Valuing the impact of food:

Towards practical and comparable monetary valuation of food system impacts

A report of the Food System Impact Valuation Initiative (FoodSIVI)

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DEVELOPMENT AND INVENTORY OF METHODS SUMMARY

This section comments on the development of impact valuation. It also provides an inventory of the methods, data and models mentioned in previous sections.

Forums for developing impact valuation repeat general terms such as “gathering the data”, “measurement”, “quantification” and “metrics”. Contextualising these terms would further development of methods. This section recommends distinguishing data and modelling required for footprint calculation, data and modelling required for capital changes, and data and modelling required for valuation of capital changes. Examples show that data and models associated to footprint, capital changes, and valuation are substantively different. They vary in terms of sources, quality, and resolution.

The three components of valuation need to develop together. Little improvement in food impact costing will be achieved overall if development is pushed into improving the precision of measuring an actor’s footprint while methods to improve social and abatement costing languish. Incredible uncertainties and variation in the impact that a footprint creates remains unimproved by greater precision in measuring the footprint. For reducing global food system impact, disclosure efforts should be prioritised over more granular measurement of footprints that are relatively well-measured.

Technology for smart farms and big data promise greater precision in footprint data, but there is less focus on capital changes and human impacts. Many research projects and investments in food supply chains concern food safety and personalised nutrition and not data collection relevant to impact. Food safety and personalised nutrition offer more immediate sources of return on investment. This is a missed opportunity. It will be missed if incentives for food system impact reduction are not increased.

Research is required to understand how the potential areas for the greatest improvement in impact valuation match with capability and resources: what improvements are required, what aspects they need to include, where in terms of footprint, capital changes or valuation, their precision versus their practicality, and the importance of certainty in their calculation versus consensus around the calculation.

Previous sections argued from a practical, ethical, and risk-bearing viewpoint that a societal process should standardise footprints through a food system non-financial accounting standard and set and update shadow prices associated to standardised footprint units. Using single shadow prices linked to global footprints is a mistake, it only works for the marginal valuation of carbon. It is suggested that more energy will be spent arguing the numbers, or diverting the argument to the numbers, rather than on economic action. Waiting for scientific precision in impacts from global modelling and monitoring is equally seen as a mistake. Economic measures for change in food systems are an imperative now; impact neutral as an aspiration for the food sector needs to come on the back of carbon markets and mechanisms. This section finds a database of shadow prices at the resolution suggested in previous sections strikes a balance between pragmatism and precision in calculation, accessibility and expertise, and need and maturity.

CONTENTS

DEVELOPMENT AND INVENTORY OF METHODS

Food system impact valuations are likely to continue to use marginal valuations taken from literature and different sources of modelling and monitoring data. Before listing a short inventory of present methods and resources, a spectrum and timeline in the development of impact valuation is considered. The report has argued for the movement toward spatially and contextually explicit footprints and collections of marginal valuations. Food impact valuation is likely to be less effectual and more contested without spatial and contextual footprint. It has been argued in the chapter Food System Impact Valuation in Practice, from practical, ethical, and risk-bearing viewpoints, that a societal process should standardise footprint through a food system non-financial accounting standard and set and update shadow prices associated to standardised footprint units. By considering steps in the development of impact valuation, it is argued that developing the accounting standard and shadow prices as a shared asset is an effective application of the time and resources of stakeholders toward using social and abatement costs of food system impact to contribute to food system transformation and incentivise sustainable products and practices.

Spectrum of approaches

The description of the steps in the valuation process in Food System Impact Valuation in Practice, the discussion of ethical choices and uncertainty in that chapter, and the examination of the case studies in Case Studies of Food System Impact Valuation, evidence that it is unlikely agreement on food impact costing can be achieved through "having the data". That is, having enough precision to scientifically establish impact costings as "facts". It is unclear that, even with complete disclosure of the footprints of all food actors, and assuming that those footprints could be determined precisely by science, that the fiscal adjustment required from changing those footprints to achieve optimal social and human welfare would be equally precisely determined.

Data, meaning "facts collected together", is generally distinguished from information produced by modelling[1]. Impact valuation is an outcome of modelling with a complicated array of data used in models at different steps. Data and models are needed to calculate footprint, to estimate capital changes, to estimate changes in social and human welfare in different communities now and into the future (Figure 17 in Food System Impact Valuation in Practice). We distinguish data as the outcome of what can be observed or minimally interpolated from observation, and calculation and estimations as the outcome of modelling (Table 3 in Food System Impact Valuation in Practice). Distinguishing "data" and "modelling" is imprecise, but useful when forums about developing impact valuation attended by companies and civil groups with supporting institutions repeat general terms such as "gathering the data", "measurement", "quantification" and "metrics". Contextualising these terms by whether they refer to observations or calculations to determine footprint, whether they refer to the additional data or information required to calculate capital changes given the footprint, whether they refer to the calculation of attributable changes in capital quantity and quality, and whether they refer to estimated changes in welfare from capital changes, would help further development of methods (Table 4). The data required for footprint calculation is very different, both substantively and in terms of sources, quality and resolution, than the data required for capital changes, and different again from the data required for valuation of capital changes.

