Article:

Mueller, Carina, West, Christopher David orcid.org/0000-0002-5091-6514, Bastos Lima, Mairon et al. (1 more author) (2023) Demand-Side Actors in Agricultural Supply Chain Sustainability : An Assessment of Motivations for Action, Implementation Challenges, and Research Frontiers. World. pp. 569-588. ISSN 2673-4060

https://doi.org/10.3390/world4030035

world

MDPI

Article

Demand-Side Actors in Agricultural Supply Chain Sustainability: An Assessment of Motivations for Action, Implementation Challenges, and Research Frontiers

Carina Mueller [1,2,*], Christopher West [1], Mairon G. Bastos Lima [2,*] and Bob Doherty [3]

[1] Stockholm Environment Institute York, Department of Environment and Geography, University of York, York YO10 5NG, UK; chris.west@york.ac.uk
[2] Stockholm Environment Institute (SEI), 10451 Stockholm, Sweden
[3] School for Business and Society, University of York, York YO10 5DD, UK; bob.doherty@york.ac.uk
* Correspondence: carina.mueller@sei.org (C.M.); mairon.bastoslima@sei.org (M.G.B.L.)

Abstract: Agricultural supply chains of forest-risk commodities such as soy, palm oil, and cocoa have risen to the top of the global sustainability agenda. Demand-side actors, including consumer-goods companies, retailers, and civil society organizations have coalesced around a growing number of sustainable supply chain policies. However, despite rapid advances in tools and methods to convert data into useful information about impacts and policy effectiveness, and their implementation for decision-making is lagging. There is an urgent need to examine such demand-led action and understand how to accelerate progress towards agricultural supply chain sustainability. Here, we explore how demand-side actors within globalized supply chains see limitations in knowledge and barriers to progress in the context of forest-risk commodities. We draw from 20 semi-structured interviews and two focus group discussions with manufacturers, retailers, NGOs, and data providers. Our findings show that civil society pressure in consumer regions is perceived as a key driver guiding action, that certification is commonly sought to reduce detrimental impacts, but that collaboration to tackle systemic issues remains a gap. Companies also highlight the need for simple, timely, and meaningful metrics to assess impacts—practical usability concerns that need to be considered in the search for ever-greater accuracy in capturing complex phenomena.

Keywords: sustainable sourcing; traceability; supply chain; corporate sustainability; deforestation

check for updates

Citation: Mueller, C.; West, C.; Bastos Lima, M.G.; Doherty, B. Demand-Side Actors in Agricultural Supply Chain Sustainability: An Assessment of Motivations for Action, Implementation Challenges, and Research Frontiers. *World* **2023**, *4*, 569–588. https://doi.org/10.3390/world4030035

Academic Editor: Jungho Baek

Received: 2 August 2023
Revised: 4 September 2023
Accepted: 5 September 2023
Published: 7 September 2023

1. Introduction

Agricultural supply chain sustainability has become one of the top issues on the international environmental agenda. The global agri-food system is a key source of greenhouse gas emissions (GHG) [1] and the biggest driver of natural ecosystem conversion leading to biodiversity loss [2], a major cause of soil degradation [3] and freshwater depletion [4]. The same global agri-food system is likely to be hit hard by climate change, natural resource scarcity, and land degradation [5]. In response, multinational companies and governments have increased action, setting targets and making commitments to tackle these challenges [6–8].

According to Purvis et al. [9], sustainability has become ubiquitously represented as three interlinked pillars of economic, social, and environmental aspects. These pillars are also reflected in the Sustainable Development Goals (SDGs) which the United Nations [10] have developed. These goals aim to guide pathways towards sustainability and stress the interconnectedness of countries within the globalized economy [10]. To improve sustainable production within supply chain management of traded agricultural products, different approaches are adopted, such as deforestation-free standards (e.g., the Soy Moratorium), eco-certification (e.g., Roundtable on Sustainable Palm Oil (RSPO), the Round Table on Responsible Soy (RTRS)), and collective action (e.g., Chinese Sustainable Meat) [11].

The interconnectedness of countries through trade has also increased the vulnerability of supply chains to disruptions, illustrated in recent years through the COVID-19 pandemic, weather extremes, and geopolitical conflicts [12,13]. These disruptions can increase commodity prices [14] and lead to social and geo-political instability [7]. Managing these risks is challenging for agricultural products which are characterized by seasonality and sometimes perishability [15]. These risks of supply chain disruptions and price fluctuations have increased the interest in supply chain robustness and resilience [16].

