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Social footprint of European food production and consumption

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ABSTRACT

The transition towards more sustainable food systems is one of the great challenges at global level. While environmental considerations have been widely explored, the social sustainability of agri-food systems have been scarcely addressed in literature, especially regarding the externalization of impacts due to international trade. In this study, we apply Social Life Cycle Assessment (S-LCA) to address social sustainability considerations of food production and consumption, supporting the monitoring of progress towards the Sustainable Development Goals (SDGs). Building on the model of the Consumption Footprint developed by the EC-JRC to address environmental sustainability aspects, this paper presents a macro-scale assessment of social risk associated with the EU food consumption. In the context of operationalizing value chain assessment within SDGs, the analysis combines social indicators with production, trade and consumption data, allowing the evaluation of the social footprint of European food production and consumption. Selected social indicators and impact subcategories from those available in the Product Social Impact Life Cycle Assessment (PSILCA) database were employed to assess a process-based Life Cycle Inventory model of EU food consumption by means of 44 representative products selected for the EU Consumption Footprint indicators. The assessment included an evaluation of SDGs coverage by S-LCA indicators and a sensitivity analysis based on two different weighting schemes, which unveiled the need of a harmonized weighting approach. Unlike the environmental impacts, social hotspots emerge mainly in rice and fruit & vegetables categories. Hotspots are concentrated in India, Argentina, and other extra EU countries. These results suggest that trade-offs could emerge between the different sustainability pillars and that fair trade and responsible sourcing approaches should be guaranteed in order to promote sustainable food systems.

1. Introduction

The United Nations (UN) Agenda 2030 and its Sustainable Development Goals (SDGs) (UN General Assembly, 2015) offer a unique framework to assess the current European Union (EU) production and consumption system in a comprehensive manner, considering environmental, economic and social impacts simultaneously. The 2030 Agenda, its 17 goals, 169 targets and 231 indicators are a roadmap towards sustainability, globally recognized, a compass to guide coherent and integrated actions in Europe and all around the world. Since their definition, the European Commission has given a central role to SDGs (EC - European Commission, 2020b) (EC - European Commission, 2020b), mainstreaming sustainability into the entire policymaking process, especially in the impact assessment phase. The current Better Regulation Agenda requires to identify and assess all significant impacts, linking them to the 2030 Agenda (EC – European Commission, 2021). Regarding social sustainability aspects in the policy impact assessment, impacts on fundamental rights, on employment and on health should be considered. Moreover, social impacts occurring in developing countries should be regarded for what concerns, e.g. labour market, human rights, migration, poverty health systems, food security, gender equality, etc. Social considerations (like issues of inequality, inclusiveness, labour relations, investment in human capital and communities, as well as human rights issues) will be taken into account also in the context of the Sustainable Finance policy of the EU. Within the development of the EU taxonomy, i.e. a classification system establishing a list of sustainable economic activities, a dedicated expert group is working on the definition of social objectives and criteria (EU Platform on Sustainable Finance, 2022).

The operationalization of the SDGs in policy-making calls for the use of holistic and systematic approaches. At the EU level, the European Green Deal (EC - European Commission, 2019) is the new EU growth strategy seeking to transform the EU into a modern, resource-efficient and competitive economy and highlights the relevance of considering the entire value chain of products including the spill-over effects beyond the EU territory. In this context, Life Cycle Assessment (LCA) is considered more and more as pivotal to support the assessment of SDGs. More specifically, Life Cycle Sustainability Assessment (LCSA) may help operationalize the assessment of impacts on the SDGs along

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the supply chain of products. Besides environmental considerations, LCSA may support the assessment of the social dimension and unveiling potential social risks to tackle. For this purpose, a detailed analysis of the coverage of indicators used in social LCA against the goals and targets proposed in the UN Agenda is needed.

The integrated assessment of the social dimension of sustainability from a life cycle perspective is relying on the social LCA method (S-LCA). S-LCA aims at assessing the social impacts of products and services across their life cycle, e.g., from extraction of raw material to the end-of-life phase (UNEP, 2020). In the context of S-LCA, social impacts are consequences of positive or negative pressures on social areas of protection (i.e., well-being of stakeholders), while a social hotspot is defined as the location and/or activity in the life cycle where a social issue (negative impact or benefit) and/or social risk is likely to occur. S-LCA can be applied at micro- (product and/or company), meso- (economic sector or region), and macro- (country, state) levels. While micro-level studies require collection of primary and specific data, macro-scale assessments usually rely on specific databases such as the Product Social Impact Life Cycle Assessment (PSILCA) (Eisfeldt, 2017) and the Social Hotspot Database (Benoit-Norris et al., 2012). Compared to the LCA, the S-LCA methodology has a lower level of methodological maturity and implementation. While the 2020 Guidelines provided new guidance on the impact assessment phase, normalization and weighting still lack a common reference, e.g. in terms of normalization factors and a conventional weighting scheme, which are instead available in LCA (Crenna et al., 2019; Sala et al., 2018).

The Consumption Footprint indicator developed by the European Commission - Joint Research Centre (EC-JRC) (Sala and Sanyé Mengual, 2022; Sala et al., 2019; Sala and Castellani, 2019) aims at monitoring trends on SDG12 on responsible consumption and production regarding EU consumption. Contrary to other models, the Consumption Footprint follows a full bottom-up perspective leveraging on the process-based LCA of around 160 representative products and consumption statistics. By implementing the Environmental Footprint impact assessment method (EC-JRC, 2018), the Consumption Footprint evaluates 16 environmental impact categories. A detailed analysis of the coverage of SDGs by the Consumption Footprint revealed this is extended to multiple SDGs: primarily to SDG 12, but also to SDG 8 (with reference to decoupling economic growth to environmental impacts), SDG 9 (on industry, innovation and infrastructure), SDG 11 (on sustainable cities and communities). Additionally, the impact categories are linked to the goals addressing environmental aspects (SDG 6 on water, SDG 14 on marine resources, SDG 15 on terrestrial ecosystem) and human health (SDG 3). However, the socio-economic ones are only indirectly covered as determinant contextual elements of consumption patterns (Sanyé-Mengual and Sala, 2022). Therefore, further development is required to integrate social considerations and allow a more comprehensive understanding of the impacts and externalities due to EU consumption on social SDGs, particularly to understand the social hotspot and the relevance of different food products.

The Consumption Footprint embraces five areas of consumption: food, appliances, household goods, mobility and housing. Food has been highlighted as the one of those with the major role in environmental impacts. In 2018, food consumption represented around 45 % of the overall environmental impacts of EU consumption (as single weighted score) (Sala and Sanyé Mengual, 2022; EC - JRC, 2022). A consumption-based approach is necessary to address the social impacts of food supply chains by considering the embedded social impacts in imported food products, particularly in trade partners with lower sustainability standards, as observed for the environmental impacts (Sanyé-Mengual et al., 2019).

Additionally, at the EU level, the Farm to Fork Strategy (EC - European Commission, 2020a), at the core of the European Green Deal (EC - European Commission, 2019), aims to improve the sustainability of food systems while enhancing overall resilience thereof. This Strategy tackles food systems embracing a life cycle concept by outlining the role of supply chains. Furthermore, it promotes socially responsible food production and aims at addressing the social footprint of EU food consumption.

For these reasons, the paper focuses on operationalizing social LCA to support the assessment of SDGs and on assessing the social footprint of EU food consumption. For this purpose, the following specific objectives are pursued:

(a) Operationalizing the use of social LCA to assess and monitor SDGs, providing a mapping between SDGs at target level and indicators of the PSILCA database as well as a selection of indicators from those available in PSILCA;
(b) Assessing the social footprint of EU food production and consumption based on the Consumption Footprint – Food model, focusing on the contribution of products and partners in trade;
(c) Ranking individual food products based on their social footprint, including a comparison with environmental and biodiversity footprint rankings;
(d) Testing weighting approaches for PSILCA indicators towards obtaining a single weighted score.

The paper is organized as follows: Section 2 reviews the literature on the links between LCA and SDGs, on social sustainability assessment and guidance in the food sector and on macro-scale social assessments; Section 3 explains the methodology adopted to associate SDGs with S-LCA indicators, to select relevant indicators from those available in PSILCA and in the assessment of social risk of EU food consumption; Section 4 reports the results; Section 5 discusses the findings and the limitations of the study and the Section 6 presents the conclusions.

2. Literature review

The literature has explored and advanced in the linkage between LCSA and the SDGs. Several studies have linked LCA as an environmental impact assessment method to different SDGs (Sala, 2019; Sanyé-Mengual and Sala, 2022; Kørnøv et al., 2020), including the development of conceptual models (e.g., in relation to absolute measures of sustainability, Chandrakumar and McLaren, 2018) and the empirical test on case studies (e.g., Sala and Castellani, 2019). The project “Linking the UN Sustainable Development Goals to life cycle impact pathway frameworks” of the UN Life Cycle Initiative aims at providing a complete coverage of all SDGs, providing two different approaches: SDGs as further level of assessment and SDGs integrated in the impact pathway of the assessment (Weidema et al., 2020).

Concerning the role of food systems in achieving SDGs, the FAO developed a set of principles and actions aimed at transforming the agricultural and food sectors towards the objectives of the UN 2030 Agenda. Some of them focus on social aspects as for instance action 9 “Empower people and fight inequalities”, which suggest interventions to support smallholders, indigenous peoples, ensuring gender quality, access to land and decent rural employment (FAO, 2018).

From the corporate responsibility perspective, the OECD-FAO Guidance for Responsible Agricultural Supply Chains (OECD-FAO, 2016) was developed to help enterprises to observe existing standards on responsible business practices. This includes both environmental and social areas of risk arising along the agricultural supply chain, e.g. labour rights, human rights, health and safety, etc. The Global Reporting Initiative (GRI), a widespread independent sustainability standard setting institution, has developed a specific standard for the agriculture, aquaculture, and fishing sectors (GRI Global Reporting Initiative, 2022).

