 through notably the reduction of GHG emissions by 55% compared with the 1990 levels. Among its key objectives is to build a more sustainable and healthier food system. Thus, the Commission proposed over the recent years a large set of policies to bring about greater coherence between agriculture, trade and Green Deal policies.

Such a focus is adequate since agriculture and land use activities are responsible for a quarter of global greenhouse gas (GHG) emissions (Crippa et al. 2021) while agricultural GHG emissions in the EU remained almost stable between 2005 and 2019 and with only a projected modest 2% decline in this decade (EEA, 2021). This trend is expected to make **agriculture the single largest emission source in the EU by 2030**. The issue of sustainable agriculture and food systems is also perceived as a laggard in the implementation of the European Green Deal (EGD) by sustainability experts. The last iteration of the IEEP green deal barometer from June 2022[1] identifies the "path to a healthy food system" as the most important priority the European Commission should focus more on. The contribution of the agriculture sector to the EU climate objectives is therefore paramount for a sustainable and resilient transition, as it will eventually serve systemic changes towards resilient food systems, healthy food habits and a stable environment and climate.

The transition to sustainable food systems is further highlighted by the current geopolitical, environmental and climate instability that cause significant disruption to food supplies (drought, flood, storm, civil emergencies etc.) with detrimental consequences for the EU and even worse for food insecure countries. Such a transition should be accompanied by a dedicated strategy to address negative external spillovers of EU agricultural policies as European land use activities have global ramifications through international trade and are largely outsourcing environmental damage to other countries while pursuing more progressive objectives internally (Fuchs et al. 2021, ESDR 2021). This is especially concerning for the agriculture sector since, even if significant GHG emission reduction were to be undertaken in the EU, it is expected to remain a significant source of carbon leakage with "two-thirds of the reduction in non-CO2 emissions from EU agriculture being offset by higher emissions in the rest of the world" (Barreiro-Hurle et al. 2021).

Box 1 - Fertilisers as key elements of our food systems

Beyond CO_2 and water, a plant also needs three primary nutrients in large quantities for its growth: nitrogen, phosphorus and potassium. These nutrients are extracted from the soil by the plant's root system and play different roles for its growth (Nitrogen is a component of chlorophyll, Phosphorus is involved in the plants energy production process while Potassium relates to the plant ability to carry and transport water).

Nitrogen is the most abundant element on Earth, but under the form of "unreactive" or "inert" nitrogen gas in the atmosphere which makes it impossible for plants to incorporate it into their cells directly. Plants instead rely on symbiotic relations with other organisms such as microbes in the soil to extract nitrogen gas from the air and "fixing" it into ammonia, a reactive, or "biologically available" form of the element which plants can absorb. The use of fertilisers provides these active elements directly to the plant with no need for intermediaries.

Even though fertilisers requirements vary for different crop and soil types, yield expectations or climatic factors, their use has a massive impact for the optimisation of agricultural production, hence their importance of for our food production processes today. They mainly come in the form of organic fertilisers such as manure or compost, and mineral (or chemical/synthetic) fertilisers which have been

[1] https://ieep.eu/publications/green-deal-barometer-second-edition

widely used in agriculture throughout the world in the past decades to increase productivity.

The EU is now engaged in a threefold effort to achieve circular, net zero food systems and ultimately provide healthy food to the predicted population of Europe in 2050 while addressing the negative environmental impacts caused by intensive agricultural practices and avoiding offsetting any potential successes through carbon leakages. A number of solutions have been identified to work toward that objective notably through the generalisation of circular, agro-ecological practices to maintain appropriate agricultural productivity levels while substantially reducing nitrogen pollution and with minimal external spillovers (Billen et al. 2021).

In this brief we aim to focus on the importance of fertilisers in this transition, as a crucial input for food production yet also responsible for significant environmental and health impact throughout the food production processes. We will review the EU policy landscape pertaining to fertilisers before reviewing their use and trade flows. We will focus in particular on the potential positive and negative spillovers of a reduction of fertiliser use in the agriculture sector. We will then conclude by outlining initial policy recommendations.

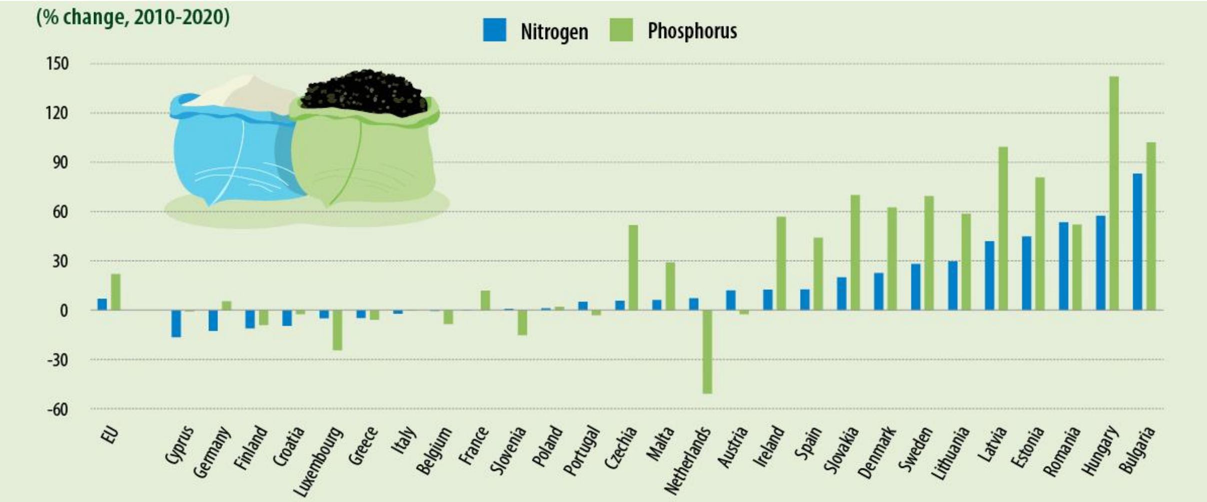
1. Material flows in the fertilisers sector