For many players in the agri-food sector, the largest environmental or social impacts take place via their supply chains and are, therefore, outside their direct control [17]. The size and influence of multinational companies (MNCs), as well as of major consumer markets such as Europe, mean their sustainability commitments are critical [18]. Still, agriculture-driven deforestation rates remain stubbornly high [19], and food-related GHG emissions have not declined, let alone decreased to levels necessary to limit climate change to 1.5 °C [1]. There remains an urgent need to understand how demand-side policy action can become more effective and deliver in a world of international supply chains and globalized sustainability issues. This article examines the features and limitations of current demand-side action on agricultural supply chain sustainability to understand how further progress can be made. It draws from an overview of the scientific literature on the subject as well as primary data collection through 20 key-informant interviews and two focus groups with multiple stakeholders. That includes representatives of consumer goods companies, retailers, consultancies, certification bodies, and civil society organizations. We examine their motivations for action on supply chain sustainability, the features and limitations of the methods and data that they utilize and identify frontiers for enabling more effective action.

The article is structured as follows. Section 2 provides an overview of the scientific literature on demand-side measures for agricultural supply chain sustainability. Section 3 describes our methods for primary data collection, and Section 4 details our findings on the perceptions of end buyers (here, manufacturers and retailers). Finally, Section 5 concludes the article with lessons and recommendations for further research.

2. Demand-Led Action for Agricultural Supply Chain Sustainability

Global sustainability challenges require a global response [20]. That involves action on both supply and demand sides as well as by actors outside of the supply chain, such as financial institutions [21]. Progress on the implementation of demand-side commitments, however, is hindered by the globalization of trade [22], which has increased the spatial distance and number of actors between production and consumption [23,24]. This complexity makes it challenging to understand the origin of products and its associated impacts [25]. It also limits the ability of actors at one end of the supply chain to influence the activities at the other end [20]. In this context, supply chain transparency is a crucial prerequisite to identifying the different roles and responsibilities of actors in the system [20]. Many supply chains lack transparency, which is in part due to limited traceability [26,27]. Improving traceability is most challenging for commodities which are traded internationally in large quantities and have complex life cycles such as palm oil, soybean, and beef [28].

Recent years have seen a variety of supply chain sustainability initiatives emerge, including the development of environmental due diligence [29], the Glasgow Forest Declaration [30], and those led by international retailers and manufacturers [31]. Other commitments, data developments, and policies have potential to further improve the transparency of supply chains and—ultimately—to decrease negative environmental impacts. Bager et al. [32], for example, lay out a set of eighty-six policy options for the EU, with varying levels of feasibility and potential impact. Many of these policy options relate to information availability and disclosure, development of shared definitions, and increased informational capacity.

Within this scope of measures, one must consider the role of demand-side actors—and those connected to them—in promoting uptake, utilizing information, and ultimately promoting change based on this information. Lyon et al. [33] lay out these roles, which are illustrated in Figure 1. Actors within and outside the agricultural supply chain can take the role of "regulator" (setting rules and standards); they may be influential decision makers, or they may "own" components of the system but not be a direct decision maker. "Certifiers", "advocates", and "guardians" act as further points of external influence on supply chain actors which span agricultural production, manufacturing, and retailing components of the supply chain (Figure 2).