Regarding the current state of social sustainability assessment in food supply chains, Desiderio et al. (2021) provide a systematic review of the scientific and grey literature, detecting approaches, methods and indicators used to measure a variety of social aspects. It finds that the production stage of the supply chain is addressed with the highest number of quantitative indicators and tools, compared to the other phases. Farmers' job conditions and quality of life are the stakeholders and social aspects that are measured more frequently in the reviewed studies. Another review of the S-LCA studies in the agri-food sectors confirmed that workers and local communities are the most frequently assessed stakeholders (Tragnone et al., 2022).

Looking specifically at S-LCA studies on food products, our review of the literature found that a total of 46 S-LCA studies have been performed on specific food products. Sugar, palm oil, dairy products, wine and tomatoes have the higher number of S-LCA studies (The details of the literature review on S-LCA studies are in the Supplementary Information file SI1, Section 1). These studies undertake a bottom-up approach, thus focus on specific product/supply chains, using primary and/or secondary data or using specific food supply chain to test a new method. The results of these studies are usually highly specific for the system under investigation (in terms of geographical scale and socio-economic features of the system) and the upscaling potential is limited. Thus, they cannot be generalized and used to assess the overall social impacts at sector or country level.

Macro-scale analysis is instead looking at the functioning of the overall economy (at global or national scale). They usually apply input/output databases (Wiedmann and Lenzen, 2018) and integrate them with sustainability related information, which so far focused mainly on the environmental dimension (for instance in terms of biodiversity (Lenzen et al., 2012), carbon, water, land (Steen-Olsen et al., 2012), etc.). This type of study provides results with very low granularity, but, including the international trade, can capture the effect of consumption activities and reveal the externalization of impacts from regions consuming final products (e.g. developed countries) to resource-rich countries (e.g. developing countries). This type of study was also extended to the quantification of social aspects: Pelletier et al. (2016) assessed social risks associated with trade-based consumption in EU Member States, showing the importance of a life cycle-based approach and comparing a set of commodities consumed in the EU. From these results, food products show a high social risk per euro spent in each sector compared to other sectors and rice (processed and paddy) emerges as a social hotspot.

Other studies focused on the social footprint of global trade (Alsamawi et al., 2017b) or on specific aspects, e.g., “bad labour” footprint (Simas et al., 2014) inequality footprint (Alsamawi et al., 2017a) and slavery footprint (Shilling et al., 2021). Blackstone et al. (2021) analysed the risk of forced labour in the US fruit and vegetable supply finding that a broad set of fruit and vegetable commodities are at risk and revealing potential trade-offs across dimensions of food systems sustainability.

Macro-scale analyses with a bottom-up approach through process-based LCA, such as the Consumption Footprint model, have been so far limited to assess the environmental dimension of sustainability (Sala and Sanyé Mengual, 2022). In order to progress towards sustainability assessment, complementing this type of analysis with social risk assessment would allow addressing the renewed policy and business interest on social sustainability, taking into account the effect of international trade. In this regard, social LCA can be key to quantitatively assess the EU food system at the macro-scale level.

3. Methods

The method followed to develop the analysis is based on three main steps: i) mapping of SDGs with the indicators available in the PSILCA database; ii) selection of relevant indicators and impact subcategories; iii) assessment of social risk of the representative products included in the full bottom-up Consumption Footprint indicator – Food area of consumption.

The S-LCA database used for the assessment is the PSILCA (Product Social Impact Life Cycle Assessment) professional database v2 (Eisfeldt, 2017) (that was the latest version available when the analysis was started), composed by 87 indicators that measure social aspects in different categories of stakeholders. This database was selected because it offers a transparent documentation of the data sources to assess each indicator and a description of data quality for each data point. This allows to perform checks and validation on the social data used in the assessment and eventually compare them with alternative sources or more recent estimates.

3.1. Mapping PSILCA indicators to the SDGs framework

Mapping the indicators of the PSILCA database to the SDGs framework allows understanding how it relates to its goals and targets, as well as the current coverage by social LCA. The SDG mapping has been performed in two steps: firstly, looking in detail at each PSILCA indicator and linking them to the corresponding targets of the SDG framework; secondly, grouping the indicators at the level of stakeholder (social LCA category), impact category (social LCA subcategory) and SDG goal level. This allows deepening the analysis at the three different levels, depending on the type of aggregation needed on both social LCA and SDGs classifications.

Other studies have mapped PSILCA database generally at goal level (UNEP, 2020; Herrera Almanza and Corona, 2020), while in this case the analysis goes more in detail at target level, similarly to Wulf and colleagues (Wulf et al., 2018), who considered the SDG indicators to complete the mapping.

3.2. Selection of indicators from PSILCA

PSILCA is based on the combination of a multi-regional input/output database, i.e. Eora (Lenzen et al., 2013), with a database including statistics on the diverse social aspects covered in the indicators. Based on Eora, PSILCA contains an inventory of monetary exchanges for almost 15,000 industry sectors and commodities in 189 countries. Besides, it includes social indicators for each country-sector combination (country-specific sectors, CSS). Social indicators are structured according to the UNEP's social LCA framework (UNEP, 2020) including five stakeholders' categories and 23 impact subcategories (e.g. child labour, fair salary, etc.). A total of 87 indicators address negative impacts or social risks, apart from the indicator “contribution to economic development” that refers to a positive impact or a social opportunity.

Regarding the indicators, data on social risk are provided with a scale ranging from no/very low risk to very high risk. For each risk level, a characterization factor (CF) is assigned on an exponential scale expressing the risk level in terms of medium risk hours per worker hour.[1] This quantification allows the aggregation of various CSSs in the supply chain, using the so-called activity variable, i.e. worker hours. Worker hours represent the time needed to produce 1 USD output of the sector.

The social risk is attained by multiplying the activity variable (worker hours) by the CF of the given social indicator in the CSS and cumulated along the supply chain. Medium risk hours specify the observed indicator risk in worker hours related to its average (medium) risk to produce 1 USD output of the assessed sector.

Regarding social data in PSILCA, most sources used in the database are obtained from recognized official statistical agencies, such as International Labour Organization (ILOstat[2]) and World Bank,[3] and from other well-established public or private sources. The PSILCA database also offers a data quality evaluation for each data point, assessed based on its technical, temporal, completeness and geographical conformance, and for the data source reliability.

[1] Most commonly, CF very high risk = 100; CF high risk = 10; CF medium risk = 1; CF low risk and no data = 0.1; CF very low risk = 0.01.

[2] https://ilostat.ilo.org/.

[3] https://data.worldbank.org/.

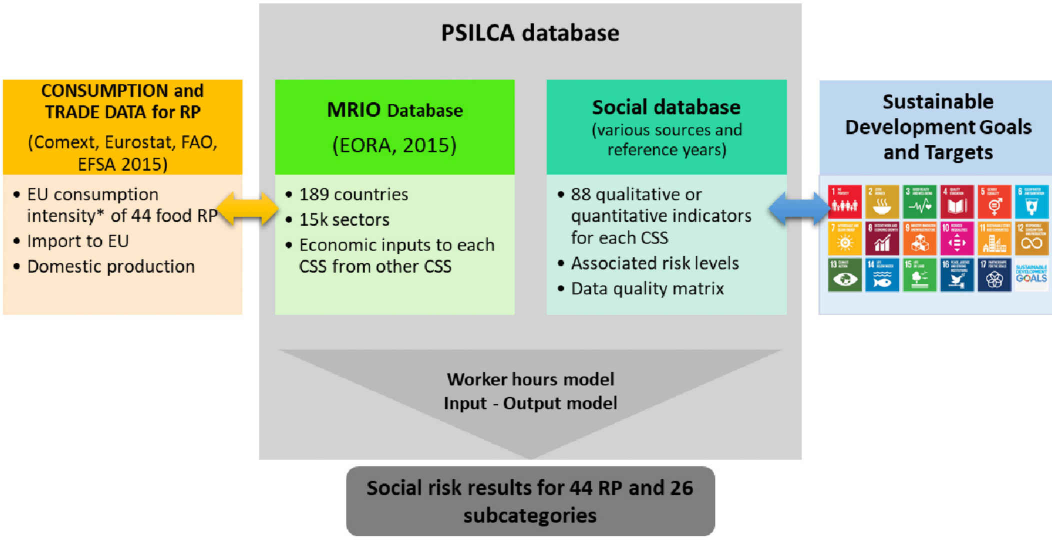

Fig. 1. Main building blocks of the model developed to assess the social footprint of the EU food consumption. (RP: representative product; CSS: country-specific sector; MRIO: Multi Regional Input-Output; PSILCA: Product Social Impact Life cycle Assessment). *consumption intensity refers to the apparent consumption of a certain product in a given year. *Apparent consumption = production + import − export.*

The selection of indicators and impact subcategories from those available in PSILCA followed these criteria (listed in detail in the SI1, Section 2.1):

- Environmental aspects: Exclusion of environmental aspects, which were already assessed with a LCA methodology in previous studies (Castellani et al., 2017).
- Local level: For some impact subcategories and indicators, data used in the assessment (as well as the input-output database and social data used in PSILCA) are only available at country level. These country averages are judged as not enough meaningful to detect social risk at local level (e.g. local employment or flow of migrant workers in a certain area due to specific production activities cannot be captured by the national level of employment or the country migration stock). As a result, such data are not meaningful to assess local impacts such as "local employment" and "migration", under the stakeholder category "local community". This aspect also applied to some indicators assessing environmental aspects.
- Data completeness and quality: The stakeholder category "Consumers" has only one indicator in the PSILCA v.2 database, referring to the presence of business practices deceptive or unfair to consumers. However, for several country-sector combination data are not available on this aspect and therefore it was excluded from the analysis. The impact subcategory "social responsibility along the supply chain" presents many data gaps and data quality is usually very low according to the database evaluation and therefore it was excluded from the analysis.

