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Over 80% of the European Union's Common Agricultural Policy supports emissions-intensive animal products

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The European Union's Common Agricultural Policy strongly influences the European Union's food system via agricultural subsidies. Linking global physical input–output datasets with public subsidy data reveals that current allocation favours animal-based foods, which uses 82% of the European Union's agricultural subsidies (38% directly and 44% for animal feed). Subsidy intensity (€ kg^{-1}) for animal-based foods approximately doubles after feed inclusion. The same animal-based foods are associated with 84% of embodied greenhouse gas emissions of EU food production while supplying 35% of EU calories and 65% of proteins.

The global food system is responsible for approximately one-third of greenhouse gas emissions[1], occupies half of global habitable land[2] and accounts for more than four-fifths of all water consumption[3]. Current global food emissions alone will probably preclude the 1.5 °C Paris Agreement target[4]. The food system is also vulnerable to the impacts of environmental and climate change, which include increasing temperatures and shifting precipitation patterns. More frequent and severe extreme weather events are already affecting food security[5], and additional European Union funds are already supporting farmers experiencing climate damages[6].

As a result, several studies have pointed out that a low-emission food system transition towards more plant-rich diets is urgently needed and may even result in greater food security[7–9]. Such a transition requires supportive market and policy instruments[10]. The EU's Common Agricultural Policy (CAP) could potentially be reconfigured as such. Currently, the CAP is composed of two pillars: Pillar I, which comprises to market management and income support (that is, direct payments), and Pillar II, which targets more diverse rural development. Direct payments constitute most of the CAP budget and are allocated based on utilized agricultural area, whereas other measures/schemes are earmarked for specific objectives and projects and are more diversified.

CAP payments represent the largest expense (~30%) of the total EU budget[11] (Supplementary Fig. 6 includes timeline). However, the CAP lacks long-term strategic planning for transforming agricultural systems and reducing emissions[12–14]. This is concerning in the face of global environmental targets required to keep within the 1.5 °C target, which requires net-zero emissions, eliminating reliance on fossil fuels and substantially reducing livestock farming within 20 years (ref. 15).

In contrast, the CAP supports high-emissions livestock farming through various mechanisms, including direct payments, commodity support for livestock products (for example, border tariffs) or explicit support linked to the production or consumption of livestock products (for example, coupled support, subsidies for investments and improvements on farms, EU School Milk Scheme)[16]. Whereas some investments are geared towards improving feed quality and traceability, the de facto subsidizing of livestock production may lead to animal-rich diets becoming artificially cheap, both monetarily and in unaccounted externalities, supporting unsustainable patterns of production and consumption[17,18].

Here we investigate how public funds support and promote animal agriculture by tracking how EU27 + UK (the 27 EU members in 2020 plus the United Kingdom) CAP subsidies flow across the global food supply chain. We use the physical-flow Food and Agriculture Biomass Input–Output (FABIO) database[19] coupled with EU CAP subsidies using the Farm Accountancy Data Network (FADN) Public Database[20] (Methods). We trace upstream subsidies embodied in products sold domestically, imported by other EU countries or exported to non-EU countries. For example, we account for subsidies allocated to animal feed production in France and then fed to cattle in the Netherlands, which is either consumed as beef domestically or exported. As such, we trace the CAP subsidy regime from producer to consumer for different products.