After World War II, the evolution of major agro-food producers, including the EU, has been marked by intensified production through increased use of synthetic fertilizers in addition to territorial specialisation and further integration in global food and feed markets. Today, the world's consumption of fertilisers has quadrupled since the 1960s to about 200m tonnes per year, mostly to support the production of cereals[2]. In the EU, the amount of mineral fertilisers used in agricultural production has broadly stabilised over the past decades, although this hides strong regional disparities among EU member States (See Figure 2 below). It was of 11.2 million tonnes in 2020, which is an 8.3% increase compared with 2010[3], yet looking specifically at nitrogen (N) fertilisers the consumption was essentially the same in 2000 and 2017 at 10.64 million tonnes.

We note that N fertilisers represent the vast majority of utilised mineral fertilisers in the EU (89% - See figure 3 below). Phosphorus fertilisers (P), though less important in terms of quantity used, remains a key input for plant growth and a strategic material as its main source is phosphate rock which is a non-renewable resource. This prompted the EU to list phosphate rock as a Critical Raw Material (CRM) in its second list of CRMs from 2014[4]. In terms of overall use, unsurprisingly, the largest agricultural producer countries such as France, Germany or Poland are the main users of mineral fertilisers in EU agricultural production (Figure 4).

[2] FAO - World fertilizer trends and outlook to 2022. Link.
3 Eurostat - Agri-environmental indicator - mineral fertiliser consumption. Link.
4 COM/2014/0297 on the review of the list of CRMs for the EU and the implementation of the Raw Materials Initiative. Link.

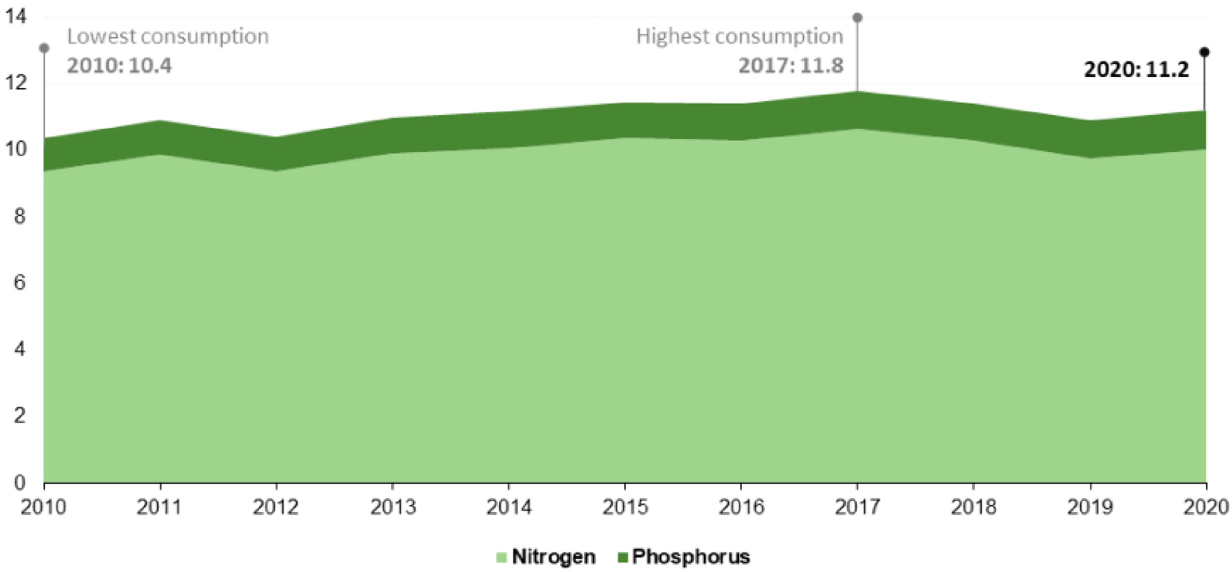
Figure 1: mineral fertiliser consumption by agriculture