[1] https://www.lexico.com/en/definition/data; I. Tuomi, "Data Is More than Knowledge: Implications of the Reversed Knowledge Hierarchy for Knowledge Management and Organizational Memory," *Journal of Management Information Systems* 16, no. 3 (1999), https://doi.org/10.1080/07421222.1999.11518258.

The Natural Capital Coalition Food & Beverage Guide illustrates the distinctions between footprint, capital changes and valuation under Steps 05 to 07. It gives simple illustrations of data for the calculation of impact under each step, but the distinctions have yet to permeate. The complexity of food systems compared to the simplicity of examples obfuscates the large gulf between data and model in implementation.

The discussion in Food System Impact Valuation in Practice gave examples of models and data for footprint. For example, sensors on-farm, pollution sampling of wastewater from factories, accident logs, etc. perform data collection. Lifecycle analysis databases are a mixture of collected data and calculation. Footprints obtained from Coolfarmtool[2] and inferred footprints from EEIO models, etc. are calculations.

The discussion in Food System Impact Valuation in Practice gave examples of models and data for capital changes including the calculation of societal footprints. Different institutions and different tool-sets measure societal footprint compared to actor footprint. Global monitoring of environmental capital stocks and flows is undertaken by bodies such the UN Environment Programme (UNEP), or compiled from statistics and monitoring performed by national bodies (e.g. USGS[3]). The UN Food and Agriculture Organisation (FAO) collates national statistics in FAOSTAT and AQUASTAT relevant to the global environmental, social, and economic state of the food system. Satellite and remote sensing are an increasing global monitoring capability.

There is a wave of research and projects about smart farms, big data, and smart supply chains. Many of these initiatives and investments are currently being shaped around food safety and personalised nutrition and not on data collection relevant to impact. Food safety and personalised nutrition are more immediate sources of return on investment. The opportunity may be missed to shape the data infrastructure that will be built into digital supply chains of the food sector to track impact. Monitoring of social capital at national and community levels is more diverse and less clearly articulated than environmental and health capital. There can be large barriers, in terms of technical knowledge and resources, to accessing detailed monitoring data. Most data are accessible in an aggregated form. Where capital stocks are not covered by direct monitoring, they must be interpolated or extrapolated by models. Institutions such as UNEP and FAO, and national bodies, are sometimes model developers for this purpose as well as collators of data. For capital changes associated to the food system there is an almost unmanageable diversity of models, from statistical, to integrated computer models, at global, national, and local scale. The latest IPCC report on climate change, land use and food security, at 1542 pages with 96 Contributing Authors including over 7000 cited references[4], still covered only a sample of modelling conducted in relation to food system impact. Models for estimation and attribution of natural, social and human capital changes (also called impact assessment) are generally different than those used to extrapolate or estimate footprints at the scale of activities. Socio-economic scenarios used to set exogenous parameters for the models are another diverse academic industry, discussed in Food System Impact Valuation in Practice. Future food scenarios usually depend on other models to develop quantitative projections[5].

The WorldBank, the IMF, etc. have a diverse range of trade, human development, and welfare indicators. Diverse sources of data are used in econometric statistical models of economic responses to inputs. Production factor models seek to identify the sensitivity of sectorial or

[2] https://coolfarmtool.org/
[3] https://www.usgs.gov/mission-areas/water-resources/data-tools
[4] https://unfccc.int/news/land-is-part-of-the-climate-solution-ipcc
[5] I. Y. R. Odegard and E. van Der Voet, "The future of food — Scenarios and the effect on natural resource use in agriculture in 2050," *Ecological Economics* 97 (2014), https://doi.org/10.1016/j.ecolecon.2013.10.005.

national production statistics to time series data on suspected production factors. Surveys are used to calculate individual preferences for direct payments for non-financial services or substitutes for non-financial services. Simple or sophisticated models can relate preferences to economic statistics reflecting narrow or inclusive measures of welfare.

Figure 25 in the chapter Food System Impact Valuation in Practice depicts compounding uncertainty from footprint to impact. The compounding is not just because the calculations are chained together in a conditional sequence. Footprint is more likely to be able to be measured or more directly informed by measurement. Attribution and valuation become increasingly more modelled outputs, starting with physical processes and then quickly moving into socio-economic linked systems (Figure 33).

Table 4: Examples in the division of measurement and calculation (data and models) in the three conceptual components of impact valuation

	Footprint	Capital Change	Valuation
Data	sensors on-farm, pollution sampling of waste-water from factories, accident logs, some parts of LCA databases	national environmental surveys, water gages network, satellite, and remote sensing	Human well-being surveys, national economic statistics, contingent and preference studies
Models	some parts of LCA databases, Coolfarmtool, EEIO models	UNEP-WCMC Madingley Model, FAO MOSAICC, FAO GLEAM CSIRO MAgPIE, GBD log dose-response models	Economic growth models, Integrated Assessment Models, Production function approach, Computable General and Partial Equilibrium economic models

The components of valuation need to develop together. There is little improvement in food impact costing overall if development was pushed into improving the precision of measuring an actor's footprint while methods to improve social and abatement costing languish (relying on existing diverse and partly applicable preference or contingent valuations spread through literature). Incredible uncertainties and variation as to the impact that footprint creates remains unimproved by greater precision in an actor's footprint.