The implementation of these criteria led to the selected list of 14 impact sub-categories and 34 indicators, which is available in the SI1, Section 2.2.

For the sensitivity analysis, we tested two different weighing schemes based on policy relevance and data quality (information about the schemes are available in SI1, Section 5).

3.3. S-LCA implementation to the EU food production and consumption

Using PSILCA is possible to calculate the average social risk associated with an economic unit of output from a certain country-sector, taking into account all the risks related to upstream phases of the supply chain. In this study, this macro-scale assessment was applied to the Consumption Footprint – Food indicator, which models the EU food consumption based on the life cycle of representative products. This indicator includes 44 representative products that were selected based on their consumption intensity (EUROSTAT, 2021a, 2021b). The assessment was performed for the reference year 2015.

Fig. 1 visualizes the main building blocks of the model developed to assess the social footprint of the EU consumption of food. For each representative product consumed in the EU, trade and domestic production data were retrieved in order to build the average mix of EU sourcing, i.e. the shares of EU countries and extra-EU country producing/exporting the product in/to the EU. To define the EU sourcing mix, a 95 % threshold was established (i.e. the mix included at least the detail of countries contributing to 95 % of the overall consumption mix) and the remaining share was distributed among the countries according to their contribution in the mix. The annual consumption of products was calculated as the apparent consumption (i.e., production + imports − exports) based on multiple data sources (EFSA, 2021; EUROSTAT, 2021a, 2021b; FAO, 2021).

The different data sources employed in the building blocks used a different classification system and a mapping was required to combine trade data for products used in the Consumption Footprint with the country-sectors combinations available in PSILCA.

For each food product, a list of producing countries and sectors, and the corresponding economic shares, is derived, based on the available trade data. The MRIO database used in PSILCA, EORA, includes different national sectors classifications, which can be very detailed (including hundreds of sectors for the same country) or more rough, with 26 sectors per country. For this reason, each product included in the analysis was mapped with one of the sectors available for the various producing countries. In some cases, the sector available from MRIO was very specific for certain countries and more general for other countries (for instance, for the product "rice" from India the sector "paddy rice" is used, while the sector "agriculture" is used for Cambodia). The full list of country-sectors associated with the sourcing country is available in the SI2, Table 1. The input of the model is therefore represented by the list of country-specific sectors for a certain product, while the output was set as 1 euro of representative food product.

4. Results

This section first describes the result of the mapping between SDG targets and PSILCA indicators, showing the aspects that are better

Table 1
Heat map of 44 representative food products by risk category, considering unitary risk values. Note: CL: Child Labour; FL: Forced Labour, FS: Fair Salary, WT: Working Time, D: Discrimination, HSw: Health and Safety (workers), SB: Social Benefits, Legal Issues, WR: Workers' Rights, FC: Fair Competition, C: Corruption, CED: Contribution to Economic Development, IL: Illiteracy, HS: Health and Safety (society), IN: Respect of Indigenous Rights.

Product	CL	FL	FS	WT	DI	HSw	SB	WR	FC	C	CED	IL	HSs	IR
Almonds	0.05	0.03	0.40	0.02	0.10	0.28	0.21	1.10	0.00	0.60	-0.04	0.06	0.07	0.65
Apples	0.46	0.09	0.44	0.02	0.16	1.81	0.44	1.56	0.01	2.75	-0.07	0.08	0.49	0.22
Avocado	1.70	0.05	0.29	0.02	0.17	0.93	0.54	1.56	0.01	1.41	-0.08	0.25	0.49	0.12
Banana	1.05	0.11	1.90	0.02	0.10	0.74	0.97	1.44	0.01	1.63	-0.05	0.84	1.16	0.17
Beans	0.97	0.47	5.61	0.10	0.61	13.55	3.44	3.90	0.07	28.93	-0.29	0.30	4.09	0.96
Beer	0.01	0.02	0.51	0.02	0.32	0.24	0.07	0.70	0.00	0.25	-0.04	0.02	0.02	0.03
Biscuits	0.01	0.02	0.21	0.02	0.16	0.38	0.09	0.59	0.01	0.34	-0.03	0.02	0.03	0.03
Bread	0.00	0.02	0.17	0.01	0.14	0.29	0.07	0.58	0.01	0.26	-0.04	0.02	0.02	0.02
Broccoli	0.82	0.04	0.30	0.02	0.11	0.41	0.43	1.35	0.01	1.67	-0.09	0.34	0.44	0.17
Butter	0.01	0.02	0.14	0.02	0.09	0.26	0.06	0.58	0.00	0.16	-0.04	0.02	0.02	0.04
Carrot	0.12	0.02	0.14	0.02	0.77	1.05	0.23	0.91	0.01	0.69	-0.02	0.04	0.12	0.09
Cashew	1.27	0.58	11.39	0.04	5.16	0.82	7.80	12.91	0.09	12.74	-0.30	5.90	7.97	0.44
CattleBeefMeat	0.00	0.01	0.11	0.01	0.08	0.27	0.06	0.40	0.00	0.28	-0.03	0.01	0.03	0.04
Cheese	0.00	0.02	0.10	0.02	0.09	0.26	0.06	0.50	0.00	0.24	-0.03	0.02	0.02	0.03
Chickpeas	0.24	0.31	5.02	0.07	0.58	8.26	3.12	3.97	0.05	18.17	-0.23	1.14	3.32	0.60
Chocolate	0.04	0.02	0.15	0.02	0.10	0.32	0.09	0.50	0.01	0.29	-0.03	0.05	0.06	0.04
Cod	0.25	0.12	0.83	0.02	0.20	0.44	0.28	1.58	0.01	1.38	-0.05	0.15	0.25	0.16
Coffee	0.01	0.01	0.07	0.01	0.06	0.21	0.05	0.39	0.00	0.30	-0.03	0.02	0.02	0.04
DairyBeefMeat	0.01	0.01	0.15	0.01	0.11	0.31	0.08	0.48	0.01	0.38	-0.05	0.02	0.04	0.05
Eggs	0.01	0.01	0.19	0.02	0.12	0.32	0.11	1.01	0.00	0.45	-0.04	0.04	0.03	0.68
Lentils	0.03	0.04	0.29	0.03	0.09	0.23	0.23	1.39	0.01	0.85	-0.07	0.07	0.05	1.41
MeatBasedDishes	0.00	0.01	0.18	0.01	0.12	0.20	0.06	0.33	0.01	0.10	-0.03	0.01	0.01	0.02
MilkCream	0.00	0.01	0.13	0.01	0.11	0.23	0.06	0.43	0.01	0.16	-0.03	0.01	0.01	0.02
Mineral Water	0.02	0.01	0.12	0.01	0.11	0.28	0.05	0.70	0.00	0.44	-0.03	0.03	0.03	0.02
OliveOil	0.02	0.03	0.14	0.02	0.11	0.44	0.09	0.96	0.01	0.51	-0.05	0.07	0.05	0.04
Oranges	1.06	0.79	0.51	0.03	0.20	2.63	1.65	2.05	0.01	4.31	-0.09	0.31	2.22	0.13
PalmOil	0.19	0.44	1.95	0.04	0.37	0.92	3.58	1.55	0.01	3.51	-0.09	0.23	1.01	0.21
Pasta	0.01	0.01	0.09	0.02	0.06	0.34	0.07	0.46	0.00	0.69	-0.03	0.03	0.03	0.03
PigMeat	0.00	0.02	0.12	0.01	0.08	0.28	0.07	0.53	0.00	0.20	-0.03	0.02	0.02	0.03
Potatoes	0.01	0.03	0.18	0.02	0.13	0.27	0.11	0.92	0.01	0.42	-0.03	0.03	0.03	0.03
PoultryMeat	0.01	0.02	0.17	0.01	0.12	0.29	0.06	0.70	0.01	0.32	-0.04	0.02	0.02	0.03
Quinoa	4.04	0.17	2.81	0.03	0.16	1.21	0.63	1.97	0.04	3.12	-0.09	0.11	0.11	0.08
Rapeoil	0.01	0.03	0.16	0.02	0.12	0.30	0.07	0.81	0.00	0.36	-0.05	0.03	0.03	0.03
Rice	0.33	0.85	8.60	0.05	0.99	2.04	5.26	5.25	0.02	5.80	-0.24	4.97	5.76	0.17
Salmon	0.34	0.15	0.93	0.02	0.20	0.46	0.31	2.06	0.01	1.83	-0.06	0.17	0.27	0.18
Shrimps	0.34	0.62	5.01	0.03	0.62	1.24	3.15	4.39	0.02	5.86	-0.13	3.34	3.74	1.75
SoybeanOil	0.01	0.04	0.13	0.02	0.11	0.34	0.07	0.85	0.00	0.47	-0.05	0.03	0.03	0.04
Strawberry	0.01	0.02	0.14	0.03	0.12	0.32	0.16	0.79	0.00	0.65	-0.03	0.24	0.22	0.33
Sugar	0.06	0.03	0.30	0.01	0.23	0.40	0.19	0.87	0.01	0.59	-0.05	0.12	0.16	0.03
SunFlowerOil	0.02	0.05	0.23	0.02	0.16	0.54	0.08	1.43	0.01	1.00	-0.07	0.05	0.05	0.04
Tea	0.05	0.03	0.38	0.01	0.14	0.24	0.20	0.53	0.01	0.38	-0.06	0.05	0.06	0.05
Tomatoes	0.03	0.02	0.07	0.02	0.08	0.49	0.18	0.85	0.01	1.13	-0.03	0.27	0.31	0.49
Tuna	0.01	0.02	0.22	0.02	0.15	0.22	0.08	0.99	0.01	0.38	-0.03	0.03	0.03	0.04
Wine	0.07	0.02	0.11	0.02	0.17	0.54	0.10	0.77	0.01	0.98	-0.06	0.03	0.13	0.10

covered in the context of the S-LCA methodology and which are the gaps. It then illustrates the results of the assessment of the social footprint of EU food consumption, showing the role of different SDGs, contributing countries, product groups and products. The analysis deepens later on the individual products. Lastly, different weighted approaches are presented. Note that unitary risk refers to the risk per 1 euro of product, while total risk (EU consumption based) includes the total level of consumption of each food product.