Source: Eurostat

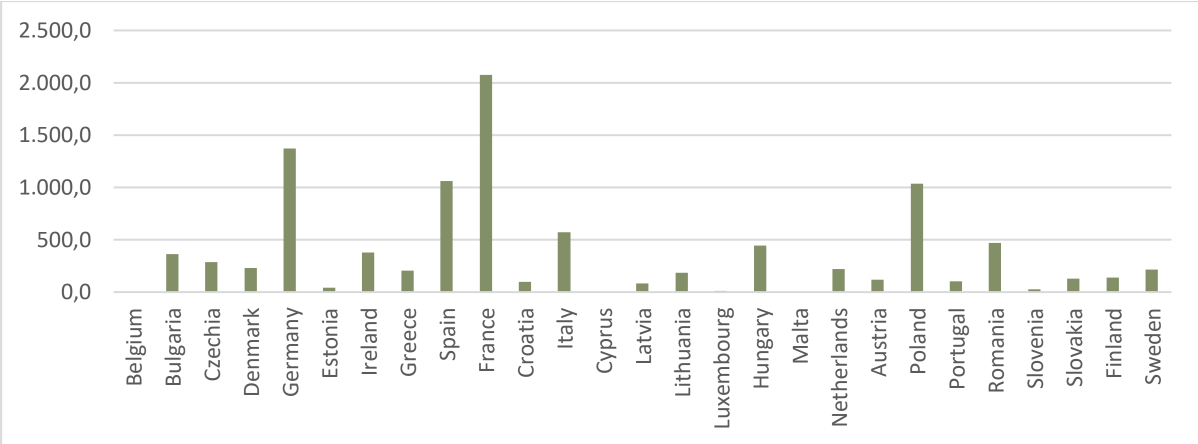
Between 2010 and 2020, the use of nitrogen fertilisers in agriculture registered its sharpest growth in Bulgaria (+83.0%), Hungary (+57.5%) and Romania (+53.4%). The same goes for phosphorus fertilisers with the sharpest rates of increase in Hungary (+142.2%), Bulgaria (+102.1%) and Latvia (+99.4%). These particular increases represent the convergence of these countries to the EU average of fertilisers use as they started from a relatively low level.

Figure 2: mineral fertiliser consumption by agriculture in the EU (million tonnes; 2010-2020)



Source: Eurostat

Figure 3: Nitrogen fertiliser consumption by agriculture in the EU (1000 tonnes, 2020)

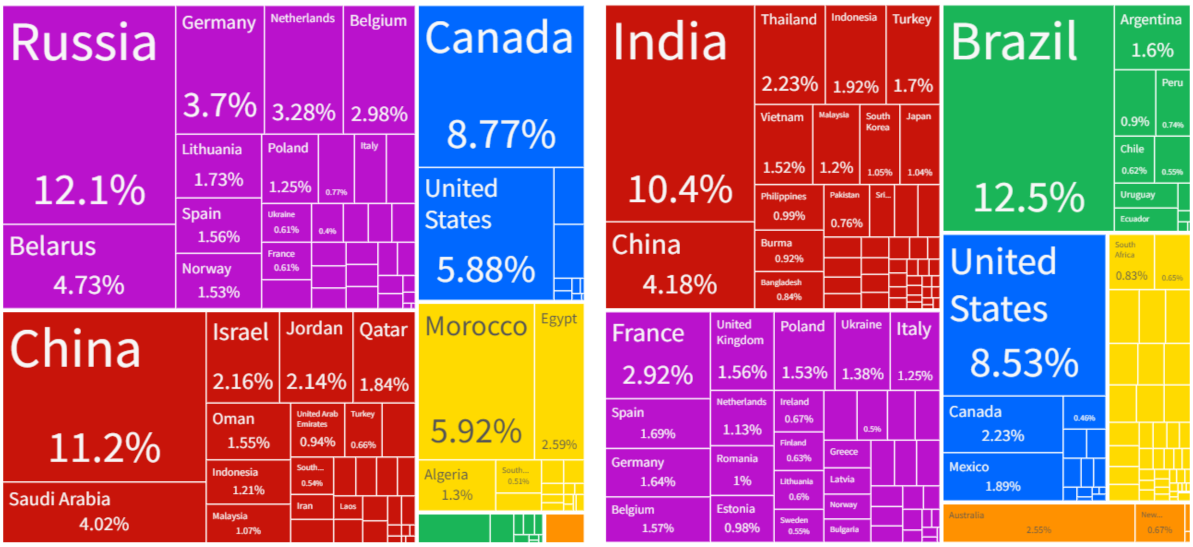


Source: author based on Eurostat data
Note: Countries marked as 0 correspond to non-available data

Looking specifically at trade flows and data, fertilisers are listed under code 31 in the Harmonized System (HS) with a number of ramifications such as for organic fertilizers (3101) or mineral/chemical fertilizers including nitrogenous 3102, phosphatic 3103, or potassic 3104[5]. In 2020, fertilisers were the world's 47th most traded product, with a total trade of $62.6 billion (bn).

The world top exporters are Russia ($7.6bn – 12.1%), China ($6.99bn – 11.2%), Canada ($5.49bn – 8,77%), Morocco ($3.71bn - 5,92%) and the United States ($3.68bn – 5,88%). The world top importers are Brazil ($7.82bn – 12,5%), India ($6.5bn – 10,4%), the United States ($5.34bn – 8,53%), China ($2.62bn – 4,18%) and France ($1.83bn – 2,92%)[6].

Figure 4 - Exporters (left) and Importers (right) of fertilisers (2020)



Source: the Observatory of Economic Complexity (OEC).

[5] European Custom Portal – Custom tariff number (2022). Link.
[6] The Observatory of Economic Complexity (OEC). Link.

EU countries also import products such as ammonia and urea for their domestic production of nitrogen fertilisers, aiming to diversify their sources of inputs and to improve their resilience to external shocks. These efforts were accelerated in recent months due to the current geopolitical context.

Impact of the Russian invasion of Ukraine

Russia had been trying to contain high food inflation at home since 2021 mostly through export restricting measures. Moscow introduced quotas for exports of nitrogen fertilisers in November 2021 in an attempt to prevent shortage on the domestic market and increased costs of food for the consumers caused by the surge in global gas prices on the prices of these fertilisers. These quotas originally set for 6 months were extended in May 2022 to last at least until the end of the year. As the world's biggest exporter of fertilizers, the restriction measures reduced fertilizer supplies and severely impacted food prices all over the world.