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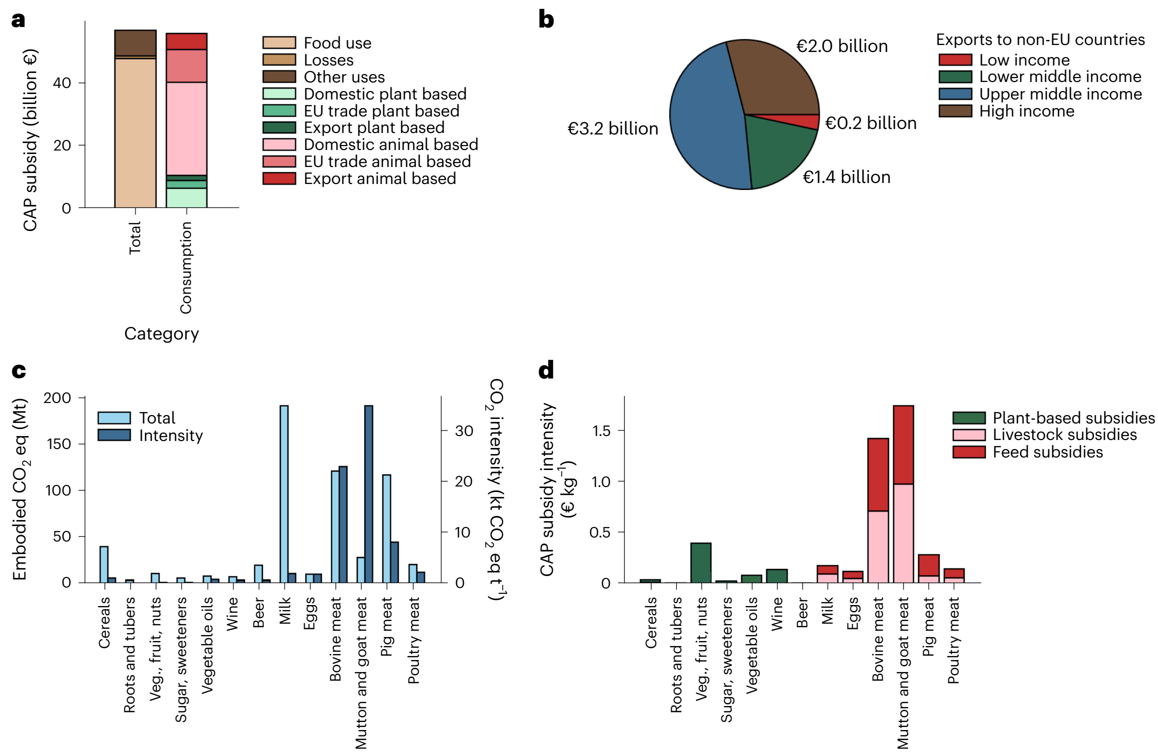

Fig. 1 | Overview of CAP subsides in the European Union in relation to food types, international exports, emissions and subsidy intensities. a, Total CAP budget (left bar) and total EU27 + UK domestic food consumption and trade by animal- and plant-based foods (right bar). **b**, Exports to non-EU countries by income level of the importing country. **c**, Embodied CO_2 equivalent (CO_2eq) (in global warming potential over 100 years (GWP100)) by food category in total (light blue, left axis) and per mass (dark blue, right axis). Veg., vegetables. **d**, Subsidy intensity of food categories in euro per kilogram of retail weight in 2013.

In 2013, the total CAP budget was €57 billion, of which 84% supported food for consumption by households, 1.5% was lost through agricultural losses and 14.5% supported other uses such as biofuels or fibres. We find that 63% of CAP subsidies were domestically consumed, 23% were traded within the European Union and 12%, or €6.8 billion, was exported to non-EU countries (Fig. 1a). The large majority, 75%, of these non-EU exports were destined for upper-middle and high-income countries, including China, Russia and the United States. As such, 12% of CAP subsidies do not support food security within the European Union, a key goal of the CAP (Fig. 1b), leading to distorted situations where China consumes more embodied CAP subsidy than the Netherlands (17% of total embodied subsidies in non-EU exports) or the United States more than Denmark (9%; Supplementary Fig. 5). Furthermore, subsidies embodied in domestic plant-based product consumption and those in exported animal-based products are similar, illustrating another example of distorted priorities (Fig. 1a).

Animal products supplied only 35% of calories and 65% of proteins consumed in the European Union. Yet the large majority, 82% of the CAP budget for food production, was spent on animal products, of which more than half (44%) was allocated to animal feed production (Fig. 1a). Our finding is higher than other estimates using OECD (Organisation for Economic Co-operation and Development) data, probably because OECD data omit some grazing and fodder crops[18,21]. Embodied subsidy amounts are highest for beef and milk, although there is variation among countries (Fig. 2). The proportion of subsidies for livestock production doubles for milk, beef, mutton and goat meat once subsidies in embodied animal feed are included. For example, subsidies embodied in beef increase from €0.71 kg^{-1} to €1.42 kg^{-1} once feed is included, and in poultry it increases from €0.06 kg^{-1} to €0.15 kg^{-1}. It triples for pig meat (€0.07 kg^{-1} to €0.28; Fig. 1d provides subsidy per retail weight of different products).