4.1. Social footprint from a SDGs lens

4.1.1. Coverage of the SDGs by the PSILCA database

The mapping exercise of the PSILCA indicators to the SDGs framework revealed that there is a clear link in terms of social impacts at stake. Most of the socio-economic goals are covered, with high prevalence of SDG 8 on decent work and economic growth, considering that almost half of the indicators (37 out of 87) are associated to at least one of its targets (Fig. 2).[4]

Exploring more in detail SDG 8, the main detected target is 8.8 for the protection of labour rights and the promotion of safe and secure working environments for all workers (19 linked indicators). Other important targets are 8.5 for the achievement of full and productive employment and decent work for all women and men (7 indicators) and target 8.7 for the eradication of forced labour, slavery and human trafficking (6 indicators).

The second goal detected in terms of number of PSILCA indicators is SDG 16 on peace, justice and strong institutions (11 indicators), in particular for an equal access to justice for all (target 16.3) and the fight against corruption (target 16.5).

Other indicators of PSILCA database are associated to SDG 3 on good health and wellbeing (e.g. health expenditure, life expectancy at birth), SDG 4 on education (e.g. public expenditure on education, illiteracy rate), SDG 10 on inequalities (e.g. discrimination, human rights issues), SDG 1 on poverty (social security expenditures), SDG 5 on gender equality (gender wage gap).

SDG 12 on sustainable consumption and production is an overarching goal, such as SDG 2 on food security, end hunger and sustainable agriculture: even it is not directly linked to any indicators of PSILCA set, it is intrinsically connected to EU food consumption.

[4] It is worth to consider that some indicators may be linked to more than one goal/target, while others are not associated to any of them (e.g. interaction of the companies with suppliers), because they are not directly linked to the SDG framework.

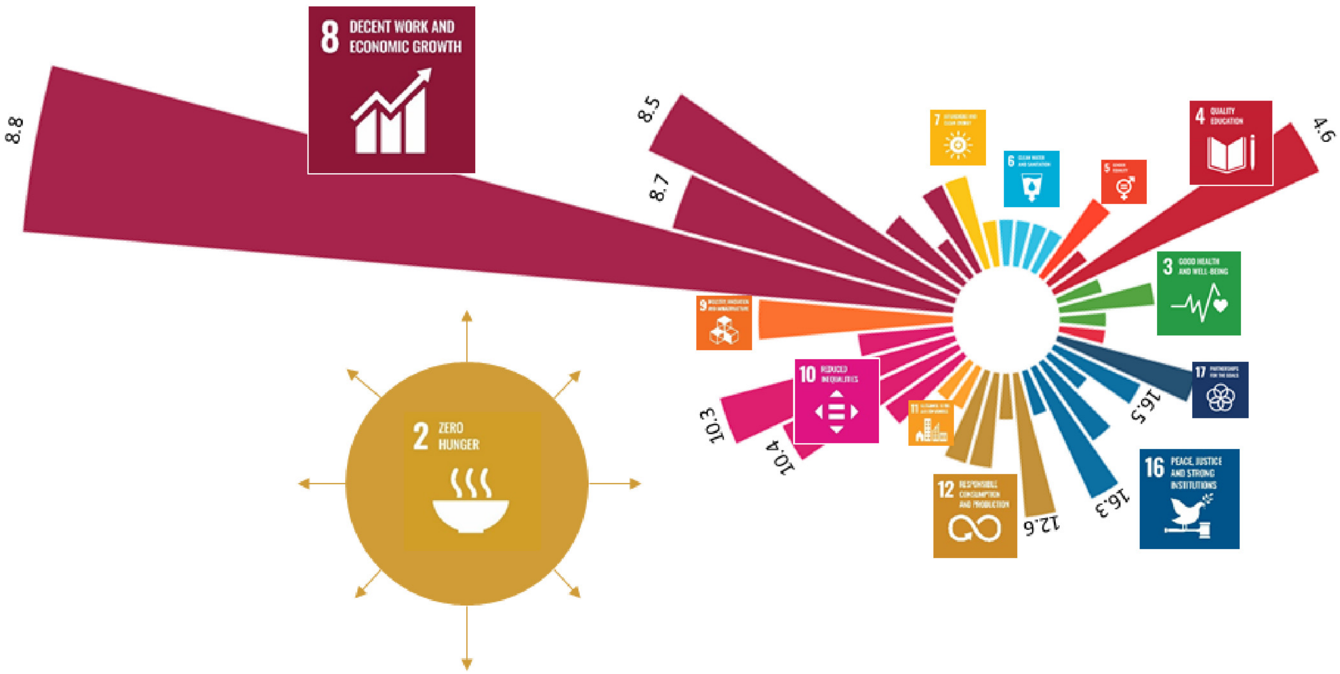

Fig. 2. Visualization of SDG goals and targets linked to PSILCA indicators. The size of icons and bars is directly proportional to the number of indicators addressing the corresponding SDG. SDG2 on food is not directly addressed by any indicator, but it is strictly linked to EU food consumption.

The full list of PSILCA indicators mapped against SDGs is available in the SI2, Table 2.

4.1.2. Social footprint of EU food consumption and analysis by SDG

Fig. 3 shows the results of social footprint of the EU food consumption for 2015, composed of social risk values for the fourteen impact subcategories selected for the study. When impact subcategories include more indicators, they were aggregated into averages, as shown in the supplementary information (SI2, Table 3) that presents the results disaggregated for each indicator and each food product. Risk results are expressed in medium risk hours for thirteen categories, while "contribution to economic development" is the only indicator assessing a social opportunity instead of a risk and therefore expressed as medium opportunity hours (moh). Looking at stakeholder categories, workers are represented by eight impact subcategories, reflecting the better data availability for workers-related issues. On the other hand, the stakeholders' value chain actors and local community includes only one impact subcategory. Note that the social risks in different impact subcategories (e.g., child labour, corruption) employ the same unit (i.e. mrh) but are measuring aspects that are conceptually distant. Furthermore, this analysis is limited to those PSILCA indicators for which data are available and show a sufficient quality, meaning that some subcategories are only partially represented. In this sense, we recommend not to consider an aggregated measure of characterized subcategories (e.g. an overall social risk of EU food consumption) or perform a direct comparison (e.g. fair salary shows a higher risk than child labour). Such analytical approaches are only recommended for comparisons or hotspots analysis, as later exemplified in this study.

Concerning the most contributing countries, Fig. 3 shows that extra-EU countries are often mentioned as the top 3 contributing for the social subcategories addressed, being India (mentioned in 6 out 13 social risk categories) and Argentina (mentioned in 3 out 13 social risk categories) the most common ones. When focusing on the European context, Italy and Spain (both mentioned in 4 out 13 risk categories) and United Kingdom (mentioned in 3 out of 13 subcategories) are the most reported in the top 3 contributing countries. The driver of social risk

Table 2
Ranking of top three product for social risk and opportunity for unitary and total values. (Products which are not in the top three ranking in any of the category are not shown in the list).

	Unitary risk														Total risk													
	CL	FL	FS	WT	D	HSW	SB	WR	FC	C	CED	IL	HSS	IN	CL	FL	FS	WT	D	HSW	SB	WR	FC	C	CED	IL	HSS	IN
Rice		1	2	3	2		2	2			3	2	2			2	1		3		1	3		2	3	1	1	
Cashew	3		1		1		1	1	1	2	1	1	1															
Beans			3	1		1			2	1	2		3	3										3				
Oranges		2				3									1	1				3	2						2	
Mineral water																		1	2	2		1	1		1			
Shrimps		3						3		3		3		1														
Apples															3					1				1				3
Beer																	2	2	1						2			
Banana															2											3	3	
Chickpeas				2		2			3																			
PalmOil							3									3					3							
Potatoes																		3				2	3					
Avocado	2																3											
Tomatoes																										2		1
Carrot					3																							
Eggs																												2
Lentils														2														
Milk cream																							2					
Quinoa	1																											