This situation worsened much further after the invasion of Ukraine in February 2022 which not only delt a new significant blow to Russian fertilisers exports but most importantly created a surge in energy prices, most notably of gas prices which is an essential part of the production process of fertilisers. This makes the prices of these two supplies highly corelated. The combination of both shocks sent fertilisers prices on a steep upward trajectory to levels which had not been seen since the crisis of 2008 and the subsequent food riots in many food importing countries in sub-Saharan Africa.

Figure 5: Prices of fertilisers, food & energy (2000-2022; nominal US dollar; 2010=100)

Source: FAO 2022 Food Outlook – Biannual Report on Global Food Markets. Link.

Such a price spike is also proving detrimental for the EU, which imports close to a third of its fertiliser imports from Russia ($1.28bn out of $4.6bn in 2020, $2.11bn out of $7.21bn in 2021)[7] for its food production processes. This trend fell apart in 2022 and the war in Ukraine even though fertiliser imports remained possible under the EU sanctions regime[8]. The EU was expected to import 2.3 million tonnes of fertilisers from Russia in 2022 but is now expected to effectively import only 0.7 million tonnes or only 30% of the previously expected amount[9].

The EU has been attempting to replace these direct imports of nitrogen fertilisers by domestic production through lower tariffs and enlarged geographical scope of non-preferential origins (currently concentrated on Russia) for urea and ammonia[10]. The aim was, as stated above, to increase and diversify the EU imports of these products to support domestic fertilisers production. Yet these efforts may prove difficult still, due to the steep increase of gas prices and their importance in the fertiliser industry's production costs. Such high costs led to many reports of European fertiliser producers effectively limiting or even halting their production in the summer of 2022, thereby hampering the EU domestic production capacities of fertilisers.

The situation remains highly volatile today and it is unclear what the next short terms evolutions will be, yet, based on the past trends and expected policy measures to be put in place in the EU, this briefing aims to discuss some long-term tendencies for the fertilisers sector in the EU, and in particular on the implications of the proposed reduction of fertiliser use in the agriculture sector set forth by the EU in the F2F strategy. This will have potential positive and negative spillovers which are considered both with regard to the environment and socio-economic impacts, and both within and outside the EU.

2. Environmental and social impacts of material flows in the EU fertilisers sector

The uptake of synthetic fertiliser use globally after the second world war boosted crop productivity and the current consensus estimates at **40-50 percent of the population to be fed based on their use** (Stewart et al. 2005).

However this excessive use led to losses (or run-off) of these nutrients from farmlands to the environment, creating unbalances of nutrients and causing GHG emissions as well as "multiple severe impacts on ecosystems and human health through tropospheric air pollution, stratospheric ozone depletion, greenhouse gas emission, groundwater pollution, freshwater and coastal marine eutrophication, as well as loss of aquatic and terrestrial biodiversity" (Sutton et al. 2011).

[7] UN Comtrade database. Link.
[8] Council Regulation (EU) 833/2014 - Article 3a.
[9] FAO - Trade tracker for Nitrogen, Phosphorous and Potassium fertilizer. Link. Note: The "normal volume" is defined as a trade level that would take place in the absence of the factors that have contributed to the currently tight market situation (e.g. soaring prices of food, energy, and fertilizer).
[10] COM(2022)359 - Proposal for a Council regulation amending Annex I to Regulation (EEC) No 2658/87 on the tariff and statistical nomenclature and on the Common Customs Tariff. Link.

Environmental and social impacts upstream

Nitrogen fertilisers are synthesised through the so-called Haber-Bosch process which combines nitrogen and hydrogen to produce ammonia gas (NH_3), the foundation for all N fertilisers. Hydrogen is commonly sourced from methane in a Steam Methane Reforming (SMR) process which releases carbon dioxide while the Haber-Bosch process itself requires a significant amount of electricity to be powered. The **production of ammonia and eventually of nitrogen fertilisers is fraught with GHG emitting operations**. The Haber-Bosch accounts for 1.4% of global carbon dioxide emissions (M. Capdevila-Cortada, 2019), about 1% of the world's total energy production - while around 40% of the required energy is lost in the process and consumes a lot of water as it takes 9 litres of water to produce 1 kg of hydrogen[11].

Barreiro-Hurle et al. (2021) also point to the significant **carbon leakage** induced in the overall agriculture sector (including fertilisers) with as much as 50 to 70% (depending on the way CAP and F2F are implemented) of all GHG emissions reduction in the EU to be offset by emission increases in the rest of the world.

Environmental and social impacts downstream

While acknowledging the massive impact of fertilisers on allowing food production to keep pace with the population growth over the past decades, numerous studies demonstrate their **detrimental environmental impacts** such as nitrate pollution, resources depletion, acidification and eutrophication (Hasler, 2017).

A number of studies also indicate that **chemical fertilizers cause both acute and long-term health impacts**. Excessive and inefficient use of fertilisers can lead to adverse impacts such as drinking water contamination and eutrophication of freshwater systems and coastal zones. This eventually brought the EU to list nitrates and phosphates as pollutants in its Water Framework Directive. Some fertilizers also impact human lives as a result of unsafe storage practices (UNEP 2022).

Fertilisers, energy and food prices are extremely correlated (see figure 6) and worldwide surges in these commodity prices produced strong tensions in food insecure countries to the point of **food riots** such as in at least 14 countries of Africa in 2008 (Berazneva and Lee, 2013). Although other factors such as levels of poverty, urbanization, climate events, oppressive regimes and/or stronger civil societies play a role in the form that social tensions can take, restricted access to and availability of food remains the key factor.