Nearly all European countries use notable more arable land than that available at the national level (that is, total land area required to produce food for national consumption is larger than the land area allocated for food production within the same country; Fig. 2). Whereas food trade remains indispensable for many of these countries in safeguarding food security[22,23], questions arise concerning the appropriateness of exporting agricultural subsidies, which have been specifically targeted to improve food security within the European Union, to non-EU countries. It could be argued that food security here simply implies farmer support, which would mean the indirect subsidizing of exports and circumventing the World Trade Organization's agreement for explicit export subsidies[24]. EU trade in embodied subsidies is more than twice as large as non-EU trade, with substantial variation among countries. Most EU countries with large agricultural outputs export more subsidies than they import (Fig. 2). For instance, Denmark, Finland and France are relatively large exporters to non-EU countries, primarily for high value-added food commodities such as milk products, pig meat and wine (Fig. 2 shows largest countries and Supplementary Figs. 1–4 shows all other countries and per capita results). These trade patterns of subsidized EU products can have a distorting influence on world agricultural markets as the European Union's exports may lower world's food prices in some cases, weakening domestic agricultural markets[25].

Previous research has shown that global agricultural support channels heavily towards emissions-intensive food commodities, which harms planetary health and hinders the production and consumption of lower-impact foods such as fruits, vegetables and nuts[26,27]. In the European Union, products with the highest environmental impacts are heavily supported via CAP subsidies (Fig. 1). Although not a policy intent, animal-based commodities represent 84% of the embodied greenhouse gas emissions from EU agriculture (Fig. 1c; all commodities, including non-foods, are included in Supplementary