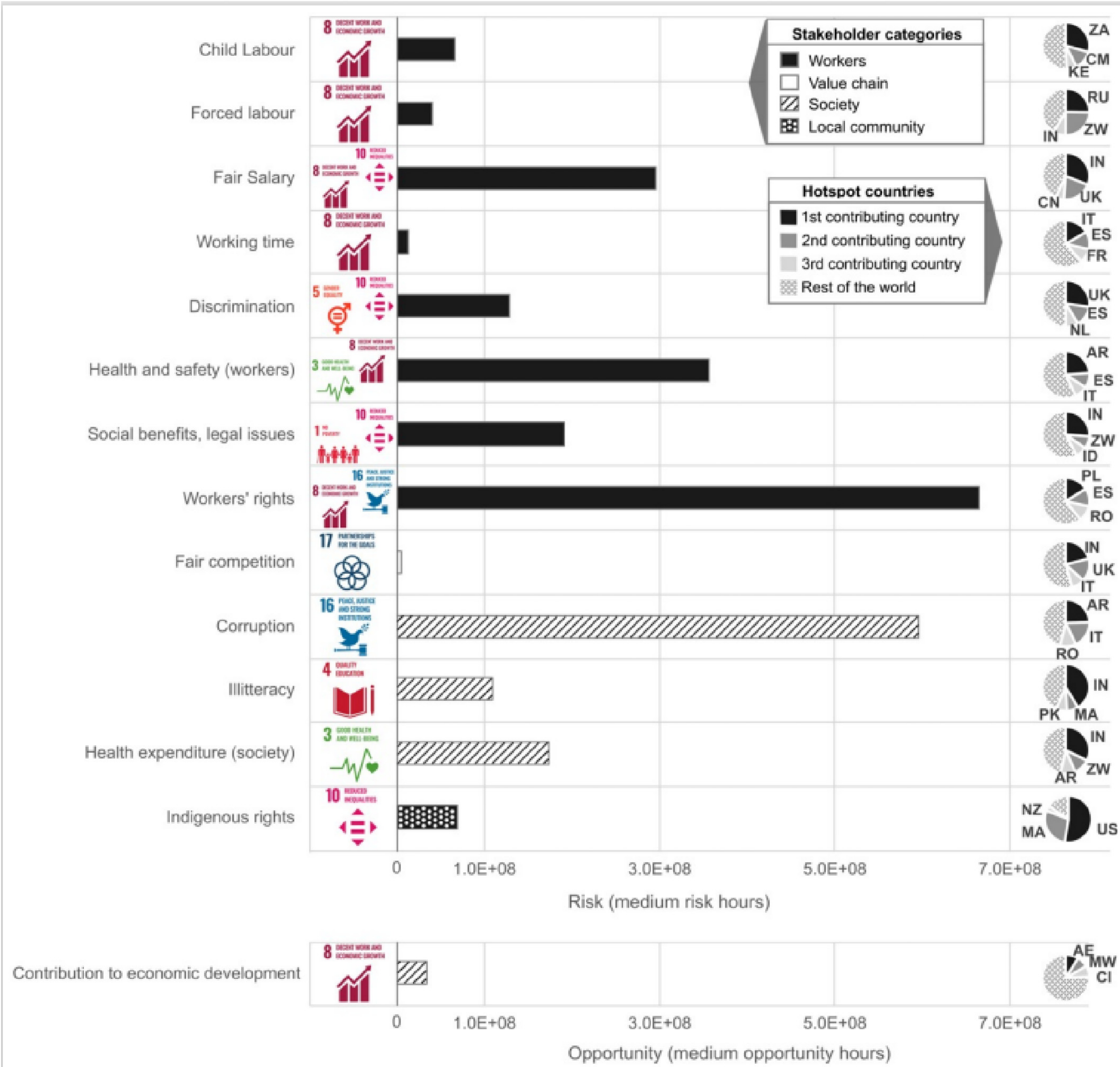

Fig. 3. Overall social risk and opportunity of EU food consumption, by impact subcategory and stakeholder category and top 3 contributing countries in each impact subcategory (pie charts at the right). In this figure, the social subcategory "Contribution to the economic development" should be interpreted as "the higher, the better". All the remaining subcategories should be interpreted as "the lower, the better". Note: ZA: South Africa; CM: Cameroon; KE: Kenya: RU: Russian Federation; ZW: Zimbabwe; IN: India; UK: United Kingdom; CN: China; IT; Italy; ES; Spain; FR: France; NL: Netherlands; ID: Indonesia; PL: Poland; RO: Romania; AR; Argentina; AE: United Arab Emirates; MW: Malawi; CI: Ivory Coast; MA: Morocco; US; United States; NZ; New Zealand.

differs between European countries and other world regions. While for European countries the main driver is found in the labour intensity (more worker hours are required from European CSSs), the main driver in non-European countries is typically linked to higher levels of risk for the social categories in the CSS.

All subcategories have been associated with the corresponding SDGs, for example child labour, forced labour, fair salary and working time are all aspects related to SDG 8 on decent work and economic growth. Other subcategories refer to health and safety (SDG 3), discrimination (including gender equality SDG 5), illiteracy (SDG 4 on education), indigenous rights (SDG 10 on inequalities), etc.

Delving into SDG 8, which is the SDG with the highest number of impact indicators associated, and the specific impact subcategory "fair salary", most contributing products and countries in the supply chain are shown in Fig. 4. The top five products with the highest risk (EU-consumption based) include rice (with India contributing alone for more than 80 %), beer (with Great Britain contributing alone for more than 80 %), mineral water and potatoes with lower risk levels, shared among several EU countries, while the risk linked to bananas is due to non EU countries (primarily Colombia and Costa Rica) In the SI1 (Section 4.1) the same results are shown considering the unitary risk values. The set of contributing products and countries varies,

Table 3
List of product-subcategory-country combinations identified as social hotspots.

Product	Impact subcategory	Product risk share within the basket	Contributing countries	Country share	Corresponding SDG target(s)
Unitary risk					
Quinoa	Child labour	29 %	Bolivia	53 %	8.7
			Peru	47 %	
Cashew	Fair salary	22 %	India	95 %	8.5, 10.3
	Discrimination	37 %	Vietnam	74 %	5.1, 10.3
	Social benefits, legal issues	22 %	India	82 %	1.3, 10.4
	Illiteracy	30 %	India	97 %	4.6
	Society health and safety	24 %	India	90 %	3.8
Beans	Workers health and safety	30 %	Argentina	98 %	3, 8.8
	Corruption	27 %	Argentina	97 %	16.5
Rice	Illiteracy	25 %	India	70 %	4.6
Total risk					
Oranges	Forced labour	24 %	Argentina	40 %	8.7
			Zimbabwe	20 %	
Rice	Forced labour	20 %	Cambodia	45 %	
			India	33 %	
	Fair salary	28 %	India	87 %	8.5, 10.3
	Social benefits, legal issues	26 %	India	74 %	1.3, 10.4
	Illiteracy	44 %	India	70 %	4.6
	Society's health and safety	32 %	India	75 %	3.8
Tomatoes	Indigenous rights	26 %	Morocco	95 %	10.2, 10.3

with the exception of rice and India that emerge in the two top five lists.

4.2. The social footprint of EU food consumption, by product and product group

Fig. 5 shows the percentage contribution of nine food product groups on the total risk for 14 selected impact categories (the composition of food groups is available in the SI1, Section 3). The contribution of the different product groups depends on the impact category and is dominated by fruits, cereal-based products, beverages, and vegetables. The product group fruits is predominant for the category child labour and forced labour (linked to SDG 8, target 8.7), as it accounts for 54 % and 33 % of the total impact, respectively. Cereal-based products have the highest contribution in the subcategory illiteracy (42 %, SDG 4), society health and safety (31 %, SDG 3) and fair salary (32 %, SDG 8). Beverages are the group with the highest share in the category discrimination (32 %, SDG 5, SDG 10) and in the positive contribution to economic development (27 %, SDG 8). Fruits and vegetables are the product groups with the highest share in the category respect of indigenous rights (20 % and 19 %, respectively, SDG 10). The contribution of meat and eggs is at maximum 13 % (for respect of indigenous rights, SDG 10) and below 11 % for all the other categories, as well as for seafood. Oils group has its highest contribution in respect of indigenous rights category (23 %, SDG 3).

The role of product groups and food products in the overall social footprint of EU consumption depends on the consumption intensity and the unitary social risk of each product. To analyze the unitary social risk of the evaluated food products, Table 1 shows the heat map of 44 representative products considering the whole set of impact subcategories. Cashew, beans, rice, chickpeas and shrimps are the products emerging as hotspots when considering the unitary risk. In the case of cashew and quinoa (which shows high risk of child labour), these are commodities that are actually consumed in small amounts, but their consumption is increasing in Europe and associated with healthy and environmental friendly life styles (e.g. quinoa is used to produce vegetarian burgers) (Migliore et al., 2017).

Table 2 complements the picture indicating the products that appear among the top three for at least one impact subcategory, considering both results of unitary and consumption based risk. When considering

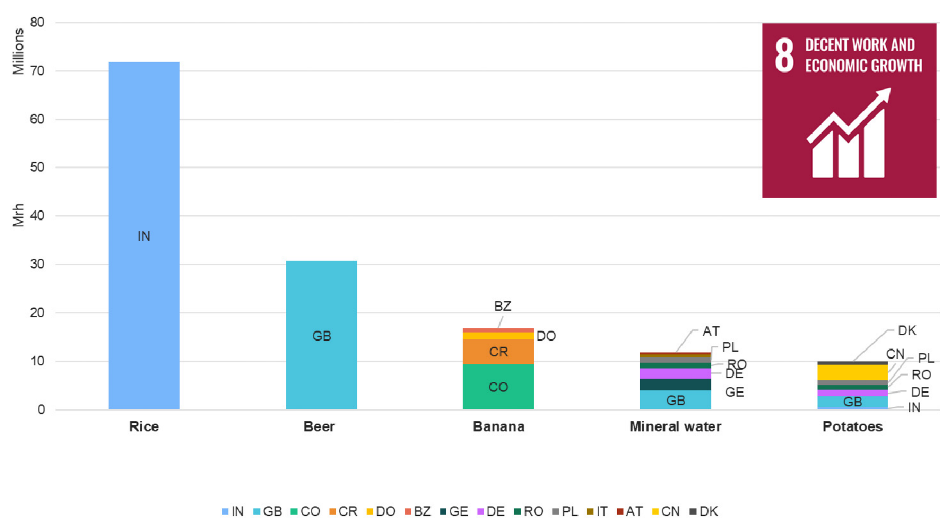

Fig. 4. Countries contributing for at least 80 % of the total (EU consumption based) risk for the top five products with the highest risk in the category "fair salary". Note: AT: Austria; BZ: Belize; CO: Colombia; CN: China; CR: Costa Rica; DE: Germany; DK: Denmark; GB: Great Britain; DO: Dominican Republic; GE: Georgia; IN: India, PL: Poland; RO; Romania.

