Journal of Cleaner Production 335 (2022) 130182

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

The impacts of soy production on multi-dimensional well-being and ecosystem services: A systematic review

Ilda Dreoni [a,*], Zoe Matthews [a], Marije Schaafsma [b,c]

[a] University of Southampton, Department of Social Statistics and Demography, UK
[b] University of Southampton, School of Geography and Environmental Science, UK
[c] Department of Environmental Economics, Institute for Environmental Studies, Vrije Universiteit, Amsterdam, the Netherlands

ARTICLE INFO

Handling editor: Cecilia Maria Villas Bôas de Almeida

ABSTRACT

International trade in soybean has been increasing exponentially over the last 30 years, stimulating agricultural expansion and intensification, primarily in South America. Trade in soybean has been promoted by national and international agencies to stimulate economic development in low- and middle-income countries. Trade in soybean has generated an increase in GDP and average income in producing countries, but soybean production is also linked to negative effects on the well-being of local populations, such as land appropriation and increased social conflicts among communities. In addition, soybean production is linked to extensive deforestation and clearance of natural vegetation as well as water pollution due to intensive agricultural practices, which in turn has negative impacts on human well-being. As such, more information is needed to understand the range of negative and positive impacts of soybean production on people and the environment.

This study presents a systematic literature review of the direct and indirect social-economic impacts of soybean agricultural production for trade. We employ the concept of multi-dimensional well-being to classify the various direct social impacts that have been found in the literature and the concept of ecosystem services to classify indirect social impacts, as the contribution of natural ecosystems to human well-being. The main finding of the review is that the empirical evidence for direct social impacts of soy production is scarce and mixed in terms of direction of impact. More tangible dimensions such as income, nutrition and living standards are more often positively impacted by soy trade, while more intangible dimensions such as freedom of choice and cultural value are found to be negatively affected. The empirical evidence for impacts on ecosystem services is more comprehensive and shows a clear picture of negative impacts associated with soybean production due to land use changes and deforestation, and agricultural intensification. There is hardly any evidence for the effectiveness of sustainable value chain policies.

1. Introduction

Agricultural expansion and intensification as a development strategy for low- and middle-income countries (LMIC) have been widely promoted by international development agencies as well as national governments over the past 30 years (World Bank, 2019). The economic liberalization of international trade in agricultural commodities is expected to attract investments and stimulate economic growth by increasing the economic productivity and the efficiency of the agricultural sector as well as all other economic sectors involved in production for export (Dornbusch, 1992). At the global level, the impact of international trade and the increase in volume of international traded commodities are found to be linked to increases in average income and reductions in poverty rates in many countries (World Bank, 2019). But it is important to acknowledge that the economic benefits of trade may be overestimated if their environmental and social costs are not taken into account.

The story of soybean trade exemplifies the complexity and diversity of impacts of liberalization of international trade on producing countries. Soybean is a legume that is widely consumed both as a whole soybean as well as after being processed as a soy oil, for biofuel and edible oils, and as soy cake, for animal feed and other food products (Boerema et al., 2016). The global production and international trade of soybean has increased greatly in the last 20 years driven by an increase

* Corresponding author. University of Southampton, University Rd, Highfield, Southampton, SO17 1BJ, UK.
E-mail address: Ilda.Dreoni@soton.ac.uk (I. Dreoni).

https://doi.org/10.1016/j.jclepro.2021.130182
Received 28 June 2021; Received in revised form 9 December 2021; Accepted 17 December 2021
Available online 22 December 2021
0959-6526/

in global demand, particularly because soy is used as a source of protein for animal feed as well as for biodiesel production (Silvério et al., 2015). Soybean is mainly produced in South and North American countries such as USA (28% of global production according to FAOSTAT in 2019), Argentina (16% of global production) and Brazil (33% of total production) accounting for almost 80% of the total global production in 2019. (De Maria et al., 2020; Trase, 2018).

In Brazil for example, the development of the soybean sector, and more broadly the agricultural sector, over the last 30 years demonstrates the positive effects of international trade in agricultural commodities on economic growth, in terms of an increase of average incomes and consumption expenditure, and a reduction in the number of people under the poverty line (Fearnside, 2001; Garrett and Rausch, 2016; Weinhold et al., 2013). Nonetheless, such development has come at the cost of deforestation and clearance of natural vegetation, due to the need to clear land for expanding agricultural areas, and environmental degradation, due to the intensification of agricultural practices (Sauer, 2018). Moreover, it has been suggested that trade liberalization has a wide range of negative social impacts, such as violent land appropriation and farmers displacement, as well as violations of human and labour rights (Busscher et al., 2020; Greenpeace Brazil, 2018). The environmental impacts, especially those associated with the deforestation of the Amazon, are more broadly recognised and acted upon through various value chain initiatives that involve national governments, international organizations and businesses, such as agribusiness companies and international traders (Heilmayr and Lambin, 2016; Lambin et al., 2018; Virah-Sawmy et al., 2019). For example, the Soy Moratorium is a voluntary agreement, involving large transnational grain companies such as Cargill, Bunge and Amaggi, soy producers and environmental NGOs, which ban the direct conversion of the Amazon forests for soy production. Other examples of value chain initiatives that aim to mitigate negative environmental impacts include certifications, such as those promoted by the Round Table for Sustainable Soy (RTRS), as well as social corporate responsibility policies of individual businesses involved in trade (Garrett et al., 2021; Newton and Benzeev, 2018).

The focus on the environmental impacts of soybean production and value chain initiatives to reduce these impacts, i.e. stop deforestation, has been discussed by Lambin et al. (2018) who performed a review of current supply-chain initiatives and its effectiveness in reducing deforestation. More recently, Garrett et al. (2021) performed a systematic literature review to examine the role of sustainable policies implemented by companies involved in trade of agricultural commodities such as coffee, cocoa and soy, not only focussing on environmental impacts, but also social and wellbeing impacts too. Their review focused on studies that provide a rigorous assessment of positive conservation outcomes and positive livelihood outcomes linked both to private reporting standards as well as third-party independent certifications of sustainable trade. The study found that almost half of their sample of 37 studies provide evidence that forest-focused supply chain interventions have at least some positive impacts, either on conservation or livelihood outcomes, but the evidence of rigorous assessments of both outcomes is scarce. Focusing specifically on soy, the review found only one study with evidence for impacts of soy interventions on conservation outcomes, and none about livelihood outcomes. Jia et al. (2020) performed a systematic review specifically focused on sustainable soybean value chain management to understand the drivers underlying social, economic, and environmental impacts. The study identified as main challenges to social sustainability issues related to child and forced labour, poverty and rural livelihoods, land use conflicts and health impacts. Moreover, the study highlights that social aspects of sustainable production have received less attention in the literature compared to environmental and economic challenges.

Overall, the evidence on the social impacts of soybean production that emerged from previous reviews is very scant and focused more on environmental and economic impacts compared to social ones, therefore in this paper we undertake a systematic review with a specific focus on social impacts of soybean production. The aim of the review is to identify the direct impacts of soybean production on human well-being that are empirically measured and that can be related to the concept of multidimensional well-being (Schleicher et al., 2018). Moreover, we recognise that soybean production may have indirect impacts on human wellbeing through impacts on natural ecosystems, such as forests, and influence the ability of natural ecosystems to provide goods and services that contribute to human well-being, i.e., ecosystem services (ES). Therefore, our systematic review also includes indirect impacts on ES of soybean production. Finally, we map the results of our review onto the Sustainable Development Goals (SDGs - United Nations, 2020).

2. Methodology

To achieve our aim, the literature review was guided by the following research questions:

1) What are the impacts of soybean agricultural production and expansion on human (multidimensional) well-being (direct impacts)?
2) How do these impacts differ across different actors?
3) What are the impacts of soybean agricultural production and expansion on the supply of ES and benefits (indirect impacts)?

2.1. Search strategy

The focus of the literature review is on original empirical studies measuring direct and indirect impacts of soybean agricultural production with a global scope, i.e., including all producing countries. The review included two main sources of literature: peer-reviewed academic literature and grey literature produced by key soy trade-related organizations. We excluded existing reviews or meta-analyses as such reviews do not provide new empirical evidence and to avoid reproducing any potential bias of previous literature reviews (Ganeshkumar and Gopalakrishnan, 2013; Grant and Booth, 2009; Liberati et al., 2009). We furthermore excluded non-English papers and papers focused on consumption benefits that occurred outside of soy production areas.

ISI Web of Knowledge was selected as the (only) search engine and database to conduct a comprehensive search of the peer-reviewed literature. For the review on direct impacts, we developed an initial list of search terms by reviewing the terms used in comparable systematic literature reviews on well-being/poverty topics, for instance Roe et al. (2013). The search was refined iteratively through filtering by disciplines, document type (article) and publication years (2000–2020) to obtain a manageable number of hits. The full search string is presented in Annex 1 (Table A1.1) and generated an initial number of hits of 19,625 reduced to 6825 for the first abstract screening.

Similarly, for the literature review of the indirect impacts an initial list of search terms was developed by reviewing the terms used in comparable systematic literature reviews on ES, for instance Harrison et al. (2014). The search was refined iteratively through filtering by disciplines, document type (article) and publication years (2000–2020). The full search string is presented in Table A1.2 and generated an initial number of hits of 34,254 reduced to 1042 for the first abstract screening.

The strategy for the grey literature search involved using e-libraries and online repositories of key organizations selected from lists that have been developed by comparable systematic literature reviews on well-being/poverty topics, for instance Bottrill et al. (2014), and the SSRN repository (https://papers.ssrn.com/sol3/DisplayAbstractSearch.cfm). Moreover, we searched grey literature from soy sector specific sources such as private sector actors, certification bodies, sector-wide multi-stakeholder bodies and NGOs, non-academic research institutes (See Annex 1 Table A1.3). The search of these repositories generated a total number of 3603 reports.

2.2. Inclusion and exclusion criteria

The peer-reviewed academic literature was screened using two sequential screening processes. The first step was to screen the article title and the abstract, while in the second step we screened the article content. The criteria applied both for the first screening of the title and abstract and for the content screening were:

- Inclusion: Empirical studies that use primary data or present a new analysis of existing secondary data, quantitative and qualitative, based in one or more countries, and that measure some form of poverty, well-being, or (human) resilience etc. at country, sub-national, household and/or individual level, focusing on soy production.
- Exclusion: As well as opposites of the above, studies using mechanistic models, scenarios or essays without providing new empirical data or new analysis of secondary data sources for links between soy production and well-being/poverty; existing reviews or meta-analyses; inaccessible papers; non-English papers.

No studies were excluded based upon lack of academic quality. We assumed that the academic publishing process provides a sufficiently rigorous assessment, acknowledging that ideas of what constitutes quality is not homogeneous.

For the grey literature, we split the first step into a screening of the title before reading the abstract. The title criteria involved:

- Inclusion: Titles must mention the relevant product (i.e., soy).
- Exclusion: Titles which suggest that the study focuses on chemical or genetic analysis or that the report does not provide an analysis of primary or secondary data (but rather, a review or meta-analysis).

The criteria applied to the abstracts were the same as for the peer-review academic studies.

Despite the large number of studies remaining after the first screening, only 18 articles about well-being impacts and 16 articles about ES impacts remained for the analysis (Fig. 1 and Annex 1 – Table A1.4). Three studies that were included in the well-being literature dataset also reported impacts on ES benefits, so the final total number of papers included in the analysis of the indirect impacts is 19. No grey literature was included in the literature dataset. The studies that were excluded during the second screening were not included because they did not meet inclusion criteria such as presenting empirical results, mentioning link between soy and human well-being or because were inaccessible.

2.3. Literature dataset and coding scheme

The relevant information from the selected articles was first extracted using an online survey tool (self-designed google form). Next, the information was coded using a standardised coding scheme such that the literature included could also be examined through quantitative methods.

2.3.1. Impacts on well-being (direct impacts)

To classify the direct impacts of soybean agricultural production and expansion reported in the literature, we employed a multidimensional concept of well-being (Schleicher et al., 2018, Schaafsma and Gross-Camp, in press) which includes nine different well-being dimensions classified as outcomes, one well-being dimension classified as an output and two other indicators of well-being (Table 1).