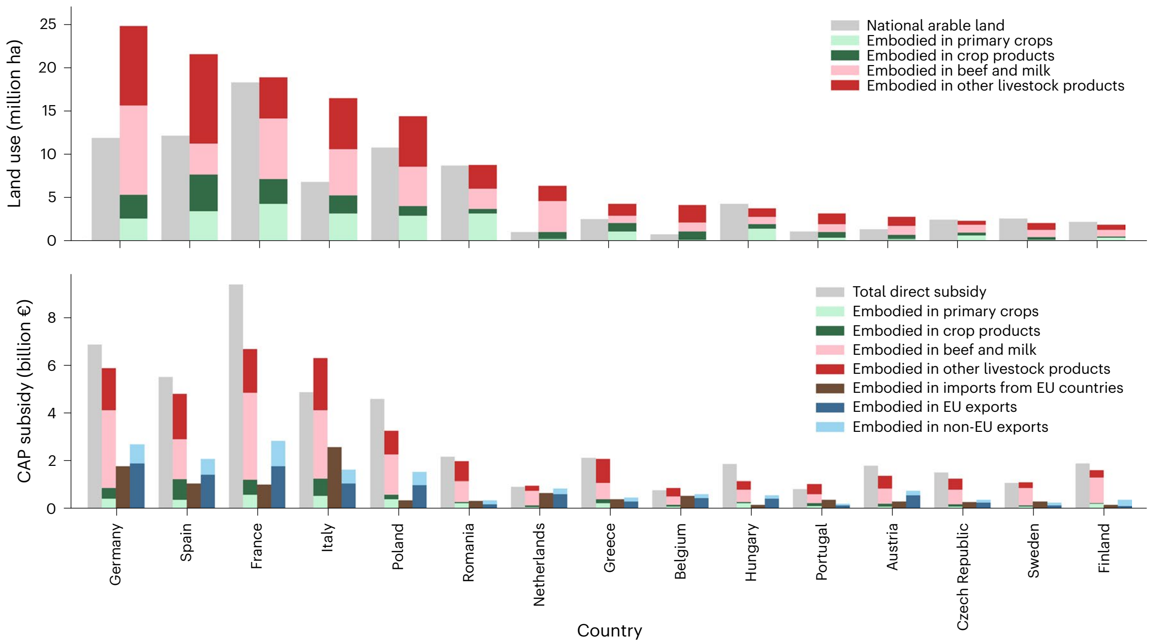

Fig. 2 | Arable land, embodied land use and subsidies for the top 15 land-consuming EU countries. Upper: land used for arable purposes[32] (cropland, meadows, pastures, gardens and fallow) within the country and embodied land use in country-level consumption of different agricultural products based on land-use extension of FABIO (Food and Agriculture Biomass Input–Output)[19]. Embodied land use represents the total land area used to supply current food consumption. Where embodied land use exceeds arable land, a country is relying on land in other countries to supply a portion of its total food consumed nationally. Lower: each bar shows (from left to right): (1) total direct CAP subsidies received, (2) embodied CAP subsidy in consumption of primary crops (for example, rice, wheat, fruits and vegetables), crop products (for example, sugar, vegetable oils and alcoholic beverages), beef and milk products and other livestock products, (3) CAP subsidies imported from other EU countries and (4) CAP subsidies exported to EU and non-EU countries in 2013. For example, Germany directly receives (bar 1) more subsidy than it consumes (bar 2), which is due to exports to other EU and non-EU countries (bar 4). Imports from other EU countries (bar 3) are part of Germany's subsidy consumption (bar 2).

Table 3). Because CAP is based primarily on land use, and animal products require large amounts of land both directly and indirectly via feed, it results in perverse outcomes for a food transition. Although the CAP does not designate animal-based commodities as desirable, by disproportionally supporting livestock farming, especially when accounting for animal feed subsidies, the CAP presents an economic disincentive for transitions towards more sustainable plant-based foods.

Despite some recent reductions in the total CAP budget, there are many opportunities for subsidy reform (Supplementary Fig. 6). The CAP holds the potential to steer the food system towards addressing environmental issues including climate change, biodiversity loss, disturbed nitrogen and phosphorus cycles, water and land degradation[16–18]. Understanding how subsidies can be redirected for beneficial outcomes first starts with mapping how subsidies flow through production to consumption[26]. We provide such a mapping for CAP subsidies, revealing several counterintuitive outcomes of the current regime and setting a foundation for future research into redesigning the CAP for environmental outcomes and food security.

Redesigning CAP policies to help support sustainable diets is urgent as current subsidies incentivize the acquisition of physical assets related to animal agriculture (for example, automatic milking machines), resulting in a physical and social lock-in. These assets may well be stranded and represent wasted capital investment[28]. Moreover, delaying action maintains current negative environmental impacts and can lead to decreased land-based response options due to climate change and other pressures, including the altered sink capacity for soil and vegetation carbon sequestration, reducing the potential of increased soil organic carbon storage[29].

Methods

We used the Food and Agriculture Biomass Input–Output (FABIO) database, which contains a global set of physical input–output tables covering the agriculture, food and forestry activities[19]. The global multi-regional input–output model allows for the tracking of socio-economic and environmental metrics throughout the entire supply chain, keeping a high level of product detail. FABIO covers 191 countries (n^r), 125 food commodities (n^s) and six final demand categories (n^y) for the years 1986–2013.

Subsidy data for 2013 were available for 14 farm types (n^f) (concordance table in Supplementary Table 1) for each EU member state[20]. We did not account for other international subsidies. Animal agriculture subsidies also include those in the Common Fishery Policy, but we only included land-based subsidies here. The overall negative picture in terms of animal-based subsidies would intensify if these were included given the high environmental impacts of fisheries, for example, in terms of greenhouse gas (GHG) emissions and eutrophication[30]. The n^f subsidy flows are proportionally allocated to the n^s commodities of FABIO using the total output of each commodity–region combination. We assume that all food items receive subsidy (about 90% of the agricultural land in the European Union receives subsidy), and overall, 99% of the subsidies are allocated. This 1% difference is probably due to the imperfect concordance between the farm and food classification systems of the different data sources. The subsidy data consist of annual surveys conducted by each EU member state, which in principle, represents the 4.9 million farms in the EU27 + UK in 2013.