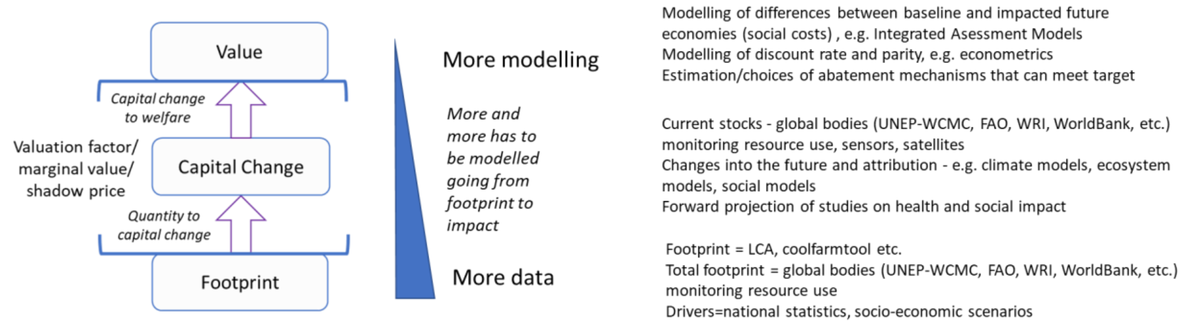

Figure 33: Footprint is more likely to be able to be measured or more directly informed by measurement. Attribution and valuation become increasingly more modelled outputs, starting with physical processes, and then quickly moving into socio-economic linked systems

Achieving change toward food system transformation targets should guide the requirements of impact valuation and its development. It is unclear if, following a logical progression, precisely knowing footprint down to individual product level is going to achieve the largest reduction of impact from the food system[6]. Investing societal resources into achieving disclosure instead of non-disclosure should be prioritised over more granular footprint modelling for footprints that are already relatively well-measured. Case studies 1-3 are initial attempts to understand the sensitivity of impact, from a global food system perspective, to environmental, social and health concerns. Case study 3 identified approximately equal impact from environment changes, social conditions, and health. Research is required to understand how the determinants of the calculation of impact match with the capability and resources for improvement: what form the improvements need to take, what aspects they need to include, where in terms of footprint, capital changes or valuation, their precision versus their practicality, and the importance of certainty in their calculation versus consensus around the calculation.

Without that research, which will also need to consider the priorities of different uses, there is no value in suggesting incremental changes relating to specific sources of data or models. There are no Integrated Assessment Models (IAMs) associated to food impact costing, and we are unable to suggest incremental improvement in such modelling in the same way the current literature on climate costing improves method and knowledge.

Should such IAMs be built for food impact costing? Yes, eventually, but probably not yet. Existing “food system models” can be augmented and utilised to inform costing. Whether they can be sufficiently integrated with the economic features required to approximate the gradients to social or abatement cost surfaces over a vector of spatial and contextual footprint (that is, calculate shadow prices) is not clear. Building equilibrium models that couple economic, environmental, social, and human health dynamic systems is a challenging task. Every food system impact valuation involves an “integrated model” in a broad sense to achieve a numerical calculation of impact. This is too ambiguous however to provide an academic focus for knowledge building and incremental improvement.

We make a recommendation on movement in a very broad direction. In previous sections, and formalised in the linear model described in Food System Impact Valuation in Practice, we have advocated for a clear delineation between footprint, compared to capital changes and valuation of capital changes. Capital changes and valuation of capital changes involve societal footprints, socio-economic drivers, impacts on national economies, projections of economic growth and global equity concerns. The data and modelling capacity, and credibility, for the estimation of marginal valuations including what footprints should be measured seems to be firmly in the camp of national and international institutions and bodies, and a societal process involving these institutions, civil society and academia. Footprint calculation is firmly in the camp of the actors.

Using single numbers linked to total global footprint is a mistake, this only works for the marginal valuation of carbon. It will produce a value, and initiate a dialogue, and is the most practical. So many features of the calculation are contestable that it will be unlikely to enable the consensus on which to facilitate economic action. More energy will be spent arguing the numbers or diverting the argument to the numbers.

Waiting for global modelling and monitoring to come online that are standardised and useable is equally a mistake. Economic measures for change in food systems are an imperative now; impact neutral as an aspiration for the food sector needs to come on the back of carbon markets and mechanisms. Models for uses that require comparison between valuations is in the future. Comparable, interoperable, standardised modelling suites validated on extensive observations of capital stocks and changes is either some time off maturity or requires

[6] A. M. Leach et al., "Environmental impact food labels combining carbon, nitrogen, and water footprints," *Food Policy* 61 (2016), https://doi.org/https://doi.org/10.1016/j.foodpol.2016.03.006.

disproportionate resources to bring to maturity. Global monitoring and almost real-time observation by satellites or networks of sensors that are capable of high-resolution determination of physical, biological and chemical changes, or analogous networks of sensors and algorithms capable of measuring changes in community and public health, are still the future. Implementation of such systems are in the future, and the ability of individual companies or food system actors to access them to determine impact along global value chains is well into the future.