For each article or report, we recorded as a single impact every empirical measure of change in one of the well-being dimensions that is associated with soybean production. The classification of each well-being dimension has been done by the person who has performed the systematic review based on the definition of each category as presented in Table 1. In some cases, the link between well-being dimensions in Table 1 and impact of soy production described in the papers required some interpretation which has been performed by the reviewer according to the information provided in the paper. We recorded the impacts either as positive, negative or no effect. Some studies, mainly those using secondary data, employ the same dataset or variable to measure

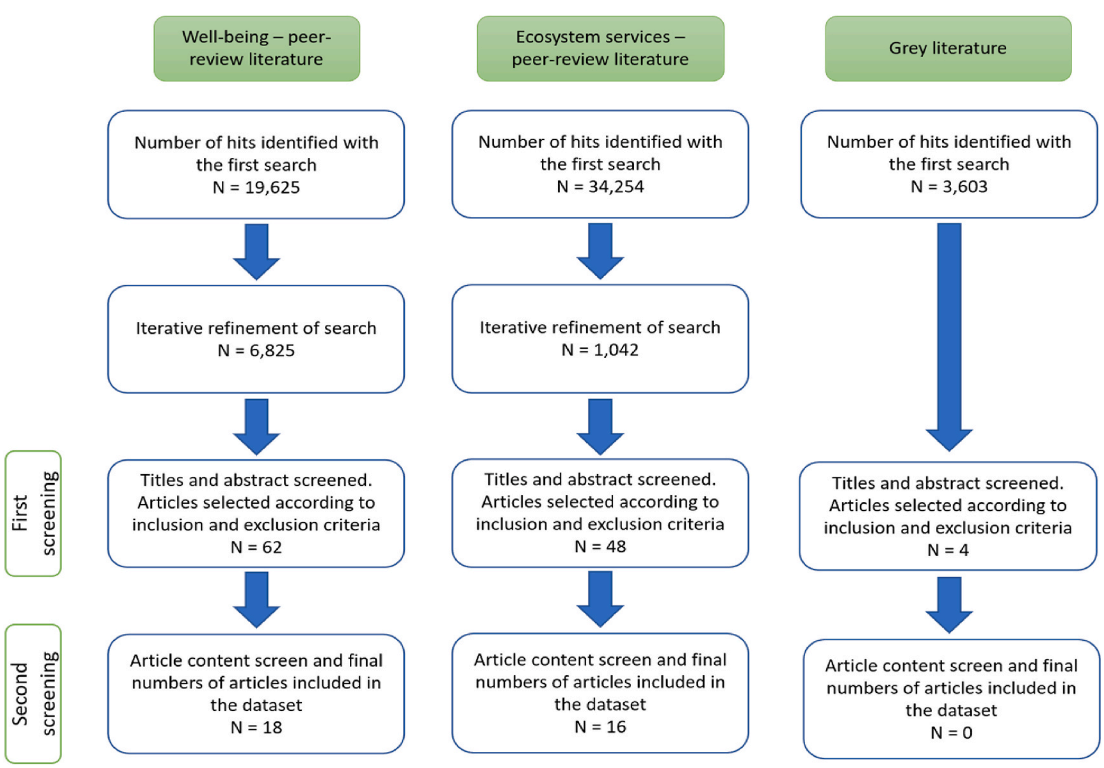

Fig. 1. Systematic review process.

Table 1
Classification of well-being impacts.

Well-being dimension - outcomes	Description
Health (physical)	Feeling strong and well; able bodied; and one's ability to maintain health
Food/Nutrition	The ability to provide in one's personal and households' food and nutritional needs throughout the year, including food that one buys, produce oneself or collect.
Education	The ability to obtain the schooling one wants personally, to send one's children to school, including the required materials (e.g. books, uniforms, materials, fees)
Living standards	Shelter (adequate flooring, roofing and walls, sanitation, electricity); motorbikes or bicycles; mobile phones; farming/fishing equipment; livestock; safe drinking water; fuel.
Cultural value	The freedom to conduct traditional, cultural, tribal and religious practices, and spiritual values, including those attached to nature.
Freedom of choice and actions	The ability to live the life one wants, with a sense of power to control and agency over one's own life; according to one's values and norms; being independent from the goodwill of others; including one's livelihood such as a self-sustaining farmer/fisher; the ability to choose and achieve your goals in life. The ability to influence decisions that are made by others in the community and beyond that affect one's life; to be empowered; a life without discrimination (race, gender, etc.)
Security, safety from other people (Sense of security)	The ability to live in safety and confidence in the future; peace and harmony – free from harm inflicted by other people, such crime, mugging, physical violence (incl. rape), lack of protection from police, lack of justice.
Living in safety from risk inflicted by nature, and in a clean, healthy environment (Environmental risk)	Extensive harm or psychological stress created by exposure to environmental risk. The ability to feel that one's life is safe from droughts, floods, heatwaves, mudslides, storms, tsunamis, earthquakes, etc. The ability to live surrounded by clean water in rivers and lakes, breathe clean air, i.e. live in a safe and healthy environment free from pollution. The ability to live without suffering crop losses, killings (by elephants, hippos, lions, etc.)
Social relations	The ability to have meaningful relationships with family and friends, to have family cohesion and respect within families, communities and external actors. The ability to help or rely on others in times of need, for example, the ability to care for, raise, marry and settle children, and to participate fully in society and social events such as celebrations, weddings and festivities.
Well-being dimension - outputs	**Description**
Income/expenditure	change in income or expenditures expressed it in monetary terms
Other well-being indicators	**Description**
Human Development Index (HDI)	a combination of income, education and health dimensions
Assets (based on Sustainable Livelihoods Framework - Scoones, 1998)	impact measured through scoring over different assets under the Sustainable Livelihoods Framework (SLF)

changes in a well-being dimension to answer different research questions. In those cases, to avoid over-representation of a single well-being dimension, we recorded just one impact for each distinct well-being dimension measured in the paper. The other well-being impacts identified in these papers are described in the narrative part of the results section to provide an overview of all the findings included in the literature selected. In addition, we collected information about methods, geographical location and scale of analysis of the study, sampling strategy and type of actors involved in the study, as well as the direction of change of each of the impacts, where possible disaggregated by stakeholder to analyse distributional differences.

2.3.2. *Impacts on ecosystem services (indirect impacts)*

Indirect impacts were included in the review using the concept of ES and are considered as outputs that contribute to well-being outcomes. ES are defined by the UK National Ecosystem Assessment as "The benefits provided by the ecosystems that contribute to making human life both possible and worth living" (UK NEA, 2011). The capacity of an ecosystem to provide ES depends on the ecosystem's functions, its environmental structure and underlying ecological processes (Potschin and Haines-Young, 2011), and such capacity is often called the potential ES flow or ES supply (Vallecillo et al., 2019) and measured using ecological indicators. This potential flow becomes an ecosystem service output if there is a population that benefits from it and the use of goods and services provided by nature contribute to well-being that can be measured using social indicators (e.g., crop production may translate in nutrition benefits). Therefore, measuring indirect impacts in the form of ES requires identifying the ecological process or structure that provides such service, i.e. the stock of natural capital, quantifying the potential service supplied and assessing how much of the potential service is actually captured by the population (Balmford et al., 2011). Research on ecosystem service provision and how ecosystems contribute to well-being is highly interdisciplinary and many articles included in our review report includes just one component of the ES concept with a strong focus on environmental properties and structure of the ecosystem. Therefore, in the following we will refer to *environmental impacts* when the studies evaluated properties of the natural ecosystem, i.e., the stock, and under *ecosystem services* impacts those studies that assessed the actual or potential final ES.

We classified the environmental and indirect impacts of soybean production using the classification of The Economics of Ecosystems and Biodiversity (TEEB, 2010). We included provisioning, regulating and cultural services, but excluded supporting services as the main objective of the review is to understand the indirect impacts on human well-being, and supporting services do not directly link to human well-being (Balmford et al., 2011). To make the direction of the impacts comparable across studies, we used specific baselines depending on the research design of the articles in our dataset. The two main research designs employed by the articles in our dataset focus on measuring the ecosystem service impact by comparing either different agricultural practices in the same cropland areas or by comparing provision of ES across ecosystems, e.g., forest and cropland. If a study examined the impact of agricultural practices, we took as the benchmark the intensive agricultural practices, e.g., monoculture practices with mechanised tillage and fertilizer and pesticides application, and we recorded impacts as positive (negative) if the alternative agricultural practices increased (reduced) the provision of ES or improved (worsened) environmental conditions compared to the benchmark practices. For studies that compared different ecosystems, we considered as the benchmark the cropland ecosystem and recorded impacts as positive (negative) if the ecosystem that was compared to cropland provided more (less) ES or if its ecological structure and functioning was more (less) 'resilient', 'healthy' or 'diverse' as defined in the studies. The classification of each recorded impact and the ecosystem service type has been done by the person who has performed the systematic review based on the definition of each ES from the TEEB classification.

We analysed the data included in both direct and indirect impact dataset using two main approaches. We first examined the datasets quantitatively using counts of recorded impact and aggregate them across categories of interests such as well-being dimensions and ES type. We then complement this quantitative summary with a qualitative narrative synthesis.

Finally, we mapped the direct and indirect impacts identified in the literature to the Sustainable Development Goals by comparing indicators employed by the literature that we systematically reviewed with the indicators used to monitor progress toward global SDGs (https://unstats.un.org/sdgs/iaeg-sdgs/tier-classification/). For this exercise we excluded direct impacts measured using qualitative indicators.

3. Results

3.1. Direct impacts of soy production on well-being

3.1.1. Descriptive statistics for selected direct impact studies

The direct impact dataset includes 18 papers out of which 44 distinct impacts on well-being were recorded. There are 6 papers that include multiple measures of well-being associated with different dimensions, while 12 papers only report on a single measure and dimension. The total number of papers using individual level data (all from studies that collected primary data) is 12 for a total of 31 impacts recorded, while the total number of papers using secondary data from the national population is 6 for a total of 14 impacts. Most of the articles study soybean production in America, both North and South America, and about 85% of the impacts are for just three countries (Paraguay, Argentina and Brazil).

Fig. 2 shows the number of times that the impacts for each well-being dimension has been measured and it includes all type of impacts recorded. For some selected well-being dimensions and indicators, i.e., income, HDI, and income inequality, we provide information on whether those impacts have been measured using individual or population level data to consider the fact that when using population level data, the impact measured by the study is an average over the total population and may not be representative of specific local context. Overall, we find evidence that the impact of soybean production and expansion on well-being is multidimensional, although some well-being dimensions have not been studied at all in the soybean literature, i.e., education and environmental risk. The dimension that is most frequently measured is income, but if we exclude articles that uses population level data (secondary data), the number of times that the different well-being dimensions have been assessed is about the same.

The set of impacts recorded in our dataset includes more tangible dimensions such as positive impacts on economic income. This was measured both as average income per capita from a census or other national statistics surveys or according to individual's perceptions elicited through semi-structured interviews and other qualitative methods, due to rural economic development and economic growth (Choi and Kim, 2016; Krapovickas et al., 2016; Lima et al., 2011; Weinhold et al., 2013). The recorded negative impacts included human health impacts due to occupational hazards and pollution of drinking water sources (Almberg et al., 2014; Bernieri et al., 2019; Ruder et al., 2009), and nutrition and food insecurity as a result of agricultural intensification and crop shifts promoted by market incentives. We also find evidence that soybean production has an effect on more intangible dimensions of well-being such as the cultural value of traditional agricultural practices and rural lifestyles (Auer et al., 2017; Krapovickas et al., 2016), and the sense of security and freedom of choice that depend on secure land tenure rights and access to development opportunities (Busscher et al., 2020; Krapovickas et al., 2016; Steward, 2007).