We conducted a contribution analysis to assess the embodied impacts (that is, the impacts associated with all emissions and resources throughout the entire supply chain) across the global food supply chain: $R^C = \widehat{b'L}Y$, where $b'L$ is diagonalized and b' is a row vector. R^C yields the matrix ($n^r{*}n^s \times n^r$) of the embodied impacts of each commodity–region combination, b the vector of the direct subsidy intensities (€ t^{-1}) which is derived by dividing the vector e of subsidy flows by the total output x ($b' = e'\hat{x}^{-1}$), L the Leontief inverse is $(I - A)^{-1}$ where I is the identity matrix (diagonalized matrix of ones ($n^r{*}n^s$)), A the matrix of

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technical coefficients ($n^{r}*n^{s} \times n^{r}*n^{s}$) and Y the final demand matrix ($n^{r}*n^{s} \times n^{r}*n^{y}$). Full contribution analysis results are provided in Supplementary Table 2.

To analyse the impacts embodied in trade (that is, the impacts associated with all emissions and resources involved in international trade), domestic consumption was isolated from the Z ($A = Z\widehat{x^{-1}}$) and Y matrices (that is, the off diagonals were set to zero) after which the R^{C_dom} was calculated as $R^{C}\_dom = \widehat{b'L^{dom}}Y^{dom}$. The difference between R^{C} and R^{C}_dom represents the impacts embodied in trade, where the row sum yields the impacts embodied in imports and the column sum the impacts embodied in exports.

To analyse the environmental impacts, the land use and the GHG emissions extensions of FABIO were used. The GHG emissions extension (in GWP100) includes direct and indirect GHG emissions by commodity and the emissions associated with land-use change[9]. Conversion factors to translate the EU diets from weight to the number of calories or proteins were derived from FAO (Food and Agricultural Organization of the United Nation) food and balance sheets[31]. Data processing was carried out using Python version 3.8.8 and Rstudion version 2022.07.2.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

All data used in this study are available in open-access databases. The FABIO database is available via Zenodo (https://doi.org/10.5281/zenodo.2577066) and the Farm Accountancy Data Network (FADN) Public Database is available via the agridata platform of the European Commission (https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html). Source data are provided with this paper.

Code availability

Example code of the performed analyses is available on FABIO's GitHub (https://github.com/fineprint-global/fabio).

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Author contributions
All authors provided inputs in the final manuscript. A.J.K., J.M.M. and P.B. designed the study. A.J.K. collected the data and performed the analysis with help of J.M.M., P.B. and H.H. and A.J.K. led the writing with major contributions by P.B., J.M.M. and H.H.

Competing interests
The authors declare no competing interests.

Additional information
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Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	Data processing was carried out using Python version 3.8.8 and Rstudion version 2022.07.2
Data analysis	The data consists of an environmentally-extended multi-regional input-output analysis and were analyzed using standard input-output calculations, which are described in the methodology of the manuscript. The code used for this study is available upon request, however, example code of similar analysis is provided by the FABIO group on: https://github.com/fineprint-global/fabio

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FADNPublicDatabase/FADNPublicDatabase.html). The disaggregated source data for Fig. 1c-d is available in the Supplementary Information. Full MRIO table results for this study are available upon request. These can also be replicated using the public databases in combination with the information provided in the methods section and supplementary information.

Human research participants

Policy information about studies involving human research participants and Sex and Gender in Research.

Reporting on sex and gender	n/a
Population characteristics	n/a
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Ethics oversight	n/a

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Study description	The existing environmentally-extended multi-regional input-output database FABIO was further extended by integrating the economic extension of CAP subsidies for all EU+UK countries. The integration was achieved through a concordance table, which is available in the supplementary tables. Limitations of this integration are discussed in the methods of the manuscript. The integration allowed for tracing the CAP subsidy regime from producer to consumer for different products.
Research sample	n/a
Sampling strategy	n/a
Data collection	n/a
Timing and spatial scale	Year 2013 and global scale
Data exclusions	n/a
Reproducibility	n/a
Randomization	n/a
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