3. EU policy framework to address fertilisers use

The original legal corpus of the European Union on fertilisers (Nitrates & Water Framework Directives) marked an inclination to approach the use of fertilisers in the EU "only" as a soil pollution issue i.e. as a contributing factor to losses of nitrate and phosphate from agricultural soils into ground and surface water bodies. The EU later on addressed fertilisers as a strategic material which access, either through domestic production or imports should

[11] Heinrich-Böll-Stiftung (Feb 2022) - Green hydrogen from Morocco; no magic bullet for Europe's climate neutrality. Link.

be secured. This tendency was personified by a dedicated initiative to regulate (ensure) the availability of fertilising products on the EU market in 2019.

The Farm to Fork Strategy (F2F) demonstrated a shift from the EU toward more targe approach on fertilisers use and their broader environmental and health impacts. The F2F strategy sits at the heart of the Green Deal as it addresses the challenges of sustainable food systems and recognises the inextricable links between healthy people, healthy societies, and a healthy planet[12]. It includes a number of relevant initiatives such as animal welfare, sustainable use of pesticides or nutrition labelling and paves the way for a proposal for a legislative framework for sustainable food systems to be published by the end of 2023[13].

Box 2 – The EU legislative landscape.

- The Nitrates Directive (1991)[14] and the Water Framework Directive (2000)[15] aim to limit nutrient losses through appropriate agricultural land management including the reduction of nutrient application or proper handling of fertilisers. Additionally, initiatives such as Natura 2000, the Birds Directive and the Habitats Directive also include measures to reduce the use of pesticides and fertilisers to ensure biological diversity through the conservation of natural habitats within the EU.
- The Urban Waste Water Treatment Directive (1991)[16] aims to protect the environment from the adverse effects of discharges of both urban waste water from settlement areas and biodegradable industrial waste water from food industries. It is currently under revision offering opportunities to foster nutrients circularity.
- The Ambient Air Quality Directive (2008)[17] and National Emissions Ceiling Directive (2016)[18] set limits for air pollution and national reduction commitments by 2030 to EU Member States for five pollutants including nitrogen oxides and ammonia as responsible for acidification, eutrophication and ground-level ozone pollution.
- The Effort Sharing Regulation (2018)[19] governs emissions linked to agricultural activities such as nitrous oxide emissions from fertiliser use and sets legally binding annual emissions targets for Member States although agriculture emissions have been so far largely left unaddressed (European Environmental Bureau, 2021).
- Regulation 1009 laying down rules on the making available on the market of EU fertilising products (2019)[20] while regulating on safety, quality and labelling requirements.
- The EU Circular Economy Action Plan (March 2020)[21] aims to make food and water pro-

[12] A Farm to Fork Strategy. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions; European Commission: Brussels, Belgium, 2020. Link.
[13] https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy/legislative-framework_en
[14] Directive 91/676/EEC. Link.
[15] Directive 2000/60/EC. Link.
[16] Council Directive 91/271/EEC. Link.
[17] Directive 2008/50/EC. Link.
[18] Directive (EU) 2016/2284. Link.
[19] Regulation (EU) 2018/842. Link.
[20] Regulation (EU) 2019/1009). Link.
[21] EU Circular economy action plan. Link.

duction, consumption, and waste more circular through notably:

  - Encouraging circular approaches to water reuse in agriculture through a new Water Reuse Regulation.
  - Developing an Integrated Nutrient Management Plan to ensure more sustainable application of nutrients and stimulate the markets for recovered nutrients.

- The Farm to Fork Strategy (F2F, May 2020) aims to drastically reducing Nitrogen pollution in the EU by 2030 by:

  - Decreasing nutrient losses by at least 50% (without deterioration of soil fertility).
  - Reducing fertiliser use by at least 20%.
  - Increasing the total farmland under organic farming by up to 25%.

- The Carbon Border Adjustment Mechanism (CBAM, proposal published in July 2021) which covers fertilisers. At the global level, the application of mineral nitrogen fertilisers by agriculture is also one of the items to be reported by countries as part of their annual emission inventories report under the United Nations Framework Convention on Climate Change (UNFCCC).

The most substantial step forward taken by the EU towards the transition to a European circular economy by adopting the new Circular Economy Action Plan in March 2020. The Action Plan paves a pathway to European circularity by targeting key value chains with great potential for circularity yet fails to adequately address circular bioeconomy. The CEAP does recognise that "the circular economy can significantly reduce the negative impacts of resource extraction and use on the environment and contribute to restoring biodiversity and natural capital in Europe". Yet the CEAP refers simply to the implementation of the 2012 Bioeconomy Strategy[22] which tend to focus on specific innovation techniques for agricultural productivity rather than promoting the application of a circular lens in the bioeconomy.

Innovations such as 'biotechnology' or 'bioresource' concepts include strong advocacy on the potential of digitalisation on natural resources production and extraction (Dieken et al. 2021) but can have negative effect on biodiversity levels by putting too much emphasis on intensive production processes such as monocultures. They are likely insufficient to address the multiple socio-ecological challenges of the sector, such as high social inequalities, while succeeding in limiting trends such as deforestation or biodiversity loss (El-Chichakli et al. 2016), thus the need for stronger circular bioeconomy concepts and approaches[23].

Supporting these new efforts to consolidate further the EU holistic approach on fertilisers, the European Commission released in July 2021 its proposal to set up a Carbon Border Adjustment Mechanism (CBAM) to prevent the risk of carbon leakage, including for the fertiliser sector. The initiative aims to align the price of carbon between domestic products and imports thus removing this incentive for EU companies to relocate production outside of

[22] COM (2012). A sustainable bioeconomy for Europe - Strengthening the connection between economy, society and the environment : updated bioeconomy strategy. Link.