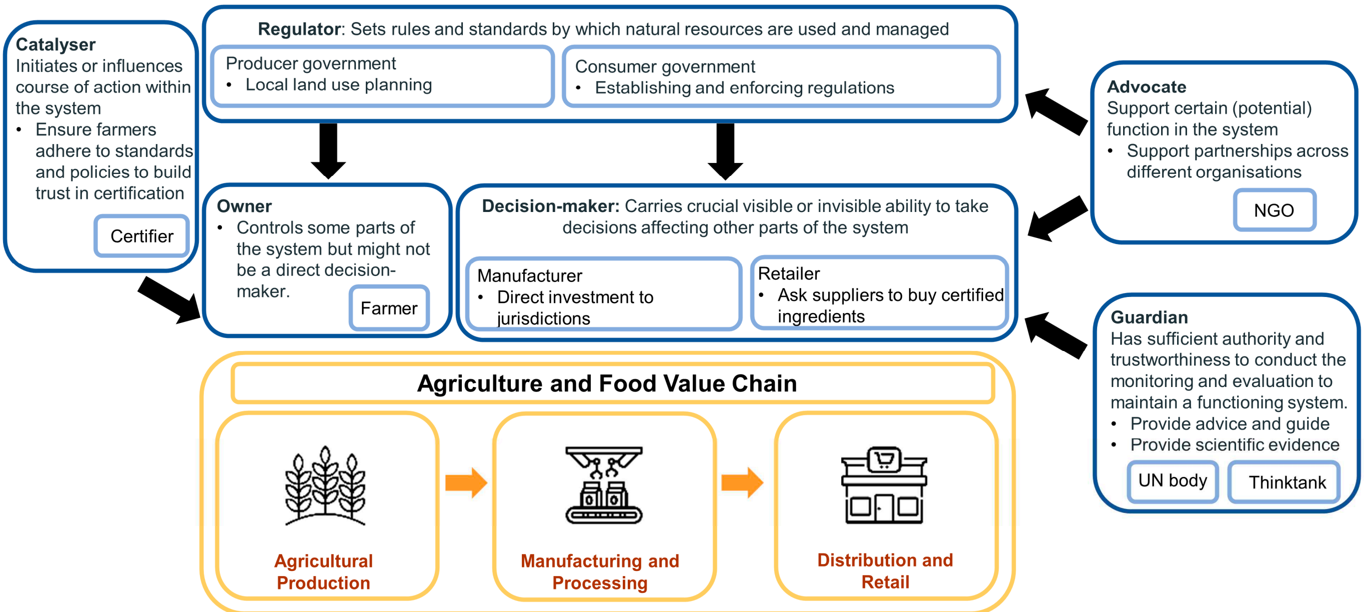

Figure 1. Roles of different stakeholders within the global food system (adapted from framework developed by Lyon et al. [33] to identify stakeholders to tackle sustainability challenge, type of organization in context of agricultural supply chain, and examples of their actions as bullet points by authors).

With any increase in data—driven by regulators, third parties, or internally promoted within the supply chain itself—comes a concurrent need to make sure this is translated into actionable information. Yet, understanding of how best to translate supply chain data into meaningful information that can guide more sustainable decisions remains lacking [34,35]. For instance, Newig et al. [36] note that more research is needed on the informational triggers required to promote sustainable consumption. For practitioners to understand the environmental impacts linked to commodities, there is a need for improvements in the understanding of where commodities come from and the metrics of impacts taking place in production regions.

To translate data into useful information to support companies, Life Cycle Assessment (LCA) and product "footprinting" approaches have been developed [37–39]. These approaches allow the measurement and analysis of the consequences of decisions in product design and procurement on the natural environment. However, improving regional detail and the robustness of environmental impact metrics to increase their relevance to consumers and producers remains a challenge [39–41]. Recently, advances in scientific understanding, computing, visualization, and data availability have allowed several improvements. First, the ability to widen the sustainability concerns that can be considered such as carbon emissions [42], biodiversity [43–45], water scarcity [46,47], and soil erosion [48]; second, enhanced accounting of spatial heterogeneity in environmental characteristics at the sub-national level (districts, provinces; e.g., [49–51]); third, regular updates linked to environmental changes in production landscapes through the integration of near-real-time Earth observation data to monitor progress [52]. Importantly, this information is now accessible to end users, through publicly available platforms such as Global Forest Watch [53], Water Risk Filter [54], or the Trase platform (Trase.earth).