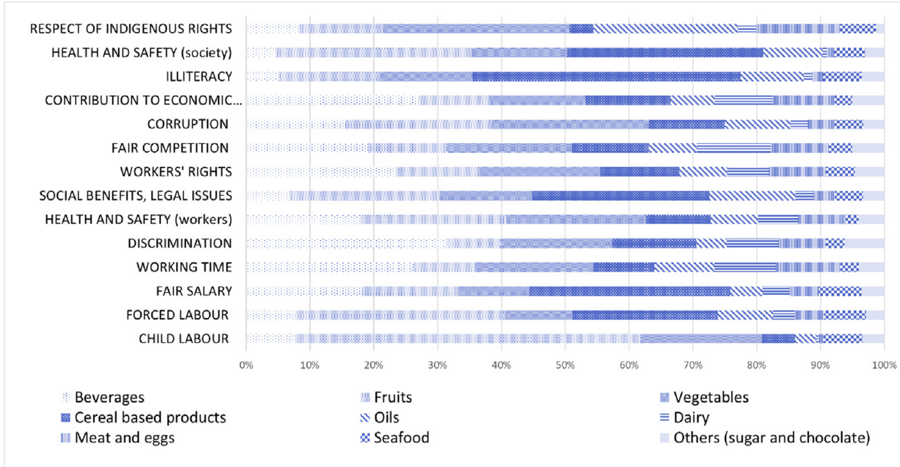

Fig. 5. Social risk of nine food groups consumed in the EU, by impact subcategory (%).
(Food groups composition: BEVERAGES: beer, coffee, mineral water, tea, wine; CEREAL BASED PRODUCTS: biscuits, bread, pasta, rice; DAIRY: butter, cheese, milk, cream; SEAFOOD: cod, salmon, shrimps, tuna; FRUITS: almonds, apples, avocado, banana, cashew, oranges, strawberry; MEAT and EGGS: cattle beef meat, eggs, dairy beef meat, meat-based dishes, pig meat poultry meat; OILS: olive oil, rape oil, sun flower oil, soybean oil; VEGETABLES: beans, broccoli, carrot, chickpeas, lentils, quinoa, tomatoes; OTHERS: chocolate, sugar)

also the consumption intensity, other products emerge as hotspot, e.g., mineral water, oranges, apples, beer, tomatoes, palm oil, etc. Rice appears as a hotspot in both analysis.

From the results at product level, social hotspots can be identified as products having a high share of total risk for a certain risk category. Setting a threshold of 20 %, the product-impact subcategory combinations that emerge as hotspots are listed in Table 3, including also the main contributing countries for each impact subcategory.

The full list of results by product and risk category is available in the SI2, table 4. Results also outline that representative food products can be divided into two main categories (Fig. 6). On the one hand, there is a group of products with high social risk intensity (i.e. showing high

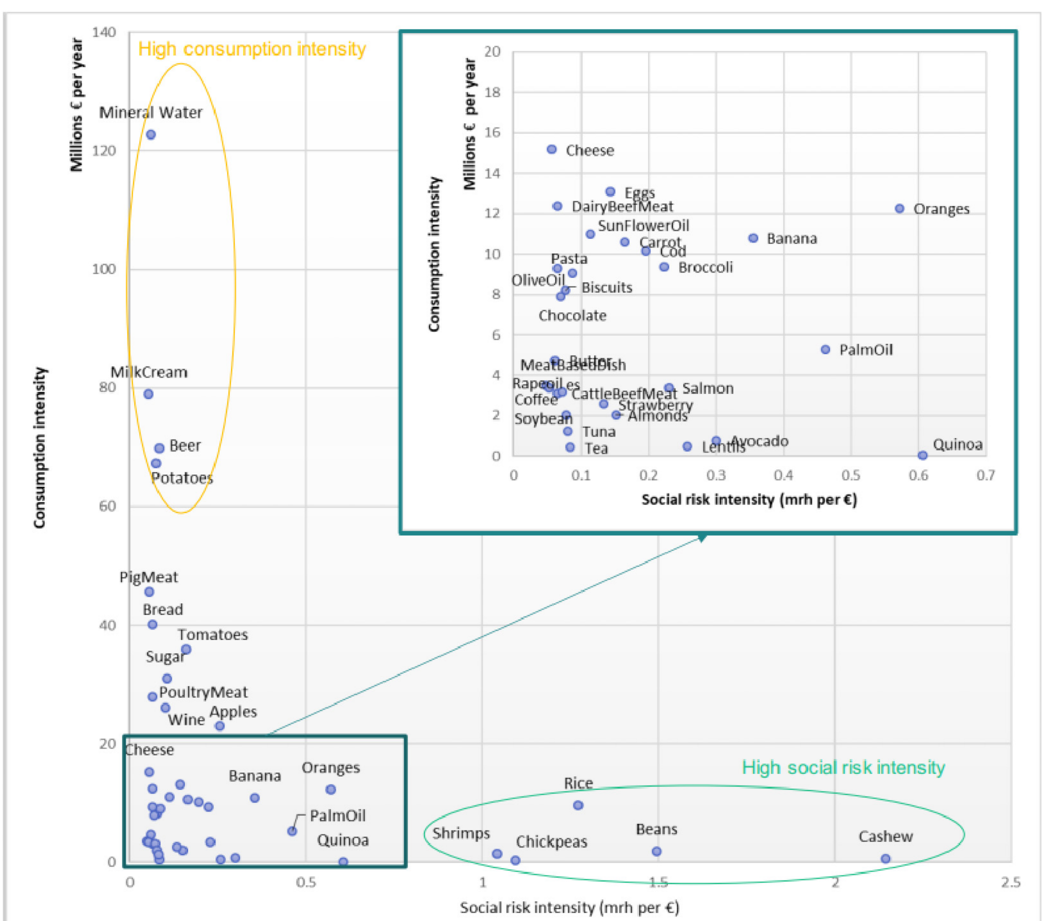

Fig. 6. Relation between the unitary social risk for the category “fair salary” per product (mrh) and the consumption intensity for the EU in 2015 (million €).

risk per economic unit) but limited consumption intensity: cashew, beans, chickpeas, rice and shrimps (in line with Fig. 5). On the other hand, some products have a high consumption intensity (in economic terms) although having a limited unitary social risk, including mineral water, milk cream, beer and potatoes. However, most food products remain in a central area where neither the consumption intensity nor the social risk intensity are high. Results for all the risk categories are available in the SI1, Section 4.2.

4.2.1. Sensitivity analysis using different weighting systems

The results shown in Fig. 3 are based on an equal weighting, with all the risk categories having the same relevance. Given that social categories have very different meanings and could imply impacts of different severity, this assumption can be challenged by applying different weighting schemes, based on the policy relevance of each category. Moreover, the background data on social aspects vary in their robustness, as well as level of aggregation and resolution. Based on these considerations two weighting schemes are proposed and compared to the equal weighting:

A. Weighting system based on the policy relevance of the impact subcategories, assessed through the analysis of social categories used in policy impact assessment.
B. Weighting systems based on the data robustness of the background social data, evaluated considering data sources reliability and technical/geographical conformance.

Detailed information on how these schemes have been developed are available in the SI1, Section 5.

Fig. 7 shows that applying the policy relevance criteria health & safety for workers, illiteracy, workers' rights, forced labour and child labour gain importance respect to the equal weighing. Looking at the data quality and robustness, instead, fair salary, workers' rights, workers' health and safety are the categories having more relevance.

5. Discussion

The contribution of the paper is to map the indicators of the PSILCA database to the SDGs at the target level, and to assess the social risk associated with the EU food consumption.

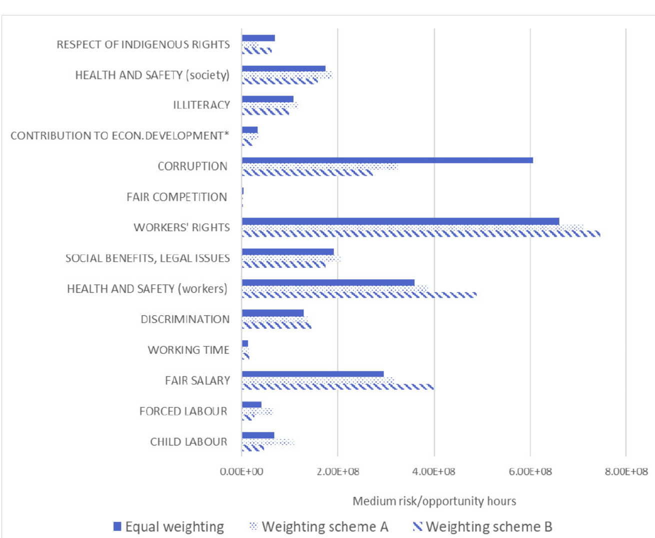

Fig. 7. Results on overall social risk by social categories, comparing three weighing schemes.

5.1. The social footprint of EU food production and consumption

The social footprint allows assessing potential impacts of the EU food systems, linked to several SDGs. Half of the impact categories presented in this study relates to SDG 8 on decent work and economic growth, reflecting the higher availability of indicators related to the stakeholders category "workers". Considering the social risk of the whole food system, the categories workers' rights and corruption, linked to SDG 8 and SDG 16 (Peace, justice and strong institutions) respectively, show the highest risk. This analysis also shows which are the aspects included in the SDGs that can be assessed with the social life cycle-based data and methods and allows identifying the gaps to be filled in order to have a more complete understanding of the food systems sustainability. Food security and affordability are currently missing in the S-LCA methodology, but these are very relevant socio-economic aspects for the food systems sustainability. In particular, it could be assessed how the EU food system is contributing to SDG 2 on food security at domestic level, but also how the food production and international trade can eventually affect food security in developing countries (e.g. due to competition in the use of natural resources).

The results of the assessment allow evaluating the role of food products and groups on the overall social footprint of EU food consumption. On one hand, vegetables, fruits and rice emerged as major contributors to the social risk of EU food consumption, being oranges, rice and tomatoes the three identified hotspots. This outcome is coherent with results from Pelletier et al. (2016), that using another database (Social Hotspot Database), shows that when a life cycle based approach is taken, rice has a very high risk per euro spent and the sector "vegetables, fruits, nuts" is within the top ten sector with the highest risk per euro.