[23] For additional recommendations on EU circular bioeconomy strategies, cf Sitra report "Tackling root causes – Halting biodiversity loss through the circular economy (2022). Link.

the EU. This could prove significant for the sector since the price of EU imports of carbon intensive fertilisers is likely to increase under the new system.

Last but not least, and building upon these past experiences and the current trend of a more holistic approach on fertilisers, the EU also plans to submit in 2023 an **Integrated Nutrient Management Plan (INMAP) as part of the CEAP** to ensure more sustainable application of nutrients and stimulate the markets for recovered nutrients.

4. Prospective positive spillovers

	Inside EU	Outside EU
Social	• Lower input costs and higher prices for producers. • Healthier diets for consumers. • Lower dependency on critical raw materials.	• Access to food? • Socio-economic opportunities for green ammonia export to the EU.
Environmental	• Reduction of greenhouse gases emissions and nitrogen pollution levels • Develop sustainable circular bioeconomy and agriculture. • Develop clean hydrogen value chains for carbon free ammonia.	• Incentive to shift away from emission intensive and/or polluting production to keep up with EU demand. • Circular approaches to address fertiliser waste.

The transition toward sustainable food system will be challenging for the EU agrifood sector, yet the EU CAP, F2F and biodiversity targets can be met, even if it may involve trade-offs in terms of production levels and leakage.

Barreiro-Hurle et al., 2021, simulated the implications of an ambitious implementation of the CAP reform proposals including four quantitative targets put forward in the F2F, notably on the targeted 20% reduction of pesticide and fertilizer use, but considering also the removal of 10% of agricultural land from production, and an increased share of organic farming[24]. The results show significant environmental benefits in the form of a **30% reduction of greenhouse gases and ammonia emissions** (against only 20% under a simulated continuation of the CAP 2014-2020) as well as a decrease in gross nutrient surplus. The model also predicts reduced agricultural production (10–20%) and exports but combined with increased agricultural prices and imports which is eventually beneficial for farm incomes but more problematic for consumers.

Prior IEEP work (Lórant and Allen, 2019) as well as other non-economic studies (Poux and Aubert, 2018) aimed to simulate the evolutions of in EU food and land systems in the EU under an even greater sustainability paradigm and their findings are even more positive. They explored the possibility of a transition towards an "EU-wide agroecological project based on

[24] Ibid.

the phasing-out of pesticides and synthetic fertilisers, the redeployment of extensive grasslands and landscape infrastructures, the reduction of non-food uses of biomass, and the adoption of healthier diets". This study forecasted an even steeper decline in EU agricultural production (-40% for livestock products) but argue that **this level of production would still be enough to meet the European demand for food in 2050 thanks mostly to dietary shifts and GHG emissions reduction coming from the reduction of nitrogen use**.

Another key to address inefficiencies in the nutrient cycle is moving to a **more circular nutrient economy**. Currently, only 20% of mined phosphorus ends up on the plate and even less of nitrogen, while globally, a third of produced food is lost or wasted, representing a quarter of the fertiliser used[25]. Staggeringly, it is estimated that between half and two-third of the nutrients we apply is not absorbed by crops and eventually runs off into the natural environment, causing major imbalances in ecosystems and pollution as well as affecting biodiversity (West et al. 2014; Lassaletta et al. 2014). The reduction of fertilisers use would have a direct impact on **reducing such pollution levels**.

One key objective to address this is to ensure that wasted nutrients are recuperated from waste streams, such as manure, food waste or sewage sludge, and recycled into a usable form once again (Vaneeckhaute et al. 2018). The transition from a fossil-based to a bio-based economy will require the recovery of nutrients from waste streams which includes the substitution of mineral fertilizers with bio-based alternatives. The usual treatment of wastewater for instance essentially transforms active nitrogen back into nitrogen gas which is a highly energy intensive process. Vaneeckhaute instead argues for the use of anaerobic digesters to break down the waste into solid and liquid fractions which can be treated further and used respectively as organic and mineral fertilisers. Such a circular process could be especially important for phosphorus fertilisers as extracted from a non-renewable, scarce, resource. The revision of the Urban Wastewater Treatment Directive offers an opportunity to decrease untreated wastewater discharges, put in place stricter nutrient emission limits and promote reuse of nutrients.

Other sustainable, circular farming approaches can include no-till practices, cover crops or rotational grazing. Cover crops for instance can build up soil organic matter content thus limiting the need to use fertilisers while decreasing soil erosion. Nouri et al. (2022) confirm that the use of cover crops reduces the amount of nitrate leached out of the soil by nearly 70% as compared to fields left to fallow.

Meanwhile, the debate on the **social, economic and environmental impact of shifting from chemical to organic fertilisers** is ongoing with studies debating issues such as crop yields, amount of land used for farming or emissions levels for both approaches. Clark and Tilman (2017) for instance found through a meta-analysis covering nearly 750 agricultural systems, that organic farming required more land than did conventional farming, while both had similar greenhouse gas emissions overall. Yet, Walling and Vaneeckhaute (2020) confirm that the adequate measurement of relative emissions intensities of organic and mineral fertilisers is not yet settled. Authors argue that calculation should either consider the whole life cycle of production or be done on a case-by-case basis where possible. This makes it difficult to point toward specific recommendations on the matter.

[25] EEB input to the roadmap consultation for the integrated nutrient action plan. Link.