This suggests a present balance between pragmatism and precision in calculation, accessibility and expertise, and need and maturity (Figure 34)

The balance will shift in terms of standard practice into the future as technology and knowledge evolves.

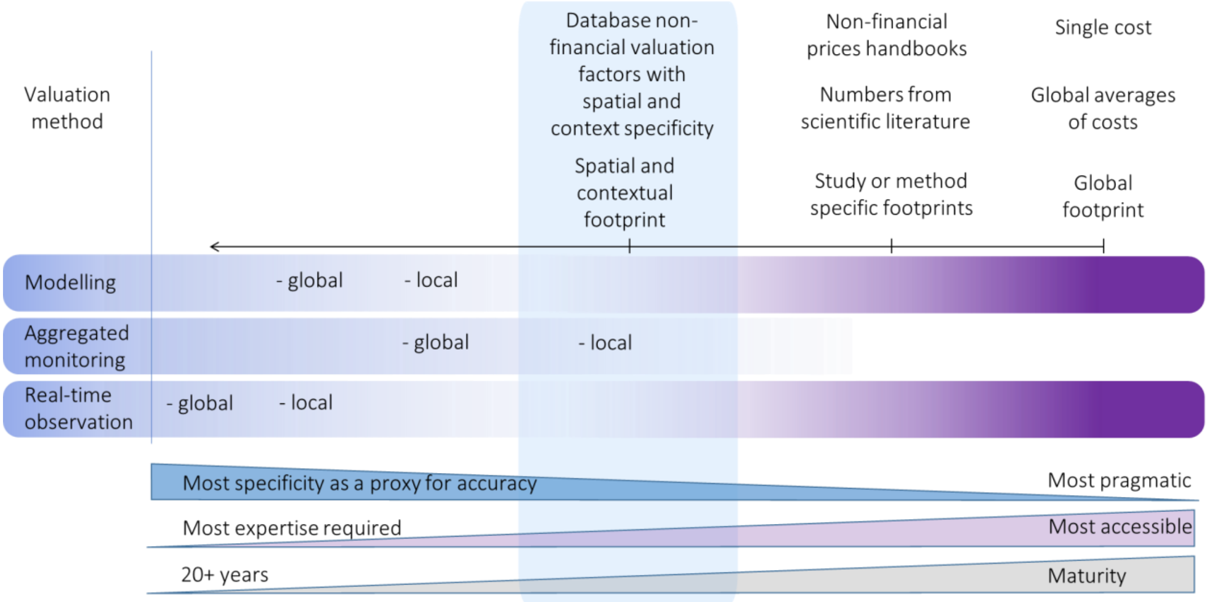

Figure 34: spectrum of approaches and development of impact costing tools moving toward the left over time. We argue that moving toward agreed and comparable food impact costing requires a pragmatic balance between spatial and contextual specification and feasibility in the ability to compile modelling and monitoring estimates into a database of valuation factors for common use. This is a step to left from the present use of national handbooks on environmental and social pricing, literature estimates, and a lack of uniformity in footprint.

Using costings and calculations ad hoc from literature is for local project analysis without comparison with projects in other locales, or for internal costing by companies. Agreed and comparable food impact costings require a consistent synthesis.

Non-financial marginal valuations provided by national handbooks are not comprehensive on the shadow prices needed for food impact costing, especially with a focus on achieving food system transformation. They predominately focus on environmental pollutants, some of which are a major concern for food system impact and some of which are a minor concern or already regulated. The presentation of uncertainty is very limited. It is difficult for national handbooks to act as comprehensive guides for food impact costing, as a common approach to which footprints should be measured (and so marginal valuations with respect to what) is missing. The food sector, as one of the most complex to associate impact costs to, needs its own development of shadow prices.

Databases able to link a marginal valuation in a footprint to where and how it was emitted, occurred, extracted or consumed at a broad contextual and catchment or subpopulation level are an intermediate step between lists in national handbooks and future integrated assessment models for food system impacts. As discussed in Food System Impact Valuation in Practice, the spatial and contextual specifics should be attached to the major distinctions in location and context relevant to impact. Experts groups, and national and international bodies, using models to inform and update valuation factors is significantly different from the models being useable and interfaced with the users themselves. This is an IPCC or IPBES style of consensus building, not an exercise in global equilibrium modelling capability[7]. The linear model described in Food System Impact Valuation in Practice is linked to the development, or initial steps toward, such a database. In advocating risk pricing, being able to incorporate uncertainty through risk pricing is mostly aimed at facilitating consensus rather than a new scientific method. We suspect it would presently cost more in terms of time and money to develop a linked socio-economic food system model so definitive it creates the same level of consensus as a societal process aimed at establishing, setting, and updating a database of shadow prices for common use. The two are connected of course, the first will link to the second, and the second will sponsor the first. We are not arguing for an exclusive either or, but proportional priority for investment. Scientific consensus building is more than collating figures extracted from scientific literature, but less than a global modelling exercise.