The primary data studies employ both quantitative (6 studies) and qualitative methods (6 studies), as shown in Fig. 3. Qualitative studies report impacts for at least two different well-being dimensions and in total measure about 80% of the impacts recorded from primary data studies. The quantitative studies focus mainly on measuring specific dimensions, as shown in Fig. 5, such as health, nutrition, freedom of choice and income. Impacts measured through quantitative methods using secondary data (n = 13) mainly focus on health and income dimensions. The most common indicators employed by the studies using quantitative methods are presented in Annex 2 - Table A2.1.

3.1.2. Direct impacts on well-being

In general, the impact of soybean production on multidimensional well-being does not have an overall unique direction, either positive or negative. Negative impacts are recorded for half of our sample (22 out of 44) while positive impacts form about 30% of the reported impacts. However, as shown in Fig. 4, the majority of positive impacts are for income and income inequality (10 counts in total), with fewer for

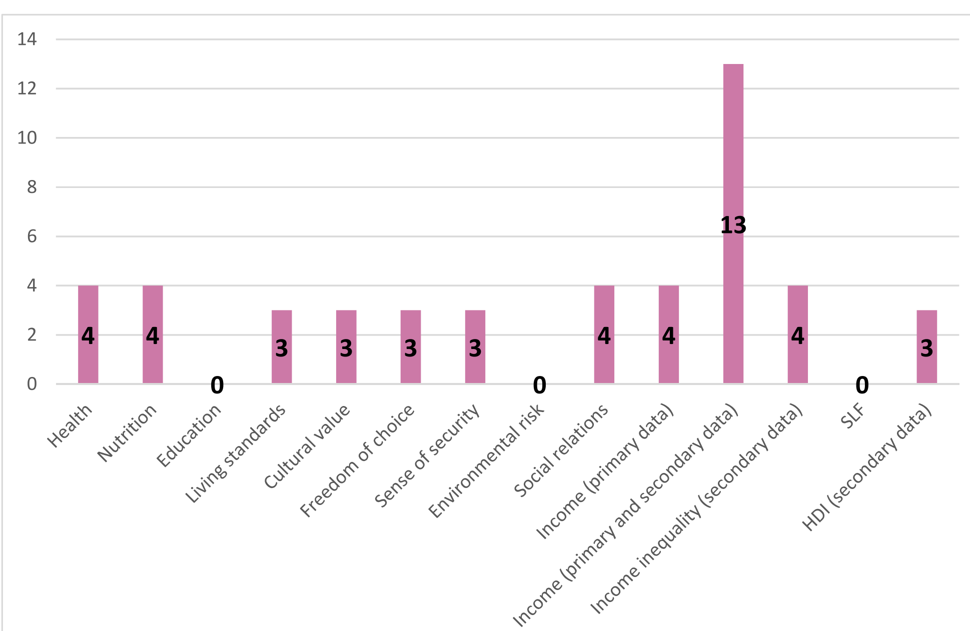

Fig. 2. Counts of well-being dimensions extract from the studies investigating direct social impacts (n = 44).

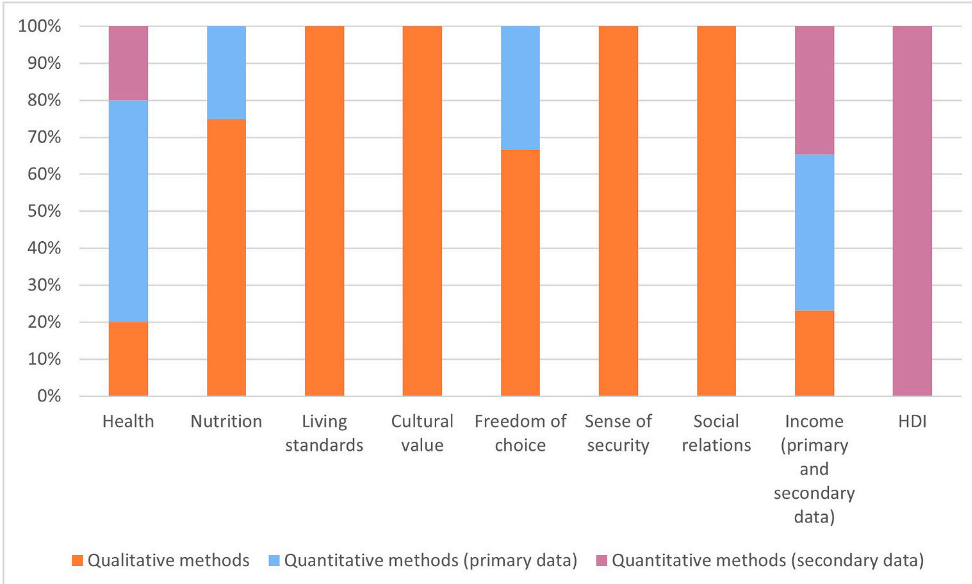

Fig. 3. Type of method used for each well-being dimension assessed by the studies investigating direct social impacts, in terms of % of the number of impacts assessed per impact (n = 44).

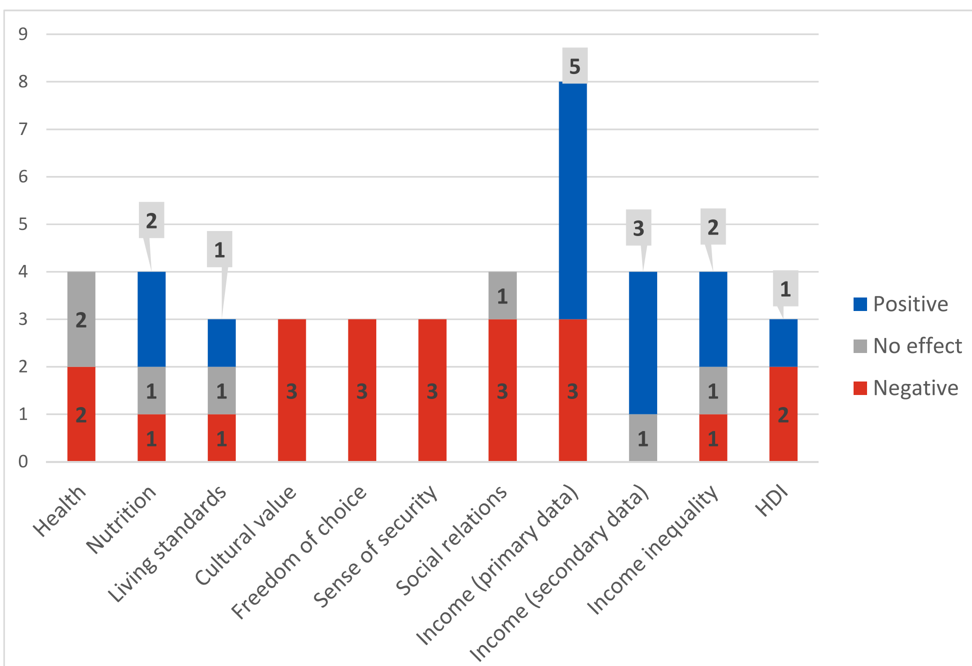

Fig. 4. Direction of the direct impacts assessed for each well-being dimension and other indicators.

nutrition and living standards (housing). Negative impacts are recorded across all well-being dimensions measured. This shows that there is a whole range of documented impacts associated with soybean production beyond the profit or economic dimension. In the remaining of the section, we will discuss in more detail all the references included in the direct impact dataset visualised in Fig. 4.

We find evidence of a positive effect of soybean trade on economic growth, measured by GDP, and a general improvement in economic conditions and development opportunities for farmers and rural inhabitants (Cardozo et al., 2016; Choi and Kim, 2016; Krapovickas et al., 2016; Lima et al., 2011; Martinelli et al., 2017; Sjauw-Koen-Fa et al., 2017; Weinhold et al., 2013). Martinelli et al. (2017) compared the HDI between Brazilian municipalities with high prevalence of soy production, i.e., more than 300 ha cultivated as soybean, and those with low prevalence. They found that the indicator increased significantly more in the soy producing municipalities than in other municipalities, indicating that soy production is positively associated with education, life expectancy and income. The study also examined the trend of each single component of HDI and found that each of them contributes positively to the increase of the overall index. Weinhold et al. (2013) explored the relationship between soy production and income indicators, measured as the proportion of people below the poverty line, income inequality (Theil index), rural household median income and aggregate GDP in the 1990–2000 period in Amazon municipalities. They found that the introduction of soy production decreased rural poverty, and that the higher the soy acreage, the higher the positive effect on the poverty rate. However, they also found that the introduction of soy was associated with an increase in income inequality.

Choi and Kim (2016) examined the regional disparities in the relationship between soy production and economic variables in Brazil. They found that at aggregate level the increase of soy production in the period 1973–2013 was not associated with economic growth, measured by GDP, but related to an increase in income inequality, measured by the Gini index, and an increase in the number of people under the poverty line. Yet, when they performed a geographically disaggregated analysis by comparing southern regions, characterised by small scale family farming, and northern regions, characterised by the presence of large-scale estates, they found that the correlation between soy acreage and the number of people below the poverty line was positive in the northern regions, yet negative in the south.

The economic benefits and the contribution of soybean trade to economic development have also been highlighted directly by the farmers and residents located in soybean agricultural expansion areas in Argentina, Paraguay and Brazil (Auer et al., 2017; Cardozo et al., 2016; Lima et al., 2011; Steward, 2007). But, these studies reveal how such development may come at the expense of intangible benefits, such as the cultural value attached to traditional agricultural systems (Auer et al., 2017; Krapovickas et al., 2016), or of alternative development opportunities (Cardozo et al., 2016; Lima et al., 2011), which may lead to displacement and migration (Lima et al., 2011) and to a feeling of lack of freedom of choice (Busscher et al., 2020).

Krapovickas et al. (2016) discuss the consequences of soy expansion for local populations and indigenous groups in Argentinian Chaco focusing on the pressures of agribusiness expansion on forests. The availability of forest resources has declined in the area due to deforestation, which was led by large-scale agricultural expansion, as well as privatization of communal forested land. By performing semi-structured interviews with local firewood users, the authors reveal that recent rural developments have decreased the availability of forest resources, and as such limit alternative income opportunities as well as access to energy, and in general the freedom to practice a forest-based lifestyle, e.g., being free to sleep in the forest. Auer et al. (2017) explored the impact of agricultural intensification in Balcarce district (Argentina) in detail, through semi-structured interviews with local people who had lived in the area for at least 20 years. They found evidence of negative impacts on the cultural value and social relations components of multidimensional well-being. Traditional agricultural practices (for potato cropping) are associated with a sense of identity and belonging to a place. Also, the relatively high presence of small-scale farmers in the past facilitated the building of good social relationships and an overall sense of community – which were lost with the intensification of soy production.

The evidence of negative impacts on freedom of choice and social relations are often related to land appropriation and conflicts over land ownership which can lead to displacement of informal landowners (Baumann et al., 2017; Busscher et al., 2020; Cardozo et al., 2016; Krapovickas et al., 2016). Studies from Paraguay, Argentina and Brazil, where almost all soybean production happens, show that the persistence of a weak land tenure system and the high presence of informal land ownership rights facilitate land appropriation and violent displacement of smallholder farmers (Busscher et al., 2020; Cardozo et al., 2016; Sauer, 2018). This is exacerbated by the high financialization of the land investment sector, where transnational corporations acquire land rights by negotiating directly with local government authorities that in many cases are formally and legally landowners. Busscher et al. (2020) discuss land appropriation in Argentina and highlight that possible ways to mitigate land appropriation require both interventions at local level, such as supporting financially and legally informal landowners to formalize their land use rights, as well as supporting processes of negotiation between new settlers and informal landowners to minimise the risk of conflicts. Cardozo et al. (2016) discuss a case study in Paraguay where the indigenous community Aché who informally owned communal agricultural land, had negotiated a partnership with agribusiness companies to participate in mechanised soy production without transferring land rights to the soy investors.