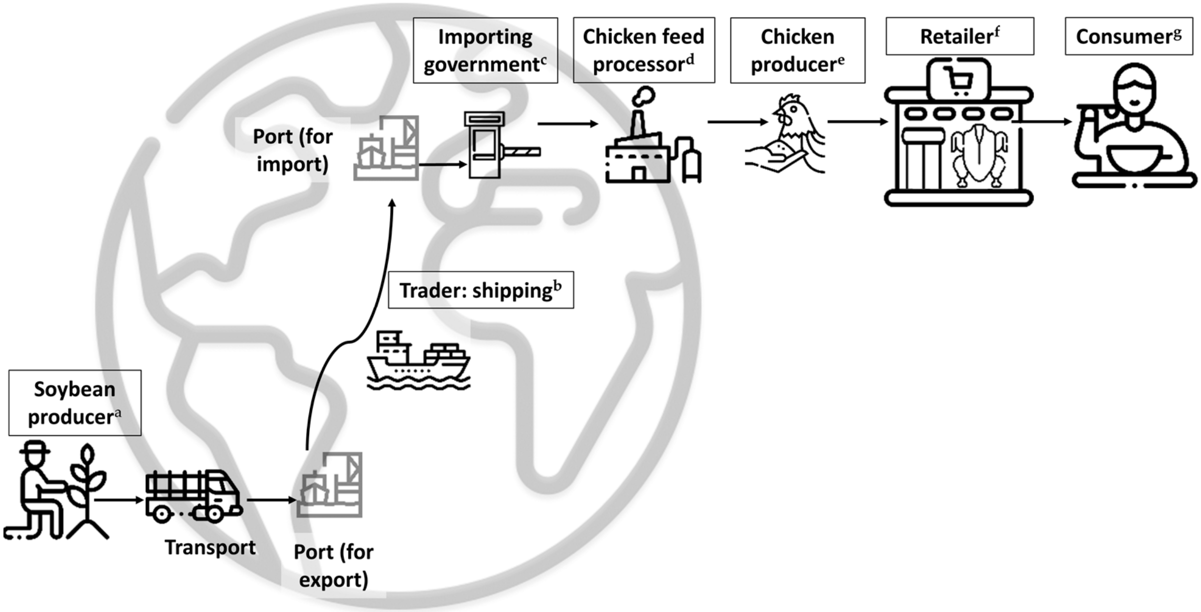

Figure 2. Flowchart illustrating the flow of goods (here with an example of soybeans) along the supply chain from producer to consumer. Relevant decisions by different actors are indicated by superscript letters: [a] What crops are grown, where, and how? [b] Where are commodities bought from? [c] What rules do goods need to fulfil to cross border? [d] Which ingredients are in chicken feed? [e] What certification standards (if any) or sourcing origins do suppliers need to fulfill? [f] What products are offered on shelves? [g] What food is on my plate?

However, despite these advances, implementation into decision making is slow [55]. There is a lack of urgent, large-scale transformative change in corporate practice required to stay within a planetary "safe operating space" [56]. This has been referred to as an "ecological-corporate disconnect" [57]. In the literature, several factors have been described that help explain why improved knowledge has not resulted in improved implementation. Examples are a lack of academic ability to develop science that is applicable in practice [57], an "explosion" of data and information about sustainability and supply chains potentially leading to further confusion and resultant inaction [20], and the challenge of ascribing responsibility to various actors along complex supply chains, with limited ability for individual stakeholders to undertake meaningful change [58]. Schröter et al. [34] have argued that research on interregional sustainability at the science-policy interface should focus on determining the level of detail that is possible based on current data availability but also necessary to inform policies.

To tackle the complexity inherent in such systemic problems, it has been suggested that a more inclusive approach is needed that incorporates the perspectives and influence of multiple stakeholders [59]. As illustrated by Figure 1, in the context of agri-commodity supply chains, this stakeholder group encompasses a wide range of roles and responsibilities, meaning that the development of sustainability information that is understood and trusted across all groups is a challenge requiring shared understanding and consensus building [60]. Social–ecological systems (SESs) thinking is a potentially useful concept to help bridge the divide between science and corporate sustainability practice (see, e.g., [57]). In the context of food, systems thinking focuses on the interactions and dynamics between the system's different components along the entire value chain [61]. In sum, building better and more actionable supply chain information to inform systemic responses requires a deeper multistakeholder understanding of informational needs and requirements.

3. Methods

This qualitative assessment relies on primary data collection to gain a rich and in-depth understanding of different perspectives among demand-side actors in international agricultural supply chains. Twenty semi-structured interviews and two focus group discussions were conducted with multiple demand-side stakeholders such as food manufacturers, retailers, and civil society organizations (see Table 1).

Table 1. Overview of interviews and focus group discussions conducted.