An aim of this report is to stimulate additional examination between the three factors of: value in doing impact costing for the food system; the costs in upfront investment in the kind of database recommended; and the benefits once established.

Food impact costing is a complicated task. Marginal valuations, though absorbing ethical choices, variations, and uncertainty, are easy to use for all parties if credible and established. From government, to agricultural producers, to large companies, to small and medium enterprises in the food sector. Large companies can measure their own footprints (upstream and downstream) as the actors which dominate the food sector in market share (and likely impact) terms. Government assistance in schemes such as the EU Product Environmental Footprint (PEF) perform footprint calculation for small and medium enterprises which dominate the food sector in terms of head count. Footprint tools and calculators are more advanced in the sector than impact calculators. Footprint to determine the health impact of consumed food products is already largely measured or modelled in the industry. Footprint associated to social material issues for society currently lags environment and health.

The use of marginal valuations is observed across the case studies in Case Studies of Food System Impact Valuation and uses of food impact costing. However, the investment in the database of food system specific shadow prices is proportional to the take up of the uses and their contributions toward sustainable food systems. The Food System Impact Valuation Initiative is primarily a network to bring closer together the triad of actors in Figure 4 in the chapter Economic Theory of Change, and match the development of food impact costing to users and uses.

The trade-off between resolution of footprint and impacts, resources available to conduct the impact costings, and the amount of change created by estimates, have been noted in previous impact valuation studies[8].

To summarise, it is the view of this report that valuation factors be used with caveats. A societal process toward a database of shadow prices at a pragmatic level of resolution – enough

[7] C. O. Flores et al., "Food Webs: Insights from a General Ecosystem Model," *bioRxiv* (2019), https://doi.org/10.1101/588665, http://biorxiv.org/content/early/2019/03/26/588665.abstract.

[8] p. 80: FAO, *Food wastage footprint: full-cost accounting*, Food and Agriculture Organization of the United Nations (Rome, 2014).. p. 13-20: COWI, *Assessment of potentials and limitations in valuation of externalities*, The Danish Environmental Protection Agency (Copenhagen, 2014). and p.26. The COWI report calls footprint “impact assessments”, valuation of footprint “economic valuation”, with marginal valuation called “unit values”.

spatial, temporal, and contextual detail to avoid gross errors but coarse enough to make compiling the database feasible. It is more important to get estimates that point in the right direction, within enough resolution to distinguish sustainable production methods, and gather a collective weight willing to promote and use scientifically based food impact costings rather than wait for synthesised and standardised modelling efforts to emerge from a myriad of scientific projects.

Additional comments on alignment and standardisation are made in the next chapter on Implications. The database building would not be starting from scratch.

Inventory of methods

The following inventory collates many of the data sources, tools and models mentioned in the report. It makes no claim on comprehensiveness. Some of these models and techniques feature in the case studies, where strengths and limitations were discussed in more detail. Another project within the food true cost accounting community mentioned in the Introduction and Glossary is developing a wider list of methods, tools and case studies. The list is structured according to the dimensions identified in previous sections: data or model; footprint, capital change, valuation; and spatial, temporal, or contextual resolution.

Name and Link	Data or Model	Step of Valuation	Spatial, Contextual or Temporal Factors
TEEB AgriFood Evaluation Framework http://teebweb.org/agrifood/home/evaluation-framework/		Impact Framework	Specific to food system. Comprehensive, downstream and upstream.
Natural Capital Protocol Social and Human Capital Protocol https://naturalcapitalcoalition.org/natural-capital-protocol-food-and-beverage-sector-guide/		Impact Framework	Not specific to food system. Food & Beverage Guide with upstream natural capital examples.
Social Return on Investment (SROI) http://socialvalueint.org/		Impact Framework	Not specific to food and beverage. Generic approach.
E.Valu.A.TE https://www.cisl.cam.ac.uk/resources/natural-resource-security-publications/evaluate-practical-guide		Impact Framework	Specific to agriculture and upstream externalities.
FAOSTAT AQUASTAT http://www.fao.org/faostat/	National data with some calculation	Footprint calculation. Capital change calculation. Market valuation.	Emissions data for carbon footprint. Land-use indicators. Fertiliser use indicators. Pesticide application indicators. Production data for human consumption footprints.