Indeed, and regarding the **lower dependency to critical Raw Materials**, food production has become highly dependent on mineral P fertilisers as agriculture represents 80 % of phosphorus use[26]. The main source of P in the world is phosphate rock - a non-renewable resource – and of which the majority of reserves in the world are concentrated in a few countries, none of them EU Member States. This is making the EU highly dependent on imports and phosphate rock is on the list of critical raw materials for the EU. It means that phosphate rock is a high supply-risk and of a high economic importance.

This transition also provides an opportunity for the **production of "green" hydrogen, combined with renewables energy for carbon free ammonia.** That would imply for instance to rely on electrolysis instead of the SMR process to extract hydrogen, while the Haber-Bosch process could be powered by renewable electricity, thus synthesising "green" ammonia. This could potentially support the EU climate effort while offering socio-economic opportunities to third countries developing their export capacities in the sector. Yet, significant challenges remain for the profitability of the sector such as high production costs, poor energy conversion rate. Moreover, even "green" ammonia cannot be regarded as a 'greenhouse gas-free' or environmentally benign energy source since its combustion leads to emissions of nitrous oxide, a greenhouse gas.

Nonetheless, countries such as Morocco are firmly set on the objective to reap the potential socio-economic opportunities for **green ammonia export to the EU**, even if the path remains arduous. The country undertook major efforts in the past years to develop a progressive climate and energy policy. In 2020, the country reached a 40% renewables capacity in energy generation, although only 20% are actually produced, and expects to reach 52% by 2030[27]. The production of green hydrogen is a key aspect of that strategy as the country intends to benefit from its potential to generate large quantities of solar energy to power not only the Haber-Bosch process but also desalinisation capacities to provide the necessary amount of water also.

Such an ambition to create a more diverse electricity market carries the potential to benefit households, communities and private enterprises through lower, sustainable energy sources combined with export opportunities. Yet, several major challenges remain as Morocco does not currently produce nearly enough electricity from renewable sources than is needed. The current, centralised system depends mainly on two public bodies[28] and fundings from external donors (mainly from the EU or EU Member States) and so far brings little social or economic gains to the population. The development of the Moroccan electricity market (including perhaps some degree of liberalisation) will need to be done in such as way as it builds on its renewables potential to bring social and economic benefit to the population.

[26] Eurostat. Link.

[27] Heinrich-Böll-Stiftung (Feb 2022). Ibid.

[28] These are the National Office of Electricity and Drinking Water (ONE) and the Moroccan Agency for Sustainable Energy (MASEN).

5. Prospective negative spillovers

	Inside EU	Outside EU
Social	• Lower productivity of the agriculture sector • Higher food price for consumers. • Domestic fertiliser production capacities	• Health issues due to increased fertilisers use and storage • Impact on fertilisers production and export capacities.
Environmental	• Health issues due to fertilisers use	• Carbon leakage

The study from Barreiro-Hurle et al., 2021 concludes toward reduced agricultural production and exports combined with increased agricultural prices and imports, domestically and internationally. Despite clear environmental gains, the benefits for farmers brought by lower input costs and higher prices are more than offset by the lower productivity of the sector, in addition to increasing food prices for consumers. The model eventually predicts that EU farms incomes will be **impacted negatively**. Yet, the authors also stress that this negative socio-economic impact varies across sectors and can be mitigated through an ambitious CAP and F2F implementation.

We mentioned in section 2 that **inefficient use and in particular unsafe storage practices of fertilisers can severely impact human lives**. An uptake of fertilisers use in developing countries, particularly in zones with limited capacities to adequately use (or store) them, would result in increased exposure to such detrimental impacts.

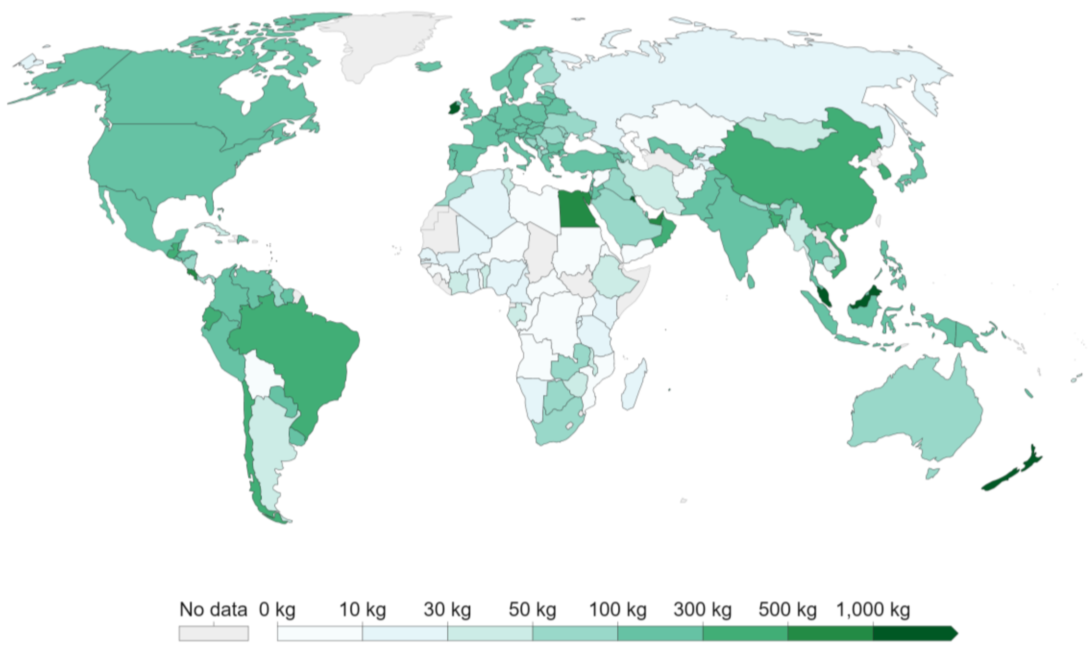
In terms of **carbon leakage**, it is estimated that 70% of EU agriculture emissions reduction could be substituted by emission increases in the rest of the world under the CAP 2014-2020 situation (Barreiro-Hurle et al., 2021). This rate falls to around 50% in a scenario where the EU implements an ambitious CAP, F2F and Biodiversity strategy. Carbon leakage could also be further reduced through dietary changes including lower demand for meats as well as reduced food waste thus limiting the need for imports to substitute the reduced domestic production. Furthermore, this scenario convers the EU alone and the authors note that incorporating international climate agreements to the analysis would also reduce the leakage and negative impacts for the EU.