Some studies focus on understanding how impacts on multiple well-being dimensions vary across different social groups and stakeholders within the value chain. Steward (2007) interviewed different actors in the soy value chain in Brazil (Santarem area) and found that they value benefits and costs of soybean expansion differently. The potential economic benefits of soy trade are highly valued by local government officials as well as agribusiness actors, while NGOs members strongly emphasise the possible negative environmental effects (see section 3.2.2). Local residents and smallholder farmers are negatively affected by the increasing pressure to sell their land and by the lack of alternative development opportunities. On the contrary, Lima et al. (2011) also interviewed different local actors, soy farmers, non-soy farmers and soy labourers, living in three different areas of soybean production in Brazil (in the state of Pará and Mato Grosso). They find that respondents had an overall positive opinion of development brought by soybean and strongly valued the related effects on income and improved housing and infrastructure. However, some of the respondents were also concerned about the negative impacts on water quality and the health risks associated with increasing use of agrochemicals. For example, Bernieri et al. (2019) show that soybean agricultural practices in Brazil may pose a risk for the health of plantations labourers as, during their working time, they were exposed to thyroid-disrupting pesticides which can potentially determine long-term detrimental effects on their health. On the contrary, Ruder et al. (2009) look at the relationship between exposure to pesticides among farmers in the US and risks of glioma and find that living on a farm on which soybean and other crops such as corn were cultivated was associated to decreased risk of glioma. Finally, Almberg et al. (2014) explore whether populations located in close proximity to pesticide-treated fields experienced adverse health outcomes such as low birth weight or preterm births, but find no significant effects.

3.2. Indirect impacts of soybean production on ecosystem services

3.2.1. Descriptive statistics for selected indirect impact studies

The dataset of studies focussing on ES impacts includes 19 papers for which 40 different environmental and indirect impacts on people have been recorded. Most of the articles focus on soybean production in the Americas. Fig. 5 shows the number of impacts associated with soybean agricultural production and expansion recorded for each ES using the TEEB classification. Regulating ES are the most frequently studied (75% of the impacts) followed by provisioning ES (20% of the impacts). Specifically, the most often studied regulating ESs are climate regulation, water quality regulation and maintenance of soil fertility. The most frequently studied provisioning ES is food provision supplied by cropland ecosystems, but a few studies also measure impacts on wild food provision, raw materials, and water provision.

ES research is highly interdisciplinary, and this is reflected in the wide range of methods used in the selected papers: 43% used primary data collection of environmental or biophysical indicators, 35% used secondary data, and 23% used data on direct benefits enjoyed by the population collected through qualitative interviews with farmers and other rural residents or by estimating the contribution of land cover/use categories to the country's economic wealth (e.g. GDP) (see Annex 2).

3.2.2. Indirect impacts on ecosystem services

Overall, according to the evidence, the number of positive impacts of soybean production is small (10% of all recorded indirect impacts) and only for one ecosystem service, namely food provision, while all the other ecosystem services are negatively affected. The two main drivers of change in ecosystem service provision due to soybean production are land use change, i.e., conversion of forest and other highly natural areas to cropland, and agricultural intensification (Fig. 6). Agricultural intensification is associated mainly with changes in food provision,

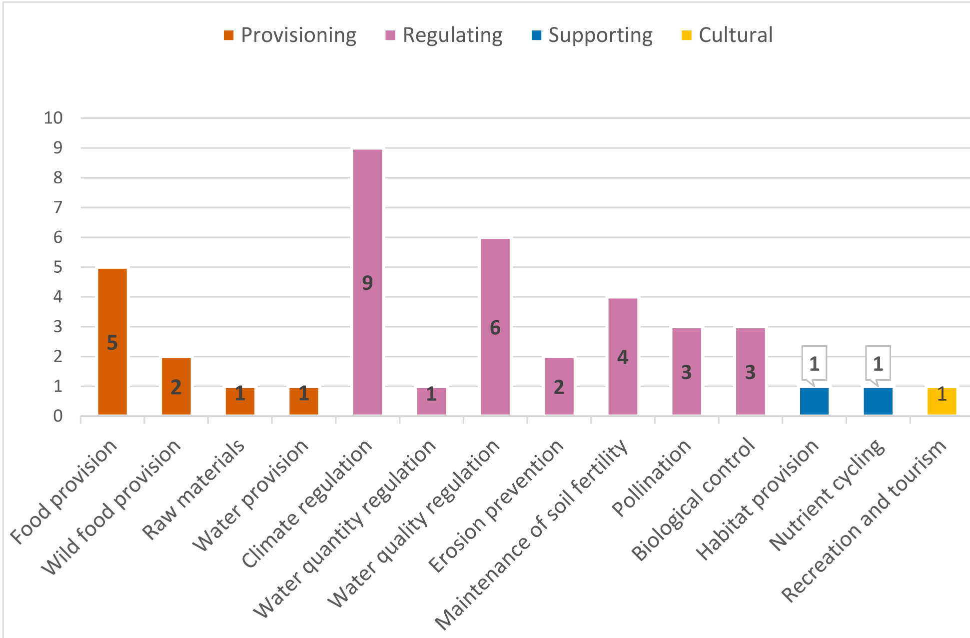

Fig. 5. Counts of ES impacts of soy production per ES category extracted from the studies investigating indirect social impacts (n = 44).

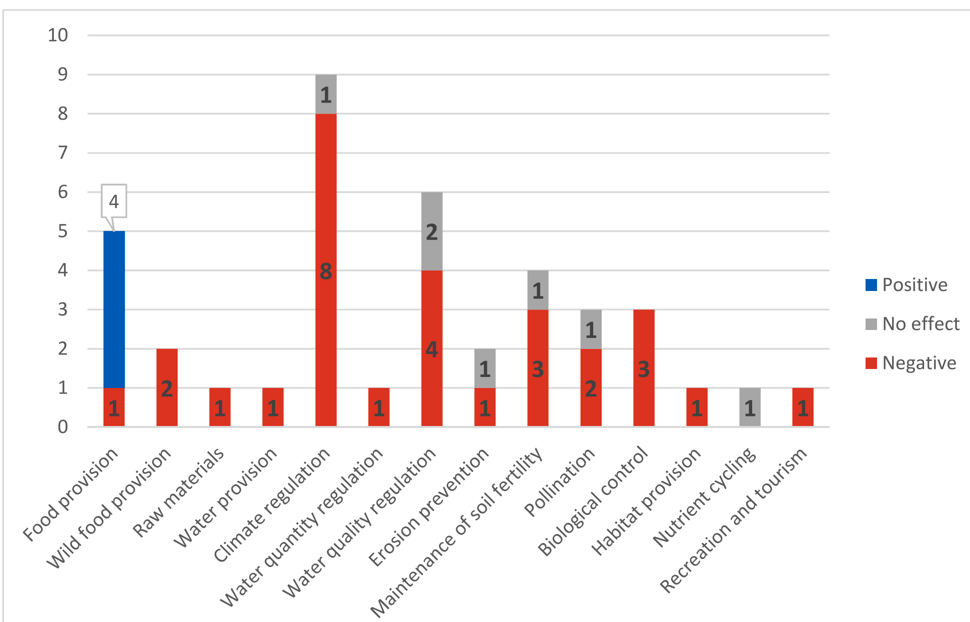

Fig. 6. Direction of the impacts of soy production assessed for each ecosystem service category.

water quality regulation and soil-related ES, while land use changes (deforestation) are mainly associated with carbon sequestration impacts. In the remaining of the section, we provide a narrative description of the references recorded in the indirect impact dataset that are visualized in Fig. 6.

The two main drivers of indirect impacts associated with soy production are land use changes due to cropland expansion and the intensification of agricultural practices (Fig. 7). Land use changes such as deforestation and clearance of other native vegetation, e.g. grassland and dryland savannah, have documented negative impacts on the supply of various ecosystem services such as climate regulation (Baumann et al., 2017; D'Acunto et al., 2014; Heimpel et al., 2013; Villarino et al., 2017), wild food provision and raw materials (Krapovickas et al., 2016; Malkamäki et al., 2016), as well as recreation and tourism opportunities offered by natural areas (Saraiva Farinha et al., 2019). Baumann et al. (2017) study deforestation patterns in the Chaco region, which includes Argentina, Bolivia and Paraguay, over a 30-year period and find that the Argentinian part of the region has been substantially deforested due to cropland and pasture expansion. The change in total carbon emissions associated with deforestation was estimated by applying conversion factors from primary data studies to land use/cover types. The study finds that over the period analysed there has been an increase in total carbon emission of 23% due to conversion of forests to cropland, mainly soybean fields, and of 71% due to conversion of forests to pastures. A more detailed study from Villarino et al. (2017) focuses exclusively on carbon stored in soil in the Chaco area using primary data to measure

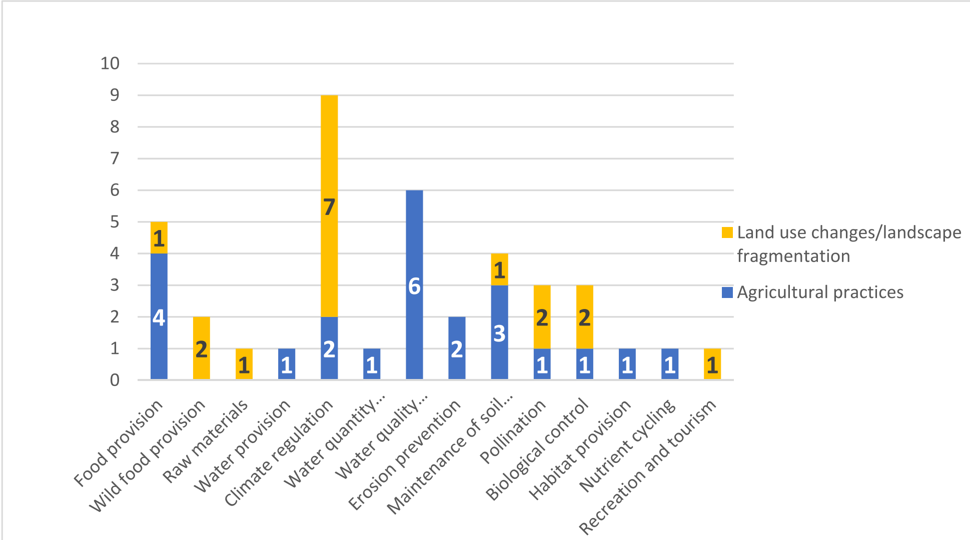

Fig. 7. Drivers of change in ecosystem service provision as a result of soy production assessed in the reviewed literature on soy.

various soil properties at different depth levels. The study found that the carbon stored in soil declined due to deforestation and that soybean plantations are associated with a greater loss of soil carbon than other crops. The distance to permanently vegetated areas within cropland (uncropped margins) may mitigate the loss of carbon storage potential: the soil within few meters from woody patches stores significantly more carbon (D'Acunto et al., 2014).

Deforestation and conversion of other natural areas reduce the availability of raw materials, such as firewood and other energy goods, and wild food, leading to local losses, in contrast to climate regulation which benefits the global population. Krapovickas et al. (2016) show through qualitative interviews of rural residents in the Chaco area in Argentina how deforestation due to soybean and increasing restrictions on access to remaining forest areas have limited the ability of the surrounding population to benefit from those natural areas. Forests and other natural areas also provide habitats for honeybees and support beekeepers' honey production and income. In semi-structured interview with beekeepers, Malkamäki et al. (2016) find that soybean frontier expansion had negative effects on honey production because soybean fields were characterised by a very low amount of floral resources compared to other land cover/use types, e.g. grassland or eucalyptus plantations.

Bees as well as other insects, such as soybean aphids and arthropod herbivores and predators, interact with cropland ecosystems and contribute positively, e.g. through pollination, or negatively, e.g. in case of agricultural pests, to crop productivity (Dale and Polasky, 2007). Few studies, using primary environmental data, focus on understanding pollination ES for soybean yield (Monasterolo et al., 2015) and how the landscape structure and the presence of highly natural areas such as forest or grasslands influence the prevalence of these insects in cropland areas (Koh and Holland, 2014; Mitchell et al., 2017; Ruiz-Toledo et al., 2020). Monasterolo et al. (2015) examine the role of landscape fragmentation and the destruction of the insects' natural habitat in the Argentinian Chaco. They find that the distance of cropland areas to forest influenced the visitation rate of bees and that soybean productivity was positively affected by the presence of bees, i.e. the higher the visitation rate of bees, the higher the plant productivity. Ruiz-Toledo et al. (2020) examined the presence and diversity of native bees in a small-scale agriculture landscape in Mexico, where non-irrigated crops such as maize, soybean and sorghum are cultivated under a rotation regime. When they compare areas fully converted to crops to areas where some forest or vegetation was still present, they find no significant difference in the amount and diversity of bees, indicating that land conversion in this case did not negatively affect the pollination services. Forests and other semi-natural land use also provide a natural habitat for natural enemies of agricultural pests, e.g. soybean aphids, which support crop productivity by reducing the number of pests and provide an alternative to the extensive uses of pesticides. Two studies (Koh and Holland, 2014; Mitchell et al., 2014) focused on cropland in North America (Canada and US) and found that the presence of forest and grassland increases the number of natural enemies of pests and therefore enhances the biological control services.