Name and Link	Data or Model	Step of Valuation	Spatial, Contextual or Temporal Factors
			Trade. Market values.
LCI https://www.iso.org/standard/37456.html https://www.iso.org/standard/38498.html	Mostly data from studies, interpolated or extrapolated to other regions and production lines	Footprint calculator: GHG emissions Ozone depletion Particulate matter and air pollutants Land and water acidification Human toxicity Water use Land use Resource Scarcity	Life cycle inventory analysis. Full lifecycle possible, input to consumption to waste. Contextual detail built into the LCI model and dependant on database characteristics. Spatial detail depends on availability or aggregation in LCA databases.
Coolfarmtool https://coolfarmtool.org/	Model based on scientific data	Footprint calculator: GHG emissions Water Biodiversity	Agricultural production. Different land-use and management contexts. Different production contexts. See https://coolfarmtool.org/wp-content/uploads/2016/09/Data-Input-Guide.pdf Farm, fertiliser and energy inputs, and limited storage and processing. Calculation inferred spatially and contextually from the original study sites underlying the scientific data. More granular and specific than LCA databases.
Environmentally Extended Input Output (EEIO) https://www2.mst.dk/Udgiv/publications/2014/03/978-87-93178-33-5.pdf	Model based on input-output data and regression of environmental damage per sector.	Footprint calculator: GHG emissions Particulate matter and air pollutants Water use Land use	Upstream. Proportion of flow other of sectors into a target sector the economy is determined from an IO model. Little spatial distinction. The IO model is based usually on one developed economy. Then quantities of emission, pollutants, etc. assigned per value of subsector (“environmental intensities”), which is the EE part of the EEIO model. Footprint calculations are sector averages. Resolution is coarser than LCA.

Name and Link	Data or Model	Step of Valuation	Spatial, Contextual or Temporal Factors
			Environmental information may be hybridized with LCA. See COWI (2014).
SOL-m http://www.fao.org/nr/sustainability/sustainability-and-livestock/en/	Model	Footprint calculation: Production per country per commodity Nitrogen and Phosphorous application per country per commodity GHG emissions Land-use Pesticide use	FAO Sustainability and Organic Livestock model. Can back-calculate spatial footprints at national level. Contextual difference concentrates on organic versus conventional agriculture.
World Bank https://data.worldbank.org/	Data	Capital changes: Socio-economic drivers and development	Statistics on populations, demographics, Human Development Indices (HDI), Corporate activity, etc.
Co$ting Nature Tool: Kings College London	Model	Capital change	Conservation priority, biodiversity, water quantity and quality, water provisioning services, carbon services, nature-based tourism are mapped, together with threats and pressures and vulnerability to hazards which can indicate priority capital changes. High spatial resolution data sources. Receivers of services also mapped. Users apply own valuation factors. https://blogs.kcl.ac.uk/eoes/2016/06/07/costing-nature-tool-to-support-sustainable-decisions/
Institute for Health Metrics and Evaluation (IMHE) Global Burden of Disease (GBD) database http://www.healthdata.org/diet	Model from underlying health data	Capital changes: Human preventable disease and death	DALYS attributable. Dietary risk factors (obesity, diabetes, non-communicative diseases, child growth failure) Air pollution Diaorheaa
Lifecycle Impact Assessment (LCIA)	Model	Capital changes.	LCIA calculates from an LCI to midpoint capital changes, or impact pathways to endpoint impacts on human health,

Name and Link	Data or Model	Step of Valuation	Spatial, Contextual or Temporal Factors
		Changes in GHG emissions, Ozone depletion, Particulate matter and air pollutants, Land and water acidification, Human toxicity, Water use, Land use, Resource Scarcity to Human health impact (DALYs), Ecosystem impact (species lost), Resource scarcity (additional monetary cost)	ecosystems and resource availability. ReCiPe 2016: https://www.rivm.nl/bibliotheek/rapporten/2016-0104.pdf CML 2016 https://www.universiteitleiden.nl/en/research/research-output/science/cml-ia-characterisation-factors
RAND study on Anti-Microbacterial Resistance https://www.rand.org/pubs/research_reports/RR911.html	Model	Capital changes and valuation	AMR shock to human morbidity and mortality and labour losses. Global general equilibrium economic model used to calculate costs under seven scenarios of AMR resistance. Regional morbidity and mortality and GDP losses over time.
Water Scarcity	Model	Capital Changes Water use	Designed to add water stress indicator to LCIA midpoint and calculate damages to LCIA endpoints. Human health functional model allowing input of local and contextual factors (variance of precipitation, water extraction, agriculture use, water stocks, HDI, malnutrition) with output in DALYs. Function is non-linear in water extraction, quadratic in HDI and linear in malnutrition rates. Pfister (2015).
Pesticides	Model	Capital change Pesticides	Pesticide exposure pathways of inhalation (workers), soil and drinking water contamination and vegetal consumption with human health effects in DALYs. Non-linear model with uncertainty analysis. Fantke (2016)