Beyond carbon leakages, the impact on third countries of a reduced EU demand for fertilisers must be a nuanced one. The EU's limitation and circularity objectives are combined with strong push to **improve resilience in food insecure countries notably through increased fertilisers use**. There are 100-fold differences in how much fertilisers are used across the world (See Figure 6 below). In many of the world's poorest countries – particularly across Sub-Saharan Africa – farmers apply only a few kilograms of fertilizer per hectare.

As we saw above, cutting fertilisers use in most major agricultural producers such as the EU would bring major environmental improvements with no significant socio-economic consequences. However, in many poorer countries more fertilisers could be used for improvements in crop yields and better access to food for the population. This increased crop yield achieved through the use of fertilisers in food insecure countries could improve their resilience to external shocks such as food prices spikes on which they have zero control.

This could also have positive environmental consequences as less land would be needed for agriculture, thus improving our global capacities to build carbon sinks, while efforts could be made to limit nutrient loss from the start.

Figure 6 - Fertilizer use (Kg / ha of cropland, 2018)



Source: UN Food and Agricultural Organisation (FAO); Our world in Data. Link.

This idea of **facilitating access to affordable fertilisers** in developing nations has been widely advocated at the global level, and notably since the Russian invasion of Ukraine in February 2022. France announced for instance in the margin of the United Nations General Assembly of September 2022 that its Food and Agriculture Resilience Mission (FARM) set up in March 2022 to address food insecurity as a response the Russian invasion of Ukraine would get a dedicated pillar on fertilisers and be renamed FFARM. This new pillar includes initiatives such as collective purchasing to get access to fertilisers at a cheaper price, or on improving local fertiliser production in Africa. The geopolitical context also brought the EU to reallocate its cooperation funds towards food relief. The European Commission announced in June 2022 a new support of 350 million euros to "support investments in sustainable production to underpin more resilient food systems"[29], mostly in sub-Saharan Africa. The stated aim of this financial envelope is to overcome the continent's high food import dependency notably through the strengthening of the continent's own fertiliser industry.

While the stated objective of such initiatives to facilitate access to food and improve resilience in Africa is hardly arguable, **food security support for the continent should not be about "more fertilizers at all costs"**, since many countries do not have the capacities to

[29] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_3889

adequately use/spread them, which could eventually turn out counterproductive and even detrimental for soil fertility. Indeed, the key to achieve reduction of nutrients loss is being more precise about fertiliser application – making sure that fertiliser is being applied at the right time, in the right quantity and in the right manner (Sutton and al., 2021). This can be achieved thanks to approaches such as precision farming which allows farmers to see exactly where fertilizers are needed the most in a given field, or simply through favouring crops that facilitate 'biological fixation' (such as legumes) when possible. This eventually greatly limits any run-off of nutrients in the environment (Mueller and al. 2012). Most developing nations have limited or no access to such technologies and/or advanced approaches.

Instead, adaptation options for African food systems include investments in research, development and **deployment of sustainable land management based on agroecology and implementing nature-based solutions**. The latest advancements in technology, research and digital innovation could allow for leapfrogging towards a climate-smart and green transformation in the agricultural sector. (Knaepen, 2022; Ijjasz-Vasquez and al. 2021; Sulser and al. 2021).

6. Policy recommendations for a socially- and environmentally-just circular transition

These recommendations are destined to support the EU Members States to further develop sustainable, fertilisers free, food industries to cover the national and regional needs and ensure resilience of the sector in the long-term.

- Implement fully the F2F Strategy including its fertilisers-related objectives (decreasing nutrient losses, reducing fertiliser use, increasing up the total farmland under organic farming) through relevant policy packages such as the upcoming proposal for sustainable food systems. This is projected to bring substantial environmental gains both in terms of GHG emission reduction as well as a decrease of nutrient surplus.

- Promote nutrient circularity, for instance, through the current revision of the Urban Wastewater Treatment Directive. This offers an opportunity to decrease untreated wastewater discharges, put in place stricter nutrient emission limits and promote reuse of nutrients.

- The actions promoted by the INMAP toward reducing the amount of nitrogen in the environment should take into account the objectives set forth in the National Emission Ceilings Directive (NECD) and Ambient Air Quality Directives for ammonia emissions which mostly originate from the agricultural sector.

- Deployment of sustainable land management based on agroecology and implementing nature-based solutions in Europe and in third countries such as no-till farming, cover crops or rotational grazing. The latest advancements in technology, research and digital innovation could support a climate-smart and green transformation in the agricultural sector.

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