Type of Actor	Number and Type of Data Gathering Method (Interviews/Focus Group Discussions)	Number of Organizations	Number and Type of Participant
Phase 1		Companies	
Manufacturers (M) [1]	5 interviews and 1 focus group discussion	4	6 (Sustainability Manager/Director, Sustainable Sourcing Manager/Director)
European retailer (R)	5 interviews	5	5 (Sustainability Manager, Sustainable Sourcing Managers, CSR Manager)
Phase 2		NGOs	
European-centred NGO	3 interviews	3	3 (Program Managers)
Global NGO (N)	1 interview and 1 focus group discussion	1	4 (Sustainability Directors, Program Managers)
Phase 3		Data providers	
Consultancies (C)	4 interviews	4	4 (Sustainability Consultants, Partner)
Certification bodies (CB)	3 interviews	3	3 (Program Managers, Director)

[1] Note: abbreviations of types of actors used throughout the publication to anonymize interviewees.

The data collection followed a phased approach. Initial interviewees were selected based on their ability to provide meaningful insights from their professional experience within consumer-facing companies. Therefore, first, manufacturers and retailers were interviewed about their perspectives and underlying motivations for acting on agricultural supply chain sustainability (Phase 1 in Table 1). According to Lyon et al. [33], they are "decision-makers" in the system (Figure 1). As those private sector players revealed that their motivations and concerns were in part shaped by civil society organizations acting as "advocates" ([33], see Figure 1), in a second phase, NGOs were interviewed (see Figure 1 and Phase 2 in Table 1). Thirdly, as it became clear that the NGOs themselves depend on others to provide information, consultancies and certification bodies involved in gathering supply chain data were talked to (Phase 3 in Table 1), having the role of "catalyzers" in the system ([33], Figure 1).

Relevant consumer goods manufacturers and retailers for Phase 1 were identified through their use of certification standards such as RSPO and RTRS [7], their commitment to science-based GHG emission targets including their supply chains [8], or their association with the food and beverages sector with sizeable market share (and therefore, responsibility). A snowball sampling technique [62] was employed to identify other relevant interviewees, particularly in Phases 2 and 3. Both the interviews and focus group discussions were semi-structured, which allowed flexibility to ask further follow-up questions depending on the interviewee's knowledge and experience (see [63]).

Adopting such an iterative interview process allowed for a better understanding of the drivers of demand-led action on agricultural supply chain sustainability, narrowing down the core issues acting as barriers to implementation and pinpointing some significant research or tool gaps that companies, consultancies, and NGOs identify. The interviews lasted for 30–60 min, depending on the participant's availability. Most took place via phone or Skype/Zoom, though some were conducted in person at the University of York, UK. Focus group discussions were conducted in case multiple individuals from the same organization were required to answer all the interview questions, following the same structure as the interviews. These focus group discussions lasted about one hour and were conducted online using Skype/Zoom. The purpose of the interviews and focus group discussions was sent in written format to the participants in advance of the meeting. To ensure anonymity, names of specific organizations were omitted (see Table 1 for the abbreviations used here). All interviews and focus group discussions were audio recorded, for which participants' approval was received. Primary data collection took place between January and May 2020.

All the interview and focus group transcripts were coded into broad categories, which included motivations, specific sustainability concerns, type of decisions, limitations of existing methods, to quantify their environmental impacts and barriers to implementation. In a second round of more in-depth coding, the findings were classified into major emerging themes [64]. Thematic content analysis was used to iteratively refine themes and codes based on research team discussions [65]. A general inductive approach to analyze the qualitative data has been applied [66] to allow flexibility to find themes or codes in the raw data which were not pre-defined. In the analyses and interpretation of the data, particular attention was paid to the similarities and differences in the perceptions between the different types of actors (see [67]).

Interviewees were asked to consider which environmental sustainability concerns within producing countries' end buyers perceive as relevant for their own organization. The focus was on their views on approaches or solutions to bridge the gap between knowledge and implementation of activities to address these sustainability concerns.