Name and Link	Data or Model	Step of Valuation	Spatial, Contextual or Temporal Factors
Stunting effects	Model	Capital Changes Malnutrition	Model to link dietary intake in first 1000 days (from conception) and link to outcomes in Adulthood and hence to income. Hoddinot (2013)
GLASOD/GLADA http://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1036321/	Model and database	Capital change: Land degradation	Degraded land. Qualitative severity of degradation, 12 types soil degradation types and 5 causal factors. Spatial explicit 1:10million scale global map. Updated by GLADA. Additional spatially explicit resources on soil see ISCRIC World Soil information: https://data.isric.org/geonetwork/srv/eng/catalog.search#/home
GLOBIOM https://www.globiom.org/	Model	Capital changes or total footprint calculation	Partial equilibrium model of agriculture, bioenergy and forestry sectors. Needs exogenous settings of GDP, population, technological advance and consumption demand. Endogenously determines agricultural land use, crop and livestock production, water use, estimates of fertiliser use, GHG emissions, commodity prices and yields. Environmental data spatially explicit collated and aggregated data based on 5 arcmin. Economic data national.
IMPACT https://www.ifpri.org/program/global-futures-and-strategic-foresight	Model	Capital changes or total footprint calculation	Partial equilibrium multi-market model. Needs exogenous settings of GDP, elasticities, population, and consumption demand. Endogenously determines agricultural land use, crop and livestock production, water use, GHG emissions, trade, commodity prices and yields. Environmental data spatially explicit collated and aggregated data based on 5

Name and Link	Data or Model	Step of Valuation	Spatial, Contextual or Temporal Factors
			arcmin. Economic data national.
Natural Capital Project https://naturalcapitalproject.stanford.edu/	Model	Capital changes and valuation: Ecosystem modelling.	Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) modelling platform for natural capital. Spatial resolution of ecosystems (sources of good and services) and human habitats (receivers of goods and services) integrated with GIS. From website: "InVEST is a suite of models used to map and value the goods and services from nature that sustain and fulfill human life." Free and open source.
Shared Socio-economic pathways (SSPs)	Model	Scenarios	Socio-economic scenarios used widely in environmental change science. O'Neill (2014)
Representative Agricultural Pathways (RAPs)	Model	Scenarios	Part of the Agricultural Model Intercomparison Project (AGMIP), Valdivia (2014)
OECD Productivity Statistics https://www.oecd.org/sdd/productivity-stats/	Data with some calculation	Valuation	Productivity figures for standard valuations of improvements in DALYs.
EU-28 Handbook Environment prices https://www.cedelft.eu/en/publications/2191/environmental-prices-handbook-eu28-version	Model	Handbook of valuation factors	The CE Delft EU-28 handbook mostly adapts the EU funded NEEDS model of impact pathways to calculate shadow prices for environmental pollutants to air, water and soil. Structured to connect to LCI, LCIA midpoints and LCIA endpoints and harmonize pricing between them. See LCI and LCIA for priced quantities (or Tables 1-3 of Handbook). Uncertainty in EU-28 Handbook. Low-Central-High pricing is used. European prices.
FAO 2014 Food wastage footprint full-cost accounting study	Model	Table of valuation factors	Water (N and P eutrophication and pesticide contamination), biodiversity and soil valuation factors collected in Table 2 (p.

Name and Link	Data or Model	Step of Valuation	Spatial, Contextual or Temporal Factors
			33) http://www.fao.org/3/a-i3991e.pdf
Nitrogen costs	Model	Table of valuation factors	Marginal valuation and ranges for air, soil and water nitrogen pollution in Table 1 van Grivsen (2013)
IWGSCC social cost of carbon	Model	Valuation factor	US EPA Interagency Working Group Social Cost of Carbon (IWGSCC) distribution of estimates for the social cost of carbon https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf
CPLC marginal abatement cost of carbon	Model	Valuation factor	Carbon Pricing Leadership Coalition (CPLC) range for the marginal abatement cost of carbon https://www.carbonpricingleadership.org/report-of-the-highlevel-commission-on-carbon-prices.
UK Treasury Green Book https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent	Data and models	Handbook of valuation factors	Describes role of discounting and SROI. Valuation factors on air pollution and water quality in Annexes, with links to other UK government sources of valuation factors. Also discusses substitution or “unmonetizable values”.
TruCost methodology	Models	Valuation factors	Global averages used in GaBI software. Country factors proprietary. Environmental. GHG Emissions, air land and water pollutants, eutrophication, water consumption, land use. https://www.gabi-software.com/fileadmin/GaBi_Databases/Thinkstep_Trucost_NCA_factors_methodology_report.pdf.
Ecosystem Services Valuation Database (ESVD) https://www.es-partnership.org/services/data-knowledge-	Model (synthesis of literature)	Database of valuation factors	Searchable online database of valuation studies on ecosystem services. de Groot (2012)