Finally, in Brazil the loss of the most natural and highly biodiverse areas such as the Amazon and the Cerrado due to the agricultural frontier expansion may also be detrimental for recreation and tourism. Mann et al. (2012) and Saraiva Farinha et al. (2019) estimate monetary values associated with the loss of natural areas to provide a measure of potential losses due to agricultural development and compare those to potential profit gains from soybean plantations. They find that the value of forest and other natural areas is higher than potential economic gains from soybean.

The intensification of agricultural practices for soybean production was the other driver affecting ES supply; the literature has mainly focused on understanding the impact of such intensification on water-regulating ES, both quality and quantity, as well as soil-related and food provision ES. Water-related ES are influenced by the intensification of soybean production which causes both a relative increase in water consumption for irrigation (Maydana et al., 2020) – although it is noted that irrigation of soy is not commonplace - as well as an increase of water pollution due to the use of pesticides and fertilizers (Darré et al., 2019; Lima et al., 2011; Syswerda and Robertson, 2014; Villarini et al., 2016). Freshwater provision and water quantity regulation are affected by the increased water use for intensive soybean practices, in contrast to rainfed or extensive agricultural systems (Darré et al., 2019; Maydana et al., 2020). Water quality regulation services are affected by the application of fertilizers (nitrate and phosphorous), and pesticides. Nitrate and phosphorous leaching is a well-known environmental impact of intensive agriculture, which can lead to the disruption of the water ecosystems through eutrophication and therefore lead to further reduction of other ES such as freshwater provision (Darré et al., 2019; Maydana et al., 2020; Syswerda and Robertson, 2014). The use of pesticides also impacts water quality and may have a more direct effect on the population's well-being by increasing the toxicity of water used for drinking or other domestic purposes and posing a risk for their health. At the same time, the use of fertilizers and pesticides is also found to have a positive impact on food production as it increases crop yield (Darré et al., 2019; Mitchell et al., 2014; Paul et al., 2015; Syswerda and Robertson, 2014), indicating a trade-off between positive impacts on food provision and negative environmental consequences. As shown by Maydana et al. (2020) and Syswerda and Robertson (2014), conservation agricultural practices, including avoiding tillage, limiting use of chemical fertilizers, and using organic rather than chemical pesticides, may help in mitigating these negative environmental impacts while still maintaining a high level of food production.

Intensive agricultural practices that involve mechanised tillage and the use of chemical compounds also affect soil-related properties such as fertility and erosion, and in turn may over time reduce yield and food provision. The maintenance of soil fertility is usually measured by soil organic carbon content. Avoiding mechanised tillage strongly increases soil organic carbon, while the use of pesticides does not seem to have an effect on soil properties (Paul et al., 2015).

3.3. Impacts linked to Sustainable Development Goals (SDGs)

We link the reported direct and indirect impacts to the Sustainable Development Goals (Fig. 8). The evidence collected reports only positive counts related to indicators of SDG 2 (Zero hunger), SDG 8 (Decent work and economic growth), and more positive than negative counts for SDG 10 (Reduced inequalities), while for indicators of SDG 3 (Good health and well-being), SDG 5 (Gender equality), SDG 6 (Clean water and sanitation) and SDG 15 (Life on land) more negative counts are reported. However, given the very limited available empirical evidence, these results need to be taken with caution. The well-being impacts related to SDG 1 are characterised by three positive impacts and two negative impacts. Similarly, for SDG 10 for instance the Gini index in Brazil over 30 years (1990–2010) shows a decrease in inequality, but when such impacts are examined in more detail at local level through qualitative fieldwork or more detailed quantitative analysis, a different picture of inequality emerges. Weinhold et al. (2013) discuss how economic gains realised at municipality levels are unequally distributed, with ethnicity playing a role, which may generate or exacerbate tensions and social conflicts at local level. Similarly, Choi and Kim (2016) reveal that when looking at different soy production areas in a more disaggregated analysis the impact on reduction of poverty does not seem to be consistent across all geographical areas. The recorded impacts on indicators for ecosystem-related SDGs, i.e., impact on land and water, are mostly negative as highlighted in the section on the indirect impacts.

4. Discussion

The available evidence that emerges from our systematic review of social impacts of soybean production portrays a mixed picture of negative (14 counts) and positive impacts (20 counts) across the multiple dimensions of well-being examined. Our narrative described that such impacts, and their direction, vary across space, between countries and regions within countries. Although not evidenced in the reviewed studies, impacts may also vary across time as new policies are enforced or old policies abandoned, or because production practices changed over time.

Our review used counts to synthesize the existing evidence, because of the small size of the evidence base. This means that we do not differentiate between studies with small and large samples or study areas. We also observed that no studies were available that met our inclusion criteria for many smaller or up-coming soy producing countries, such as China and India as well as African countries such as Zambia where soybean production is increasing to support the development of the biodiesel industry (Drabik et al., 2016; German et al., 2011). Nonetheless, our review, which is global in the sense that we aimed to include all countries, provides a useful identification of the numerous impacts of soy production on multiple dimensions of wellbeing.

Overall, we found that income effects are more often studied than other well-being dimensions given that are considered among the main positive impacts of agricultural production for trade. Impacts on income are also easier to measure using available statistics. The documented impacts of soy on income, measured using a variety of different indicators including average income per capita from census or other national statistics survey or according to individual's perceptions elicited through semi-structured interviews and other qualitative methods, are predominantly positive, confirming claims that trade will lead to average economic growth. Qualitative studies however provide evidence of impacts on less tangible dimensions, such as cultural value, social relations, and sense of security; soybean production tends to negatively affect those dimensions. Moreover, our review suggests that both qualitative and quantitative methods are employed to measure changes in different well-being dimensions, and we note that qualitative methods are used more often to measure impact on intangible dimensions while quantitative methods are used mainly to measure changes in material well-being dimensions.

The overall picture portrayed by the review of indirect impacts, i.e.,

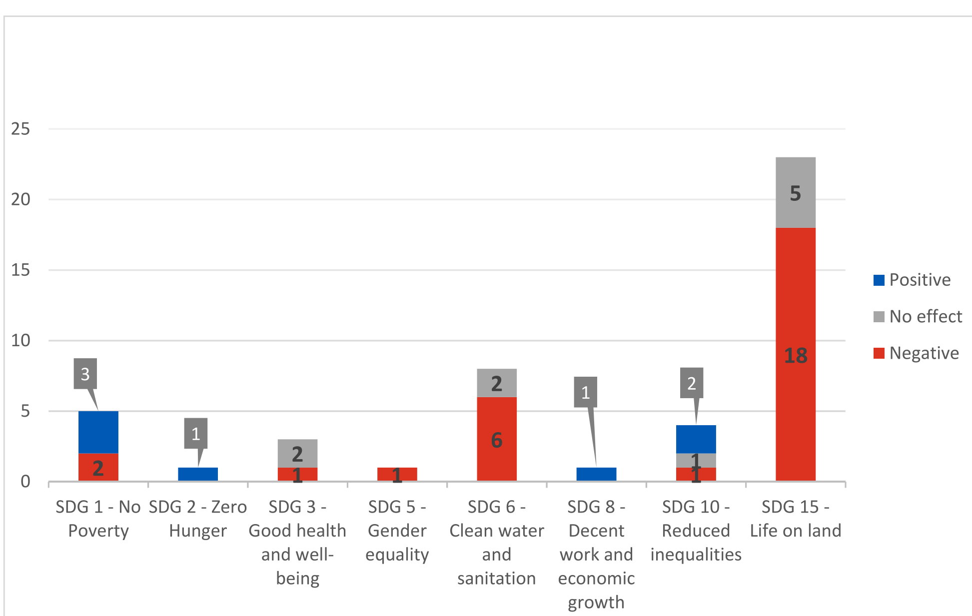

Fig. 8. Direct and indirect impacts of soy production linked to the Sustainable Development Goals.

ES benefits, is more homogeneous in terms of direction of impact – in comparison to the direct wellbeing effects - and shows that the only ES positively influenced by soybean cultivation is food production, while all the other ES benefits are negatively affected as a consequence of loss of highly natural areas. The most frequently studied ES are carbon sequestration, due to its relevance considering the deforestation phenomenon, water quality and quantity and soil fertility, mainly affected by agricultural intensification that includes the increased use of agrochemicals and fertilizers as well as mechanised tillage. Nonetheless, at least for half of the impacts recorded, the indicators used to measure the quality of the ecosystems and the potential impact on the supply of ES, but they rarely quantify actual or potential impacts for human wellbeing. For example, the use of pesticides and other agrochemicals will negatively affect the groundwater quality, and potentially human health, but these empirical links are rarely studied, and if studied, only through theoretical modelling of future scenarios in combination with expert valuation (Maydana et al., 2020).

The role of policies has barely been studied in the well-being literature, and hardly more so in the ES literature. This is despite the high relevance of such results for value chain initiatives such as the Amazon soy moratorium, the RTRS and voluntary standards included in international trade agreements (e.g., Europe – MercoSur trade agreement) which aim to mitigate environmental impacts of soybean production driven by land use change, deforestation, and habitat conversion. Earlier reviews by Jia et al. (2020) and Garrett et al. (2021) similarly find a lack of evidence for social impacts of supply chain interventions. Evidence on the role of certifications such as the RTRS, ProTerra and others, as well as private governance policies for corporate social responsibilities adopted by companies in mitigating negative direct and indirect social impacts, are currently missing.

The lack of evidence on effectiveness of market governance policies is particularly problematic given that soy production and international trade has increased over the last 20 years due to increased demand for cattle feedstock as well as biodiesel production (Silvério et al., 2015). Demand for animal feed is driven by the importance of meat in global diets and is likely to remain high as long as diets do not move towards low-meat eating habits (Westhoek et al., 2014). The main countries that produce soybean, i.e., Brazil, US, Paraguay and Argentina, are also large-scale producers of meat products. Cattle rearing, similarly to soybean production expansion and intensification, is a source of many negative environmental and social impacts, primary due to land use changes and clearance of forest and other natural vegetation (le Polain de Waroux et al., 2019). Moreover, although trade initiatives and interventions on reducing deforestation associated with soy production receive quite some attention with regards to their role in reducing environmental impacts such as deforestation their effectiveness in promoting more sustainable trade is minor. Currently, only an estimated 13% of soy used in the EU is deforestation-free, with high variation across EU member states in this percentage (IDH and IUCN NL, 2019). Given the large role of a handful of transnationals in the soy sector, actions to improve supply chain performance may need further public-private governance interactions. One option would be to request traders to declare the sustainability performance of imported goods and put the administrative responsibility of demonstrating attribution on traders, while at the same time increase supply chain transparency (Godar and Gardner, 2019).

Our review is presented with some limitations, primarily related to the scope. We focused on impacts in rural soy producing areas, but did not include impacts further down the value chain (e.g. Boerema et al., 2016; Sun et al., 2018). Our selection of ES studies did not include research on deforestation itself or biodiversity loss due to deforestation. The quantitative summary of the literature focus on counting the number of impacts and its direction, negative and positive, because of the small size of the literature selected. This approach does not allow to take into account the sample size of the study, which may affect the precision of the estimate of impact, and it does not provide an indication of the size of the impact. However, we overcome this limitation by complementing the quantitative finding with a narrative synthesis that provides detailed insights on each impact recorded. Arguably, our inclusion of a diverse range of study designs makes the comparison of evidence across findings less comparable, but we argue that the diversity of study designs provides a more holistic picture that allows us to explore links between drivers, pressures, and impacts. Finally, we did not incorporate non-English studies (Konno et al., 2020).