This is in contrast with environmental assessments on food, which revealed the higher impact of animal-based products. In particular, in the environmental assessment of EU food consumption meat and dairy products emerged as environmental hotspots in all LCA impact categories (Castellani et al., 2017; Sanyé Mengual and Sala, 2022). Similar outcomes emerged in terms of material intensity (Mancini et al., 2012), and environmental impacts like climate change, land use change, biodiversity loss (e.g. Clune et al. (2017); Crenna et al. (2019); Rust et al. (2020); Stoll-Kleemann and Schmidt (2017); Van Vliet et al. (2020)).

Another relevant product group in environmental assessments of EU food consumption is beverages, having a high contribution for the LCA categories water depletion, resource depletion and ionizing radiation (Sala et al., 2019). In the social assessment, the role of beverages is limited to specific categories: it contributes for 32 % in the subcategory discrimination but has also the highest share in terms of positive contribution to economic development. The low social risk linked to beverages can be explained by the fact that mineral water, beer and wine consumed in the EU are produced in the EU for more than 90 % of their value, according to Eurostat data.

The unitary risk results unveiled the relevance of different product groups (cashew, quinoa, beans and rice). Among the hotspots shown in Table 1, cashew and quinoa are produced in tropical and/or developing countries and have low levels of consumption. Countries predominantly contributing to the high risk are India (cashew), Peru (quinoa and avocado), Argentina (beans) and Bolivia (quinoa). Indeed, for these countries several social indicators are assessed as very high risk in PSILCA: for instance, illiteracy rate, health expenditure and the fair wage in the case of India; child labour in Bolivia and Peru (20 % and 22.5 % of children in employment according to World Bank data), or high risk for corruption and accidents at work for Argentina. Given that consumer interest in tropical fruits has experienced a significant increase in Europe during the last decades (Migliore et al., 2017), also due to an increased health consciousness, policies on sustainable food consumption should take into account the role of fair trade and responsible sourcing practices for products imported from developing countries, in order to avoid shifting of burdens towards extra EU countries. This also applies to some products having higher consumption intensity, in particular for rice, whose social risk is predominantly due to India (even though 50 % of the rice consumed in EU is sourced from Italy and Spain), bananas (20 % of the sourcing from Colombia, 18 % from Ecuador), oranges (23 % sourced from South Africa, but most of the risk associated to Argentina and Zimbabwe) and tomatoes (31 % sourced from Morocco).

Mineral water, potatoes and milk cream, which are sourced mainly from EU countries (e.g. Italy, Germany, UK, France, Poland) and are the products with high total risk in the categories workers' rights, fair competition and working time. Apples is sourced both from EU and extra EU countries (14 % New Zealand, 11 % Chile) and have high risk in the categories corruption, child labour and health and safety of workers.

It is evident that social risk results reflect, to some extent, the level of development and governance of producing countries, especially for some impact subcategories which do not have any sector-specific indicator. This is the case of the stakeholder category society and local community (with only one subcategory on indigenous rights).

5.2. Limitations of the study

The current assessment was a first attempt to expand the model of the Consumption Footprint towards social aspects, thus combining the bottom-up approach (based on assessment of representative products) with the top-down evaluation of country-sectors provided by the PSILCA database. The input/output database (EORA) included in PSILCA allowed considering all the inputs in the supply chain of food products. However, the classification of sectors available in the EORA database is not always enough specific to account for sectoral differences (i.e., among different product groups). For instance, in the case of meat, the EU trade mix is composed of EU countries and some extra EU countries like US, Argentina, Brazil, Australia, UK etc. For some countries (e.g. Spain, US, Argentina, Brazil, UK, etc.) specific sectors are available in EORA.[5] In the case of France (the country with the highest share in the trade mix) and other EU countries like Italy, Poland, Sweden, etc. a specific sector for meat is not available and the generic sector "Manufacture of food products and beverages" was used (the detailed mapping between country-sectors and products are available in the SI2, Table 1). This low specificity of the input/output database for these countries could result in an underestimation of these results, as the inputs considered in the system do not refer specifically to cattle production but to a generic food product. Thus, the social risk due to feed imported from extra-EU countries might be not properly accounted for. The same reasoning would apply to other animal-based products included in the set, i.e. cheese, milk cream, butter, etc.

In the case of coffee, chocolate, tea and soybean oil, trade data from Eurostat refer to the processing phase and not to the production of the agricultural products, which in the case of these commodities occurs to a large extent in extra EU countries. Indeed, 99 % of the chocolate and of the coffee consumed in EU is produced in EU countries, UK and Switzerland; 89 % of soybean oil and 90 % of the tea is produced in the EU, according to this data source. Given that for many EU countries only the generic sector "Manufacture of food products and beverages" is available, it is likely that social risk for these products is underestimated. Indeed, the production of the agricultural materials in developing countries is probably not fully accounted in the EORA generic food manufacturing sector.

The table in SI2, Table 5 shows the list of processed food and agricultural products considered in the study, in order to transparently document which product might be underestimated or having a higher uncertainty. Further research could complement this aspect by developing a more detailed modelling of the food products supply chain based on the EU consumption. However, this would not overcome the limited granularity of the EORA database and would only reflect the different trade mix between final and intermediary products.

The proposed implementation of the PSILCA database to assess the entire EU food system has some limitations in terms of data gaps, quality and granularity of the background social aspects. Indeed, for some social aspects there is a lack of disaggregated data from the source of social data (e.g. ILO estimates on percentages of child labour are not sector-specific). Moreover, temporal and geographical conformance of the social data varies and is usually poorer for developing countries.

These aspects hindered the potential evaluation of an absolute social risk that covers the full plethora of social aspects to be considered in supply chains. For example, some impacts at local level if assessed by country-based indicators do not provide meaningful insights and therefore other impact subcategories were left out. The risk concerning indigenous rights, while being a local aspect, is estimated at country level using indicators on the presence of indigenous communities in the country and the ratification of the ILO convention on indigenous and tribal people. A detailed description of each impact subcategory and related indicator is available in Eisfeldt (2017). Based on this limitation, we recommend interpreting the provided results focusing on the hotspots and the comparison among products, rather than on an absolute value at the macro-scale.

Beyond further developments in social LCA databases, the LCA community should tackle normalization and weighting. On one hand, the different impact subcategories address social risks that are conceptually distant and normalization approaches could enhance a fair aggregation into a single score. On the other hand, no weighting schemes exist so far as for environmental LCA (e.g., the weighting framework for the Environmental Footprint (Sala et al., 2018)) and different approaches have been tested in this study, setting the pathway towards exploring different options for a comprehensive weighting set for social LCA studies based on PSILCA indicators. Further developing normalization and weighting approaches to achieve a single weighted score can be of great relevance for employing social LCA results in policy-making and associated monitoring and distance-to-target exercise, where headline indicators are more consolidated.

Lastly, the exercise unveiled potential gaps of PSILCA database to cover the multidimensional context of SDG framework, especially for SDG 1 on poverty, SDG 2 on zero hunger, SDG5 on gender equality and SDG 10 on inequalities. A set of additional indicators could be used in a further exercise, to explore more in detail specific targets of the Agenda 2030.

6. Conclusions

This study proposed an approach to operationalize the SDGs applying data and methods used in macro-scale S-LCA. The approach was tested in a case study on EU food system (production and consumption), building on previous work on the Consumption Footprint which is addressing environmental impacts. The results of the study showed that SDG 8 is the SDG with wider coverage of indicators and data, especially for what concerns workers' rights, safe working environment, full employment for all and the eradication of forced labour.

The results of the case study revealed potential social hotspots in terms of products, product groups, country of origin and consumption levels. Unlike environmental impact, social risk appeared to be higher for fruits and vegetables instead of animal-based products, suggesting that trade-offs might occur in the design of sustainable diets.

The role of international trade, which was included in the assessment, appears relevant in terms of potential social impacts occurring in extra-EU countries. Therefore, this type of assessment could enable an analysis of potential social risk arising from a change in the trade mix for food and agricultural products deriving from shocks in the supply of agricultural commodities. These can arise in the case of conflicts (e.g. the current conflict in Ukraine which is affecting the supply of

[5] E.g. "Animal (except poultry) slaughtering, rendering, and processing" for US, "Killing of animals, conservation and meat processing" for Argentina and "Beef and other live animals" for Brazil (full list in Supplementary Information, SI2, Table 1).

grains and vegetable oils (EC - European Commission, 2022)), environmental crisis (e.g. droughts, pest outbreak, etc.), economic sanctions, etc.

The results of the assessment show that, as pointed out in Blackstone et al. (2021), trade-offs can emerge between the need of promoting the consumption of fruit and vegetable and the potential social risks occurring in the supply chain of these agricultural products, especially when imported from extra EU countries. This suggests that, in order to achieve sustainable food systems, responsible sourcing of agricultural products should be guaranteed. Moreover, fair trade agreements (ensuring dignified working conditions and a fair compensation of producers) and supply chain due diligence (aiming at avoiding severe social risks in the supply chain) should be promoted and sustainable practices should be transparently communicated to the consumer.

Finally, this study, while hindered by data gaps and heterogeneous data quality, offers a basis for deepening the knowledge on the social sustainability of EU food consumption, taking into account also the use of intermediate products and raw materials. As far as more robust social data become available, more complete assessments could be built based on this case study. The role of raw materials and intermediate products used in the food supply chain could be investigated. Moreover, the assessment of other areas of consumption included in the consumption footprint (e.g., household goods, mobility, appliances) would allow the comparison between different consumption areas and further contribute to the achievement of SDG 12 on responsible consumption and production.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.spc.2022.11.005.