Name and Link	Data or Model	Step of Valuation	Spatial, Contextual or Temporal Factors
sharing/ecosystem-service-valuation-database/			
Global Health Cost-Effectiveness Analysis (GHCEA) Registry http://healtheconomics.tuftsmedicalcenter.org/ghcearegistry	Model (synthesis of literature)	Database of valuation factors	Review of cost-per-DALY estimates with ranges. Neumann (2016)
Health Utility of Income https://www.valuingnature.ch/single-post/2018/07/20/VALUING-THE-IMPACT-OF-WAGES-ON-HUMAN-CAPITAL	Model	Valuation	Calculates health benefits of income. Is a function that inputs income and country and outputs DALY benefit. DALY benefit can be monetised. Linear regressions.
Global Value Exchange http://www.globalvalueexchange.org/	Synthesis of literature	Database of valuation factors	Global Value Exchange (GVE) ingested data from literature or reports to connect outcomes to valuations. Search on food lists 6 outcomes, 27 indicators of those outcomes and 127 valuations that have been. Valuations are specific to the study sites and participants. Links to the sources of the valuations. http://www.globalvalueexchange.org/news/b07bcb501c
Literature review	Model based on social discount rate review	Discount rate	Moore (2004) provides a review and a prescription for discount rates.
UK Treasury Green Book supplementary guidance: discounting https://www.gov.uk/government/publications/green-book-supplementary-guidance-discounting		Discount rate	In the United Kingdom, HM Treasury fixes the social discount rate for the public sector at 3.5% with recommended adjustments for intergenerational effects. See UK Treasury Green Book Table 8 and (Lowe 2008)
ReCiPe perspectives: individualistic, hierachistic, egalitarian	Model	Discounting	From ReCiPe 2016 LCIA method and utilised in CE Delft Environmental Prices Handbook. Individualist: proven cause-effect relationships, short-term perspective (20 years). Hierarchistic: facts backed by scientific and political bodies (100 years). Egalitarian:

Name and Link	Data or Model	Step of Valuation	Spatial, Contextual or Temporal Factors
			precautionary approach, long-term perspective (1000 years).
Currency Exchange Rates	Data	Parity	Compare national economies by currency exchange rates. https://www.imf.org/external/np/fin/data/param_rms_mth.aspx
Purchasing power parity (PPP)	Model based on consumption data	Parity	Compare national economies by ability to purchase basic goods. World Bank Intercomparison Program. https://www.worldbank.org/en/programs/icp
Global Utilitarianism	Data	Parity	Global PPP GDP per capita.
Prioritarianism	Model	Parity	Greater value for benefits to the socio-economically worst off. Applied in literature studies, e.g. Adler (2017)
Benefit transfer	Model	Parity	Applied ad hoc to transfer economic value from study sites to other sites https://link.springer.com/chapter/10.1007/978-94-017-9930-0_2
PPP GDP	Model based on economic data	Welfare measure	IMF, World Bank
Satisfaction complemented GDP	Model based on economic data	Welfare measure	Stiglitz (2009), Jones and Klenow (2010)
Wealth measures	Model based on economic data	Welfare measure	UN Inclusive Wealth 2018
PAGE	Model	Integrated model	Climate damages (see IWGSCC social cost of carbon)
DICE	Model	Integrated model	Climate damages (see IWGSCC social cost of carbon)
FUND	Model	Integrated model	Climate damages (see IWGSCC social cost of carbon)
NEEDS	Model	Integrated model	Air pollution damages (see EU-28 Handbook Environment prices)
LCA Software	Model	Integrated model	Allows LCI (footprint calculation), LCIA and pricing to be performed together. Environmental focus, e.g. SimaPro uses EU-28 Handbook Environmental

Name and Link	Data or Model	Step of Valuation	Spatial, Contextual or Temporal Factors
			prices and GaBI uses TruCost prices.

Listing the methods from the report shows that environmental and health considerations applicable to the food system impact valuation are the most developed. Social impact pathways the least.

REFERENCES

COWI. *Assessment of potentials and limitations in valuation of externalities.* The Danish Environmental Protection Agency (Copenhagen: 2014).

FAO. *Food wastage footprint: full-cost accounting.* Food and Agriculture Organization of the United Nations (Rome: 2014).

Flores, C. O., S. Kortsch, D. Tittensor, M. Harfoot, and D. Purves. "Food Webs: Insights from a General Ecosystem Model." *bioRxiv* (2019): 588665. https://doi.org/10.1101/588665. http://biorxiv.org/content/early/2019/03/26/588665.abstract.

Leach, A. M., K. A. Emery, J. Gephart, K. F. Davis, J. W. Erisman, A. Leip, M. L. Pace, *et al.* "Environmental impact food labels combining carbon, nitrogen, and water footprints." *Food Policy* 61 (2016): 213-23. https://doi.org/https://doi.org/10.1016/j.foodpol.2016.03.006.

Odegard, I. Y. R., and E. van Der Voet. "The future of food — Scenarios and the effect on natural resource use in agriculture in 2050." *Ecological Economics* 97 (2014): 51-59. https://doi.org/10.1016/j.ecolecon.2013.10.005.

Tuomi, I. "Data Is More than Knowledge: Implications of the Reversed Knowledge Hierarchy for Knowledge Management and Organizational Memory." *Journal of Management Information Systems* 16, no. 3 (1999): 103-17. https://doi.org/10.1080/07421222.1999.11518258.

PREVIOUS SECTION: 7. CASE STUDIES OF FOOD SYSTEM IMPACT VALUATION

Valuing the impact of food:

Towards practical and comparable monetary valuation of food system impacts

A report of the Food System Impact Valuation Initiative (FoodSIVI)

May 2020

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NEXT SECTION: 9. IMPLICATIONS