5. Conclusion

Our review provides an overview of the broad range of impacts of soybean production for international trade, and it demonstrates how the production of soybean is associated with a wide range of positive and negative impacts. The results of this systematic review highlight that there is limited empirical evidence of the social and ES impacts of soybean production in exporting countries. Moreover, we found almost no evidence on the effectiveness of market governance policies which is especially problematic given that these type of interventions is becoming the predominant approach for mitigating negative impacts of soy production for international trade.

To investigate social impacts of soy production we employed a multidimensional well-being concept. We found that for the education and environmental risk wellbeing dimensions, there is a particular need for more evidence using both qualitative and quantitative methods, as we did not find any evidence of direct impacts that could be related to those dimensions. For the income and health dimensions there is a need to increase the evidence base using qualitative methods and individual-level data. This would allow a more detailed analysis of these impacts at local level and evaluate whether they differ across different producing contexts as well as across different local stakeholder groups, such as those actively involved in soy production and those who are not. Primary studies in such under-researched areas would allow for further insight into local contexts. Moreover, we suggest that further research on measuring social impacts should make use of a mixed methods approach which would allow to highlight possible trade-offs between negative and positive impacts of soybean production across different well-being dimensions. Lastly, more evidence is needed to investigate the links between environmental impacts and relative changes in ES and consequences for human well-being as environmental impacts have been studied extensively but empirical evidence for the consequences for human well-being of those environmental impacts are much rarer.

Finally, to guide evidence-based decision-making processes for economic development through trade requires further research into the value chain activities, starting from the production phase. In order to improve performance on SDG10 and reduce inequalities, due attention to equity and power issues is required (Grabs and Carodenuto, 2021; Ingram et al., 2018). Actions to avoid land appropriation, such as customary land rights formalisation, but also empowerment of smallholders in supply chains in particular, may help to distribute gains and burdens of trade more equitably.

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.

Acknowledgments

We acknowledge funding from the UK Research and Innovation's Global Challenges Research Fund (UKRI GCRF) through the Trade, Development and the Environment Hub project (project number ES/S008160/1).

Annex 1. Systematic review protocol: search terms, list of grey literature sources and list of literature

Table A1.1
Search terms – well-being

Well-being/MPI		Product
"wellbeing" OR "well-being" OR "well being" OR "income" OR "poverty" OR "human well*" OR "nutrition" OR "livelihood*" OR "security" OR "vulnerab*" OR "(social) capital" OR "human capital" OR "asset*" OR "social welfare" OR "social impact" OR "economic impact" OR "welfare" OR "poor" OR "quality of life" OR "well living" OR "living standard*" OR "utility" OR "life satisfaction" OR "prosperity" OR "progress" OR "needs fulfillment" OR "development" OR "empowerment" OR "capabilit*" OR "poverty" OR "happiness" OR "deprivation*" OR "educat*" OR "mortality" OR "wealth*" OR "marginalis*" OR "disadvantage*" OR "*equity" OR "*equal*"	AND	"soy*"

Table A1.2
Search terms – ecosystem services

Ecosystem services		Product
"Ecosystem service*" OR "Ecological services" OR "environmental good*" OR "environmental service*" OR "Provisioning service*" OR "Food production" OR "Food suppl*" OR "Foodcrop*" OR "Timber production" OR "Timber suppl*" OR "Timber" OR "Fuel production" OR "Fuel suppl*" OR "*Wood production" OR "*Wood suppl*" OR "Charcoal" OR "Fuelwood" OR "Firewood" OR "Wood" OR "Ntfp" OR "Non*timber forest product*" OR "Nwfp" OR "Non*wood forest product*" OR "*Water provision" OR "*Water suppl*" OR "Regulating service*" OR "Water purification" OR "Water quality" OR "Water regulation" OR "Water quality regulation" OR "Nutrient* retention" OR "Water quantity regulation" OR "Waste treatment" OR "Clean Water" OR "Flood protection" OR "Flood defence" OR "Flood storage" OR "Flood attenuation" OR "Climat* regulation" OR "Carbon storage" OR "Carbon sequest*" OR "Carbon loss" OR "Carbon emi*" OR "Erosion protection" OR "Soil fertility" OR "Soil erosion" OR "Disease regulation" OR "*Pest control" OR "Biological control" OR "Pollination" OR "Storm protection" OR "Natural hazard regulation" OR "Moderation of extreme events" OR "Cultural services" OR "Tourism" OR "Recreation" OR "*Aesthetic*" OR "Sense of place" OR "Heritage" OR "Spiritual"	AND	"soy*"

Table A1.3
List of organizations used for grey literature search

International organizations	NGOs
Biodiversity international	WWF
CGIAR	Greenpeace
CIFOR	Solidaridad
FAO	Oxfam international
IIED	InterAction
IMF	ActionAid international
IUCN	ActionAid UK
UNEP	Concern worldwide
WorldBank	Consumers international
UNCTAD	Mercy corps
AidData	Non-academic institutes
Care International	IDH - trade initiative
Conservation Evidence	IISD
UNEP-WCMC	International trade centre
UNDP	Chain reaction research
Sector-wide bodies	Certification bodies
Round table for responsible soy (RTRS)	UTZ
ProTerra	FairTrade
World Business council for sustainable development	Rainforest Alliance
Consumer good forum	UN Global compact
Abiove (brazilian association of vegetable oil industries)	
Private sector actors	
Producers	**Traders**
AGD	ADM
Adecoagro SA	Atagi
Amaggi	Bunge
Cresud SA	Cargill
Grupo SLC agricola	Cofco

Table A1.4
List of organizations used for grey literature search

Title	Authors	Journal, Vol, Pages	Year
A study of adverse birth outcomes and agricultural land use practices	Almberg, K.S., Turyk, M., Jones, R.M., Anderson, R., Graber, J., Banda, E., Waller, L.A., Gibson, R., Stayner, L.T.	*Environmental Research* 134: 420–26.	2014
Agriculturisation and trade-offs between commodity production and cultural ecosystem services: a case study in Balcarce County	Auer, A., Maceira, N., Nahuelhual, L.	*Journal of Rural Studies* 53: 88–101	2017
Occupational exposure to pesticides and thyroid function in Brazilian soy farmers	Bernieri, T., Rodrigues, D., Barbosa, I.R., Ardenghi, P.G., Basso da Silva, L., 2019	*Chemosphere* 218: 425–29. https://doi.org/10.1016/j.chemosphere.2018.11.124.	2019
Environmental justice implications of land grabbing for industrial agriculture and forestry in Argentina	Busscher, N., Parra, C., Vanclay, F.	*Journal of Environmental Planning and Management* 63 (3): 500–522.	2020
Soy expansion and the absent state: indigenous and peasant livelihood options in eastern Paraguay	Cardozo, M.L., Salas, D., Ferreira, I., Mereles, T., Rodríguez, L.	*Journal of Latin American Geography* 15 (3): 87–104.	2016
The impact of conglomerate farming on the poor: empirical evidence from the Brazil soy sector	Choi, S., Kim, H.	*International Area Studies Review* 19 (2): 147–64.	2016
Grain legume cultivation and children's dietary diversity in smallholder farming households in rural Ghana and Kenya	de Jager, I., Abizari, A.R., Douma, J.C., Giller, K.E., Brouwer, I.D.	*Food Security* 9 (5): 1053–71.	2017
Firewood supply and consumption in the context of agrarian change: the Northern Argentine Chaco from 1990 to 2010	Krapovickas, J., Sacchi, L.V., Hafner, R.	*International Journal of the Commons* 10 (1): 220–43.	2016
Deforestation and the social impacts of soy for biodiesel: perspectives of farmers in the south brazilian amazon	Lima, M., Skutsch, M., de Medeiros Costa, G.	*Ecology and Society* 16 (4).	2011
Fueling development? Assessing the impact of oil and soybean wealth on municipalities in Brazil	Lima-de-Oliveira, R., Alonso, M.L.	*Extractive Industries and Society* 4 (3): 576–85.	2017
Soy expansion and socioeconomic development in municipalities of Brazil	Martinelli, L.A., Batistella, M., da Silva, R.F.B., Moran, E.	*Land* 6 (3).	2017
Benefits of legume-maize rotations: assessing the impact of diversity on the productivity of smallholders in Western Kenya	Ojiem, J.O., Franke, A.C., Vanlauwe, B., de Ridder, N., Giller, K.E.	*Field Crops Research* 168: 75–85.	2014
Sustainable intensification and farmer preferences for crop system attributes: evidence from Malawi's Central and Southern regions	Ortega, D.L., Waldman, K.B., Richardson, R.B., Clay, D.C., Snapp, S.	*World Development* 87: 139–51.	2016
Using the WEAI + to explore gender equity and agricultural empowerment: baseline evidence among men and women smallholder farmers in Ghana's Northern Region	Ragsdale, K., Read-Wahidi, M.R., Wei, T., Martey, E., Goldsmith, P.	*Journal of Rural Studies* 64 (September): 123–34.	2018
Exposure to farm crops, livestock and farm tasks and risk of glioma	Ruder, A.M., Carreón, T., Butler, M.A., Calvert, G.M., Davis-King, K.E., Waters, M.A., Schulte, P.A., Mandel, J.S., Morton, R.F., Reding, D.J., Rosenman, K.D.	*American Journal of Epidemiology* 169 (12)	2009
Exploring the applicability of a sustainable smallholder sourcing model in the black soybean case in Java	Sjauw-Koen-Fa, A.R., Blok, V., Omta, O.	*International Food and Agribusiness Management Review* 20 (5): 709–28.	2017
From colonization to "environmental soy": a case study of environmental and socio-economic valuation in the Amazon soy frontier	Steward, C.	*Agriculture and Human Values* 24 (1): 107–22.	2007
Soybeans, poverty and inequality in the Brazilian Amazon	Weinhold, D., Killick, E., Reis, E.J.	*World Development* 52: 132–43.	2013
Carbon emissions from agricultural expansion and intensification in the Chaco	Baumann, Matthias, Nestor Ignacio Gasparri, Maria Piquer-Rodriguez, Gregorio Gavier-Pizarro, Patrick Griffiths, Patrick Hostert, and Tobias Kuemmerle.	*Global Change Biology*, no. 23: 1902–16.	2017
Uncropped field margins to mitigate soil carbon losses in agricultural landscapes	D'Acunto, Luciana, María Semmartin, and Claudio M. Ghersa.	*Agriculture, Ecosystems and Environment* 183: 60–68.	2014
Environmental impacts on water resources from summer crops in rainfed and irrigated system	Darré, Elisa, Mónica Cadenazzi, Sebastián R. Mazzilli, Juan F. Rosas, and Valentín D. Picasso.	*Journal of Environmental Management* 232 (October 2018): 514–22.	2019
Opportunity cost of a private reserve of natural heritage, Cerrado biome – Brazil	Saraiva Farinha, Maycon Jorge Ulisses, Luciana Virginia Mario Bernardo, Adelsom Soares Filho, André Geraldo Berezuk, Luciana Ferreira da Silva, and Clandio Favarini Ruviaro.	*Land Use Policy* 81 (October 2018): 49–57.	2019
Environmental consequences of invasive species: greenhouse gas emissions of insecticide use and the role of biological control in reducing emissions	Heimpel, George E., Yi Yang, Jason D. Hill, and David W. Ragsdale.	*PLoS ONE* 8 (8): 1–7.	2013
Seasonal abundance and diversity of native bees in a patchy agricultural landscape in Southern Mexico	Ruiz-Toledo, Jovani, Rémy Vandame, Patricia Penilla-Navarro, Jaime Gómez, and Daniel Sánchez.	*Agriculture, Ecosystems and Environment* 292 (December 2019).	2020
Grassland plantings and landscape natural areas both influence insect natural enemies	Koh, Insu, and Jeffrey D. Holland.	*Agriculture, Ecosystems and Environment* 199: 190–99.	2014
Impacts of land use and land use changes on the resilience of beekeeping in Uruguay	Malkamäki, Arttu, Anne Toppinen, and Markku Kanninen.	*Forest Policy and Economics* 70: 113–23.	2016
Ecosystem Service Value and Agricultural Conversion in the Amazon: Implications for Policy Intervention	Mann, Michael L., Robert K. Kaufmann, Dana Marie, Sucharita Gopal, James G. Baldwin, Maria Del Carmen Vera-Diaz, Dana Marie Bauer, Sucharita Gopal, James G. Baldwin, and Maria Del Carmen Vera-Diaz.	*Environmental and Resource Economics* 53 (2): 279–95.	2012
Integrated valuation of alternative land use scenarios	Maydana, Gisela, Martín Romagnoli, Maria Cunha, and Margarita Portapila.	*Science of the Total Environment* 714: 136430.	2020
A landscape view of agricultural insecticide use across the conterminous US from 1997 through 2012	Meehan, Timothy D., and Claudio Gratton.	*PLoS ONE* 11 (11): 1–17.	2016