References

Alsamawi, A., McBain, D., Murray, J., Lenzen, M., Wiebe, K.S., 2017a. The inequality footprints of nations; a novel approach to quantitative accounting of income inequality. The Social Footprints of Global Trade. Springer, pp. 69–91.
Alsamawi, A., McBain, D., Murray, J., Lenzen, M., Wiebe, K.S., 2017b. The Social Footprints of Global Trade. Springer.
Benoit-Norris, C., Cavan, D.A., Norris, G., 2012. Identifying social impacts in product supply chains: overview and application of the social hotspot database. Sustainability 4 (12), 1946–1965. https://doi.org/10.3390/su4091946.
Blackstone, N.T., Norris, C.B., Robbins, T., Jackson, B., Decker Sparks, J.L., 2021. Nat. Food 2 (9), 692–699. https://doi.org/10.1038/s43016-021-00339-0.
Castellani, V., Fusi, A., Sala, S., 2017. Consumer Footprint Basket of Products Indicator on Food. https://doi.org/10.2760/668763.
Chandrakumar, C., McLaren, S.J., 2018. Towards a comprehensive absolute sustainability assessment method for effective earth system governance: defining key environmental indicators using an enhanced-DPSIR framework. Ecol. Indic. 90, 577–583. https://doi.org/10.1016/J.ECOLIND.2018.03.063.
Clune, S., Crossin, E., Verghese, K., 2017. Systematic review of greenhouse gas emissions for different fresh food categories. J. Clean. Prod. 140, 766–783. https://doi.org/10.1016/J.JCLEPRO.2016.04.082.
Crenna, E., Sinkko, T., Sala, S., 2019. Biodiversity impacts due to food consumption in Europe. J. Clean. Prod. 227, 378–391. https://doi.org/10.1016/J.JCLEPRO.2019.04.054.
Desiderio, E., García-Herrero, L., Hall, D., Segrè, A., Vittuari, M., 2021. Social sustainability tools and indicators for the food supply chain: a systematic literature review. Sustain. Prod. Consum. 30, 527–540.
EC - European Commission, 2019. The European Green Deal. COM/2019/640 Final.
EC - European Commission, 2020a. A Farm to Fork Strategy for a Fair, Healthy and Environmentally-friendly Food System. COM/2020/381 Final.
EC - European Commission, 2020b. Delivering on the UN's Sustainable Development Goals – A Comprehensive Approach. SWD (2020) 400 Final.
EC - European Commission, 2022. The impact of Russia's war against Ukraine on global food security – KC-FNS Review - May 2022. https://knowledge4policy.ec.europa.eu/publication/impact-russia%E2%80%99s-war-against-ukraine-global-food-security-%E2%80%93-kc-fns-review-may-2022_en.
EC-JRC, 2021. Consumption Footprint Platform. Available at https://eplca.jrc.ec.europa.eu/ConsumptionFootprintPlatform.html (Accessed 14 November 2021).
EC-JRC (European Commission - Joint Research Centre), 2018. Environmental footprint. Available at: https://eplca.jrc.ec.europa.eu/EnvironmentalFootprint.html.
EFSA, 2021. EFSA Comprehensive European Food Consumption Database.
Eisfeldt, F., 2017. PSILCA – A Product Social Impact Life Cycle Assessment Database. Documentation.
EUROSTAT, 2021a. EU Trade Since 1988 by HS2-4-6 and CN8 (DS-045409).
EUROSTAT, 2021b. Sold Production, Exports and Imports by PRODCOM List (NACE Rev. 2) - Annual Data (DS-066341).
FAO, 2018. Transforming Food and Agriculture to Achieve the SDGs: 20 Interconnected Actions to Guide Decision-makers. FAO, Rome (Italy).
FAO, 2021. FAOSTAT Database: Food Balance Sheets.
GRI Global Reporting Initiative, 2022. GRI 13: agriculture, aquaculture and fishing sectors 2022. https://www.globalreporting.org/standards/standards-development/sector-standard-for-agriculture-aquaculture-and-fishing/.
Herrera Almanza, A.M., Corona, B., 2020. Using social life cycle assessment to analyze the contribution of products to the sustainable development goals: a case study in the textile sector. Int. J. Life Cycl. Assess. 25 (9), 1833–1845. https://doi.org/10.1007/S11367-020-01789-7/TABLES/4.
Kørnøv, L., Lyhne, I., Davila, J.G., 2020. Linking the UN SDGs and environmental assessment: towards a conceptual framework. Environ. Impact Assess. Rev. 85, 106463. https://doi.org/10.1016/J.EIAR.2020.106463.
Lenzen, M., Moran, D., Kanemoto, K., Foran, B., Lobefaro, L., Geschke, A., 2012. International trade drives biodiversity threats in developing nations. Nature 486 (7401), 109–112.
Lenzen, M., Moran, D., Kanemoto, K., Geschke, A., 2013. Building Eora: a global multi-region input–output database at high country and sector resolution. Econ. Syst. Res. 25 (1), 20–49.
Mancini, L., Lettenmeier, M., Rohn, H., Liedtke, C., 2012. Application of the MIPS method for assessing the sustainability of production–consumption systems of food. J. Econ. Behav. Organ. 81 (3), 779–793. https://doi.org/10.1016/j.jebo.2010.12.023.
Migliore, G., Farina, V., Tinervia, S., Matranga, G., Schifani, G., 2017. Consumer interest towards tropical fruit: factors affecting avocado fruit consumption in Italy. Agric. Food Econ. 5 (1), 1–12. https://doi.org/10.1186/S40100-017-0095-8/TABLES/5.
OECD-FAO, 2016. OECD-FAO Guidance for Responsible Agricultural Supply Chains.
Pelletier, N., Ustaoglu, E., Benoit, C., Norris, G., 2016. Sustainability in trade and development policy. Int. J. Life Cycl. Assess. 23, 629–639.
Rust, N.A., Ridding, L., Ward, C., Clark, B., Kehoe, L., Dora, M., Whittingham, M.J., McGowan, P., Chaudhary, A., Reynolds, C.J., Trivedy, C., 2020. How to transition to reduced-meat diets that benefit people and the planet. Sci. Total Environ. 718, 137208.
Sala, S., 2019. Life cycle assessment and evaluation of solutions towards sustainable development goals. In: Filho, W.L. (Ed.), Encyclopedia of the UN Sustainable Development Goals. Springer ISSN: 2523-7403.
Sala, S., Castellani, V., 2019. The consumer footprint: monitoring sustainable development goal 12 with process-based life cycle assessment. J. Clean. Prod. 240, 118050. https://doi.org/10.1016/J.JCLEPRO.2019.118050.
Sala, S., Sanyé Mengual, E., 2022. Consumption Footprint: Assessing the Environmental Impacts of EU Consumption. European Commission.
Sala, S., Cerutti, A.K., Pant, R., 2018. Development of a Weighting Approach for the Environmental Footprint.
Sala, S., Benini, L., Beylot, A., Castellani, V., Cerutti, A., Corrado, S., Crenna, E., Diaconu, E., Sanyé-Mengual, E., Secchi, M., 2019. Consumption and Consumer Footprint: Methodology and Results. Indicators and Assessment of the Environmental Impact of European Consumption, Luxembourg.
Sanyé-Mengual, E., Sala, S., 2022. Life cycle assessment support to environmental ambitions of EU policies and the sustainable development goals. Integr. Environ. Assess. Manag. 18, 1221–1232.
Sanyé-Mengual, E., Secchi, M., Corrado, S., Beylot, A., Sala, S., 2019. Assessing the decoupling of economic growth from environmental impacts in the European Union: a consumption-based approach. J. Clean. Prod. 236, 117535. https://doi.org/10.1016/J.JCLEPRO.2019.07.010.
Shilling, H.J., Wiedmann, T., Malik, A., 2021. Modern slavery footprints in global supply chains. J. Ind. Ecol. https://doi.org/10.1111/JIEC.13169.
Simas, S.M., Golsteijn, L., Huijbregts, A.M., Wood, R., Hertwich, G.E., 2014. The "bad labor" footprint: quantifying the social impacts of globalization. Sustainability 6 (11). https://doi.org/10.3390/su6117514.
Steen-Olsen, K., Weinzettel, J., Cranston, G., Ercin, A.E., Hertwich, E.G., 2012. Carbon, land, and water footprint accounts for the European Union: consumption, production, and displacements through international trade. Environ. Sci. Technol. 46 (20), 10883–10891. https://doi.org/10.1021/es301949t.
Stoll-Kleemann, S., Schmidt, U.J., 2017. Reducing meat consumption in developed and transition countries to counter climate change and biodiversity loss: a review of influence factors. Reg. Environ. Chang. 17 (5), 1261–1277.
Tragnone, B.M., D'Eusanio, M., Petti, L., 2022. The count of what counts in the agri-food social life cycle assessment. J. Clean. Prod. 354, 131624. https://doi.org/10.1016/j.jclepro.2022.131624.
UN General Assembly, 2015. Transforming Our World: The 2030 Agenda for Sustainable Development. United Nations, New York.

UNEP, 2020. In: Benoît Norris, G., Traverso, C., Neugebauer, M., Ekener, S., Schaubroeck, E., Russo Garrido, T., Berger, S., Valdivia, M., Lehmann, S., Finkbeiner, A., Arcese, M. (Eds.), Guidelines for Social Life Cycle Assessment of Products and Organizations 2020. United Nations Environment Programme (UNEP). https://www.lifecycleinitiative.org/wp-content/uploads/2020/12/Guidelines-for-Social-Life-Cycle-Assessment-of-Products-and-Organizations-2020-sml.pdf.

Van Vliet, S., Kronberg, S.L., Provenza, F.D., 2020. Plant-based meats, human health, and climate change. Front. Sustain. Food Syst. 128.

Weidema, B., Goedkoop, M., Meijer, E., Harmens, R., 2020. LCA-based Assessment of the Sustainable Development Goals.

Wiedmann, T., Lenzen, M., 2018. Environmental and social footprints of international trade. Nat. Geosci. 11 (5), 314–321.

Wulf, C., Werker, J., Zapp, P., Schreiber, A., Schlör, H., Kuckshinrichs, W., 2018. Sustainable development goals as a guideline for indicator selection in life cycle sustainability assessment. Procedia CIRP 69, 59–65. https://doi.org/10.1016/J.PROCIR.2017.11.144.