(*continued on next page*)

Table A1.4 (*continued*)

Title	Authors	Journal, Vol, Pages	Year
Agricultural landscape structure affects arthropod diversity and arthropod-derived ecosystem services	Mitchell, Matthew G.E., Elena M. Bennett, and Andrew Gonzalez.	*Agriculture, Ecosystems and Environment* 192: 144–51.	2014
Soybean crops may benefit from forest pollinators	Monasterolo, M., M. L. Musicante, G. R. Valladares, and A. Salvo.	*Agriculture, Ecosystems and Environment* 202: 217–22.	2015
Exclusion of soil macrofauna did not affect soil quality but increased crop yields in a sub-humid tropical maize-based system	Paul, B. K., B. Vanlauwe, M. Hoogmoed, T. T. Hurisso, T. Ndabamenye, Y. Terano, J. Six, F. O. Ayuke, and M. M. Pulleman.	*Agriculture, Ecosystems and Environment* 208: 75–85.	2015
Ecosystem services along a management gradient in Michigan (USA) cropping system	Syswerda, S. P., and G. P. Robertson.	*Agriculture, Ecosystems and Environment* 189: 28–35.	2014
Soybean area and baseflow driving nitrate in Iowa's Racoon river	Villarini, Gabriele, Christopher S. Jones, and Keith E. Schilling.	*Journal of Environmental Quality* 45 (6)	2016
Deforestation impacts on soil organic carbon stocks in the Semiarid Chaco Region, Argentin	Villarino, Sebastián Horacio, Guillermo Alberto Studdert, Pablo Baldassini, María Gabriela Cendoya, Lucía Ciuffoli, Matias Mastrángelo, and Gervasio Piñeiro.	*Science of the Total Environment* 575: 1056–65.	2017

Annex 2 – Metrics and indicators

Table A2.1 shows the most common indicators employed by studies using quantitative methods for each well-being dimension examined.

Table A2.1
Subset of indicators used to measure social impacts of soybean production

Well-being dimension	Indicator
Health	Serum levels of thyroid function markers (FT4, TT3, TSH, BChE)
	Cancer risk indicator (odds ratio)
	Adverse birth indicators (low birth weight and preterm births)
Nutrition	Children's soybean consumption and children's dietary diversity
Freedom of choice	Composite indicator (gender empowerment)
HDI	Human development index
	Municipal Development Index
Income/expenditure	Crop yield*market price
	Willingness to pay (preferences for profitability)
	Business reporting (profitability)
	Income
	Poverty headcount
	Theil index
	Gini index

Table A2.2 shows the different methods that have been used to measure the ES impacts included in our dataset. 43% of the studies uses environmental study measurements as a method to quantify ES supply; this category includes studies that performed primary data collection to measure properties and structure of the ecosystem and infer both the quality of the ecosystem processes and functioning and the potential ES production. An example of a study that uses environmental measurements is Paul et al. (2015) which empirically measure multiple soil properties, such as soil carbon content, bulk density, and soil aggregate fractions, at different soil depths to examine the impact of pesticide applications on soil fertility and formation. The study was complemented with a measure of crop yield across different agricultural practices treatment to evaluate the effectiveness of pesticide application on food provisioning services. Crop yield can be considered as an indicator of potential flow of ecosystem services as the crop yield can be consumed, either directly or as an input for human consumption products, by the human population and as such represents an ecosystem service benefit. Other ecosystem services such as pollination and biological control have been assessed mainly through environmental science primary data measurements (Koh et al., 2008; Mitchell et al., 2014; Monasterolo et al., 2015; Ruiz-Toledo et al., 2020). However, their actual contribution to human's well-being is very difficult to measure, as the effect on crop yield of underlying regulating services is influenced by a range of other factors. Therefore, studies that do not assess the relation to soy production are qualified as indicators of a healthy ecosystem structure which can contribute to provide benefits for humans.

About 35% of the studies employs a mixture of secondary data measuring environmental variables, either empirically measured or estimated through modelling, and information about interactions with human activities, e.g. agricultural practices. The combination of environmental modelled data with information on agricultural practices, such as the amount of fertilizer or pesticides used by farmers, permits to evaluate the impact on ecosystem services and the stock of natural capital considering the interaction between social and ecological system. In some cases, it is then possible to measure the actual flow of ES. Moreover, the use of modelled environmental and/or social data combined with empirical measurements allows to explore future scenarios of impact and draw inferences on best practices to mitigate current negative impacts. These analysis may be especially relevant for assessing the impact on water-related ecosystem services, such as water quality regulation and freshwater provision, where the magnitude of impact depends mainly on human practices, both in terms of water uses and water contamination. Maydana et al. (2020) assess both water quantity and quality regulations under alternative future modelled scenarios alternative management regimes (agribusiness vs conservation agriculture) while Darré et al. (2019) perform a similar analysis of current agricultural practices in Uruguay.

Table A2.2
Summary statistics of articles included in the dataset

Method	Count (%)
Benefit transfer	5%
Qualitative interviews	18%
Secondary data analysis	10%
Models coupled with farmers and expert information	25%
Environmental study measurements	43%

To measure the impact of human activities on the ecosystems, some studies use secondary data (10% of our studies), usually in the form of land use data, and employ proxies for ecosystem services provided by different land cover/uses (Baumann et al., 2017; Meehan and Gratton, 2016).

Finally, around 23% of the studies focus on measuring the actual flow of ecosystem services and the benefits enjoyed by the population either through qualitative interviews with farmers and other rural residents or by estimating the contribution of land cover/use categories to the country's economic wealth (e.g. GDP). Lima et al. (2011) explored the impact of agricultural intensification on water provision and soil properties through qualitative interviews with rural residents in areas characterised by recent agricultural expansion for soybean crop. Saraiva Farinha et al. (2019) monetize the recreational services provided by protected natural areas such as forests using benefit transfer.

To provide an indication of the high level of interdisciplinarity required to measure the impact of soybean production on ecosystem services, we show the set of unique indicators that have been used to measure impacts included in our dataset (Table A2.3).

Table A2.3
Most common indicators for measuring impact on ecosystem services of soybean

Ecosystem service	Indicator
Food provision	Crop yield per Ha
	Individual's perception
Wild food provision	Individual's perception
Raw materials	Individual's perception
Water provision	Blue water footprint
Climate regulation	GHG emission by land use category
	Monetary value for NPP (net primary production)
	Soil organic content (SOC)
	GHG emissions associated with insecticide use
Water quantity regulation	Water percolation
Water quality regulation	Individual's perception
	Ecotoxicity potential
	Soybean monoculture planted area
	Presence of agrochemical compounds (CY)
	Average base-flow NO3–N
	Nitrate leaching
Erosion prevention	Individual's perception
Maintenance of soil fertility	Crop residue in soybean fields
	Soil organic content (SOC)
Pollination	Abundance and diversity of native bee species
	Integrate pesticide index
	Bees abundance in soybean fields
Biological control	Relative insecticide use
	Natural enemy abundance
	Herbivore abundance, aphid abundance
Habitat provision	Species richness
Nutrient cycling	Nutrient concentration
Recreation and tourism	Benefit transfer

References

Almberg, K.S., Turyk, M., Jones, R.M., Anderson, R., Graber, J., Banda, E., Waller, L.A., Gibson, R., Stayner, L.T., 2014. A study of adverse birth outcomes and agricultural land use practices in Missouri. Environ. Res. 134, 420–426.

Auer, A., Maceira, N., Nahuelhual, L., 2017. Agriculturisation and trade-offs between commodity production and cultural ecosystem services: a case study in Balcarce County. J. Rural Stud. 53, 88–101.

Balmford, A., Fisher, B., Green, R.E., Naidoo, R., Strassburg, B., Turner, R.K., Rodrigues, A.S.L., 2011. Bringing ecosystem services into the real world: an operational framework for assessing the economic consequences of losing wild nature. Environ. Resour. Econ. 48, 161–175.

Baumann, M., Gasparri, N.I., Piquer-Rodriguez, M., Gavier-Pizarro, G., Griffiths, P., Hostert, P., Kuemmerle, T., 2017. Carbon emissions from agricultural expansion and intensification in the Chaco. Glob. Chang. Biol. 1902–1916.

Bernieri, T., Rodrigues, D., Barbosa, I.R., Ardenghi, P.G., Basso da Silva, L., 2019. Occupational exposure to pesticides and thyroid function in Brazilian soybean farmers. Chemosphere 218, 425–429.

Boerema, A., Peeters, A., Swolfs, S., Vandevenne, F., Jacobs, S., Staes, J., Meire, P., 2016. Soybean trade: balancing environmental and socio-economic impacts of an intercontinental market. PLoS One 11, 1–13.

Bottrill, M., Cheng, S., Garside, R., Wongbusarakum, S., Roe, D., Holland, M.B., Edmond, J., Turner, W.R., 2014. What are the impacts of nature conservation interventions on human well-being: a systematic map protocol. Environ. Evid. 3, 1–11.

Brazil, Greenpeace, 2018. Hold the Line: Agribusiness Expansion and the Dispute for the Cerrado. São Paulo.

Busscher, N., Parra, C., Vanclay, F., 2020. Environmental justice implications of land grabbing for industrial agriculture and forestry in Argentina. J. Environ. Plan. Manag. 63, 500–522.

Cardozo, M.L., Salas, D., Ferreira, I., Mereles, T., Rodríguez, L., 2016. Soy expansion and the absent state: indigenous and peasant livelihood options in eastern Paraguay. J. Lat. Am. Geogr. 15, 87–104.

Choi, S., Kim, H., 2016. The impact of conglomerate farming on the poor: empirical evidence from the Brazil soy sector. Int. Area Stud. Rev. 19, 147–164.

Dale, V.H., Polasky, S., 2007. Measures of the effects of agricultural practices on ecosystem services. Ecol. Econ. 64, 286–296.

Darré, E., Cadenazzi, M., Mazzilli, S.R., Rosas, J.F., Picasso, V.D., 2019. Environmental impacts on water resources from summer crops in rainfed and irrigated systems. J. Environ. Manage. 232, 514–522.

De Maria, M., Robinson, E.J., Rajabu, J., Kadigi, R., Dreoni, I., Couto, M., Howai, N., Peci, J., Fiennes, S., 2020. Global Soybean Trade. The Geopolitics of a Bean.

Dornbusch, R., 1992. The case for trade liberalization in developing countries. J. Econ. Perspect. 6, 173–177.

Drabik, D., de Gorter, H., Timilsina, G.R., 2016. Producing biodiesel from soybeans in Zambia: an economic analysis. Food Policy 59, 103–109.

D'Acunto, L., Semmartin, M., Ghersa, C.M., 2014. Uncropped field margins to mitigate soil carbon losses in agricultural landscapes. Agric. Ecosyst. Environ. 183, 60–68.

Fearnside, P.M., 2001. Soybean cultivation as a threat to the environment in Brazil. Environ. Conserv. 28, 23–38.

Ganeshkumar, P., Gopalakrishnan, S., 2013. Systematic reviews and meta-analysis: understanding the best evidence in primary healthcare. J. Fam. Med. Prim. Care 2, 9.

Garrett, R.D., Rausch, L.L., 2016. Green for gold: social and ecological tradeoffs influencing the sustainability of the Brazilian soy industry. J. Peasant Stud. 43, 461–493.

Garrett, R.D., Levy, S., Gollnow, F., Hodel, L., Rueda, X., 2021. Have food supply chain policies improved forest conservation and rural livelihoods? A systematic review. Environ. Res. Lett. 16.

German, L., Schoneveld, G.C., Pacheco, P., 2011. The social and environmental impacts of biofuel feedstock cultivation: evidence from multi-site research in the forest frontier. Ecol. Soc. 16, 26.

Godar, J., Gardner, T., 2019. Trade and land-use telecouplings. In: Telecoupling. Palgrave Macmillan, Cham, pp. 149–175.

Grabs, J., Carodenuto, S.L., 2021. Traders as sustainability governance actors in global food supply chains: a research agenda. Bus. Strateg. Environ. 30, 1314–1332.

Grant, M.J., Booth, A., 2009. A typology of reviews: an analysis of 14 review types and associated methodologies. Health Info. Libr. J. 26, 91–108.

Harrison, P.A., Berry, P.M., Simpson, G., Haslett, J.R., Blicharska, M., Bucur, M., Dunford, R., Egoh, B., Garcia-Llorente, M., Geamănă, N., Geertsema, W., Lommelen, E., Meiresonne, L., Turkelboom, F., 2014. Linkages between biodiversity attributes and ecosystem services: A systematic review. Ecosyst. Serv. 9, 191–203.

Heilmayr, R., Lambin, E.F., 2016. Impacts of nonstate, market-driven governance on Chilean forests. Proc. Natl. Acad. Sci. U. S. A. 113, 2910–2915.

Heimpel, G.E., Yang, Y., Hill, J.D., Ragsdale, D.W., 2013. Environmental consequences of invasive species: greenhouse gas emissions of insecticide use and the role of biological control in reducing emissions. PLoS One 8, 1–7.

Ingram, V., van den Bergh, J., van Oorschot, M., Arets, E., Judge, L., 2018. Governance options to enhance ecosystem services in cocoa , soy , tropical timber and palm oil value chains considering ecosystems and ecosystem services generally in. Environ. Manage. 128–142.

IDH, IUCN, N.L., 2019. European Soy Monitor.

Jia, Fu, Peng, Sujie, Green, Jonathan, Koh, Lenny, Chen, Xiaowei, 2020. Soybean supply chain management and sustainability: A systematic literature review. J. Clean. Prod. 255.

Koh, I., Holland, J.D., 2014. Grassland plantings and landscape natural areas both influence insect natural enemies. Agric. Ecosyst. Environ. 199, 190–199.

Koh, L.P., Nichols, J.D., Bailey, L.L., O Jr., A.F., Talancy, N.W., Grant, E.H.C., Gilbert, A. T., Annand, E.M., Husband, T.P., Hines, J.E., 2008. Assessing ecological responses to environmental change using statistical models. J. Appl. Ecol. 45, 1321–1329.

Konno, K., Akasaka, M., Koshida, C., Katayama, N., Osada, N., Spake, R., Amano, T., 2020. Ignoring non-English-language studies may bias ecological meta-analyses. Ecol. Evol. 10, 6373–6384.

Krapovickas, J., Sacchi, L.V., Hafner, R., 2016. Firewood supply and consumption in the context of agrarian change: the Northern Argentine Chaco from 1990 to 2010. Int. J. Commons 10, 220–243.

Lambin, E.F., Gibbs, H.K., Heilmayr, R., Carlson, K.M., Fleck, L.C., Garrett, R.D., Le Polain De Waroux, Y., McDermott, C.L., McLaughlin, D., Newton, P., Nolte, C., Pacheco, P., Rausch, L.L., Streck, C., Thorlakson, T., Walker, N.F., 2018. The role of supply-chain initiatives in reducing deforestation. Nat. Clim. Chang. 8, 109–116.

le Polain de Waroux, Y., Garrett, R.D., Graesser, J., Nolte, C., White, C., Lambin, E.F., 2019. The restructuring of south American soy and beef production and trade under changing environmental regulations. World Dev 121, 188–202.

Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gøtzsche, P.C., Ioannidis, J.P.A., Clarke, M., Devereaux, P.J., Kleijnen, J., Moher, D., 2009. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. Journal of clinical epidemiology.

Lima, M., Skutsch, M., de Medeiros Costa, G., 2011. Deforestation and the social impacts of soy for biodiesel: perspectives of farmers in the south Brazilian Amazon. Ecol. Soc. 16.

Malkamäki, A., Toppinen, A., Kanninen, M., 2016. Impacts of land use and land use changes on the resilience of beekeeping in Uruguay. For. Policy Econ 70, 113–123.

Mann, M.L., Kaufmann, R.K., Marie, D., Gopal, S., Baldwin, J.G., Vera-Diaz, M.D.C., Bauer, D.M., Gopal, S., Baldwin, J.G., Del Carmen Vera-Diaz, M., 2012. Ecosystem service value and agricultural conversion in the Amazon: implications for policy intervention. Environ. Resour. Econ. 53, 279–295.

Martinelli, L.A., Batistella, M., da Silva, R.F.B., Moran, E., 2017. Soy expansion and socioeconomic development in municipalities of Brazil. Land 6.

Maydana, G., Romagnoli, M., Cunha, M., Portapila, M., 2020. Integrated valuation of alternative land use scenarios in the agricultural ecosystem of a watershed with limited available data, in the Pampas region of Argentina. Sci. Total Environ. 714, 136430.

Meehan, T.D., Gratton, C., 2016. A landscape view of agricultural insecticide use across the conterminous US from 1997 through 2012. PLoS One 11, 1–17.

Mitchell, M.G.E., Bennett, E.M., Gonzalez, A., 2014. Agricultural landscape structure affects arthropod diversity and arthropod-derived ecosystem services. Agric. Ecosyst. Environ. 192, 144–151.

Mitchell, A.L., Rosenqvist, A., Mora, B., 2017. Current remote sensing approaches to monitoring forest degradation in support of countries measurement, reporting and verification (MRV) systems for REDD+. Carbon Balance Manag 12.

Monasterolo, M., Musicante, M.L., Valladares, G.R., Salvo, A., 2015. Soybean crops may benefit from forest pollinators. Agric. Ecosyst. Environ. 202, 217–222.

Newton, P., Benzeev, R., 2018. The role of zero-deforestation commitments in protecting and enhancing rural livelihoods. Curr. Opin. Environ. Sustain. 32, 126–133.

Paul, B.K., Vanlauwe, B., Hoogmoed, M., Hurisso, T.T., Ndabamenye, T., Terano, Y., Six, J., Ayuke, F.O., Pulleman, M.M., 2015. Exclusion of soil macrofauna did not affect soil quality but increased crop yields in a sub-humid tropical maize-based system. Agric. Ecosyst. Environ. 208, 75–85.

Potschin, M.B., Haines-Young, R.H., 2011. Ecosystem services: exploring a geographical perspective. Prog. Phys. Geogr. 35, 575–594.

Roe, D., Sandbrook, C., Fancourt, M., Schulte, B., Munroe, R., Sibanda, M., 2013. A systematic map protocol: which components or attributes of biodiversity affect which dimensions of poverty? Environ. Evid. 2, 1–8.

Ruder, A.M., Carreón, T., Butler, M.A., Calvert, G.M., Davis-King, K.E., Waters, M.A., Schulte, P.A., Mandel, J.S., Morton, R.F., Reding, D.J., Rosenman, K.D., 2009. Exposure to farm crops, livestock, and farm tasks and risk of glioma. Am. J. Epidemiol. 169, 1479–1491.

Ruiz-Toledo, J., Vandame, R., Penilla-Navarro, P., Gómez, J., Sánchez, D., 2020. Seasonal abundance and diversity of native bees in a patchy agricultural landscape in Southern Mexico. Agric. Ecosyst. Environ. 292.

Saraiva Farinha, M.J.U., Bernardo, L.V.M., Soares Filho, A., Berezuk, A.G., da Silva, L.F., Ruviaro, C.F., 2019. Opportunity cost of a private reserve of natural heritage, Cerrado biome – Brazil. Land use policy 81, 49–57.

Sauer, S., 2018. Soy expansion into the agricultural frontiers of the Brazilian Amazon: the agribusiness economy and its social and environmental conflicts. Land use policy 79, 326–338.

Schleicher, J., Schaafsma, M., Burgess, N.D., Sandbrook, C., Danks, F., Cowie, C., Vira, B., 2018. Poorer without it? The neglected role of the natural environment in poverty and wellbeing. Sustain. Dev. 26, 83–98.

Scoones, 1998. Sustainable Rural Livelihoods: a Framewrok for Analysis (No. 72). IDS Working Paper.

Silvério, D.V., Brando, P.M., Macedo, M.N., Beck, P.S.A., Bustamante, M., Coe, M.T., 2015. Agricultural expansion dominates climate changes in southeastern Amazonia: the overlooked non-GHG forcing. Environ. Res. Lett. 10.

Sjauw-Koen-Fa, A.R., Blok, V., Omta, O., 2017. Exploring the applicability of a sustainable smallholder sourcing model in the black soybean case in Java. Int. Food Agribus. Manag. Rev. 20, 709–728.

Steward, C., 2007. From colonization to "environmental soy": a case study of environmental and socio-economic valuation in the Amazon soy frontier. Agric. Human Values 24, 107–122.

Sun, J., Mooney, H., Wu, W., Tang, H., Tong, Y., Xu, Z., Huang, B., Cheng, Y., Yang, X., Wei, D., Zhang, F., Liu, J., 2018. Importing food damages domestic environment: evidence from global soybean trade. Proc. Natl. Acad. Sci. U. S. A. 115, 5415–5419.

Syswerda, S.P., Robertson, G.P., 2014. Ecosystem services along a management gradient in Michigan (USA) cropping systems. Agric. Ecosyst. Environ. 189, 28–35.

TEEB, 2010. The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Earthscan, London and Washington.

Trase, 2018. Sustainability in Forest-Risk Supply Chains: Spotlight on Brazilian Soy. Yearbook, 2018.

UK NEA, 2011. The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge.

United Nations, 2020. Global indicator framework for the sustainable development Goals and targets of the 2030 agenda for sustainable development. Work Stat. Comm. Pertain. to 2030 Agenda Sustain. Dev. 1–21.

Vallecillo, S., La Notte, A., Zulian, G., Ferrini, S., Maes, J., 2019. Ecosystem services accounts: valuing the actual flow of nature-based recreation from ecosystems to people. Ecol. Modell. 392, 196–211.

Villarini, G., Jones, C.S., Schilling, K.E., 2016. Soybean area and baseflow driving nitrate in Iowa's Raccoon river. J. Environ. Qual. 45, 1949–1959.

Villarino, S.H., Studdert, G.A., Baldassini, P., Cendoya, M.G., Ciuffoli, L., Mastrángelo, M., Piñeiro, G., 2017. Deforestation impacts on soil organic carbon stocks in the Semiarid Chaco Region. Argentina. Sci. Total Environ. 575, 1056–1065.

Virah-Sawmy, M., Durán, A.P., Green, J.M.H., Guerrero, A.M., Biggs, D., West, C.D., 2019. Sustainability gridlock in a global agricultural commodity chain: reframing the soy–meat food system. Sustain. Prod. Consum. 18, 210–223.

Weinhold, D., Killick, E., Reis, E.J., 2013. Soybeans, poverty and inequality in the Brazilian Amazon. World Dev 52, 132–143.

Westhoek, H., Lesschen, J.P., Rood, T., Wagner, S., De Marco, A., Murphy-Bokern, D., Leip, A., van Grinsven, H., Sutton, M.A., Oenema, O., 2014. Food choices, health and environment: effects of cutting Europe's meat and dairy intake. Glob. Environ. Chang. 26, 196–205.

World Bank, 2019. World Development Report 2020: Trading for Development in the Age of Global Value Chains.