4. Results

4.1. Motivations for End Buyer Companies in Sub-National Environmental Sustainability Information

To identify the knowledge that would be most useful to guide decision making, we first wanted to understand why downstream companies in the agri-food sector seek to understand the origin and associated environmental concerns of their commodities. During the research, it became clear that such motivations depend on the location of companies along the supply chain, their size, and consumer audience. However, four main motivations were most prominent in the data: (1) pressure from Western NGOs, (2) internal motivation to do the "right" thing and thereby retain and attract employees, (3) securing future supply, and (4) investors wanting to reduce their risk. For instance, one retailer representative highlighted the importance of NGO influence:

> *"Do I really care where in North America it's from at the moment? [. . .] No, not really, because there's no one in civil society or NGOs that's really telling me that there's a problem [related to deforestation]" (R4)*

Such an NGO role as a "watchdog" to point out non-ethical behavior is well-documented in the literature [68]. In turn, among manufacturers—who are closer to production and demonstrated longer-term thinking—ensuring the security of future supply has become increasingly relevant. As one manufacturer explained:

> *"As [. . .] a company that depends on agriculture we have to be aware of what our [environmental] impacts are, and we have to work to mitigate them if we want to be prepared for the future states of the world and food growing in the world" (M1)*

4.2. Solutions Which Need More Support from Science in This Field

4.2.1. Commodity Trade in Complex Supply Chains

The more complex a supply chain is, the more actors sit between the end buyer and the producer, and thus, the harder it is to obtain reliable information on the origin of the trade flows. Knowledge of the origin of supply chains is, however, crucial in order to identify effective strategies to manage sustainability challenges [20]. All end buyers that we interviewed in this study mentioned that they require external traceability information, especially for "hidden" commodities like soy, palm oil, and sugar. For example, one manufacturer mentioned *"embedded soy for chicken and beef. If [trade flow models] could unpick that, it would be super helpful. Because those supply chains, we're always very much a distant end-user of by-products" (M1).*

In contrast, interviewees explained that for less processed products such as coffee, cocoa, or tea, supply chains are shorter and less complex, and thus, it is easier to obtain the information they would like to have through engagement with their own supply chain. The level of detail manufacturers require on the origin of the commodity also depends on perceived concern within the geographic region where it is produced, as one manufacturer illustrated:

> *"Corn that's grown in the United States, we can probably classify that as a pretty low risk that we don't need to worry too much about and we don't therefore need huge, great controls in place to manage the sustainability of that production. It's also from a country that's got probably a lot of controls and checks in place already" (M4)*

This illustrates how end buyers' need for better information about the sustainability of agricultural practices depends on their perception of the sourcing region and the commodity in question.

4.2.2. Certification to Improve Production Practices

In terms of chosen solutions, most end buyers we interviewed saw certification systems such as RSPO, RTRS, or internal company schemes as important tools to manage their risks. Some companies showed a deep trust in these schemes, as illustrated by one retailer: *"I don't need to risk map that because I know that the supplier is going to have to source it on Fairtrade terms" (R1).* However, other respondents were more critical and aware of the limitations of certification, as illustrated by one manufacturer:

> *"If you look at [company internal certification], for example all of the RSPO things: They are all about the action you should take, and not measuring the outcomes of those actions. So, there is then the belief that sustainably sourced equals better or lower impact, [but] that's not necessarily proven" (M2)*

Additionally, all consultants interviewed were aware of some limitations of certification to improve sustainability. As illustrated by one consultant:

> *"Actually, they [end-buyers] buy RSPO. Then RSPO is not available for others. Then it doesn't change anything. Plus, if you actually look at what's happening in Indonesia then: 'Okay, there's RSPO certified palm oil', but then you have these mass balances and you actually don't know where the food comes from and whether there was deforestation and so forth" (C4)*

We interpret these quotes to mean that certification is commonly used—despite the recognized limitations—because many end buyers find it straightforward to affect change on choices that are under their direct control (e.g., asking suppliers to buy certified commodities) in comparison to attempting to exerting influence multiple tiers down the supply chain. Additionally, certification can be used as explicit evidence for their external stakeholders that they are making efforts to improve the environmental sustainability of their supply chains. In this regard, research could help to provide end buyers with alternative approaches besides certification to evidence the sustainability outcomes of their efforts.

4.2.3. Directing Investment to Landscapes

To overcome the limitation of certification only reaching a limited scale, investment into landscapes to which supply chains are linked was seen as a more promising solution. Though, in this context, developing an understanding of which geographic regions within supply chains require enhanced attention, supply chain transparency can be helpful, though it can be costly [20]. However, among interviewees, there was debate about how much traceability is needed to affect sustainability benefits of commodity production. As one international NGO commented, *"You need maybe to stop putting so much money in traceability and put more money in a landscape and try to drive some change in a geography" (N1).* Several NGOs, manufacturers, and retailers we interviewed saw directing investment into certain producing regions as a promising solution to improve environmental sustainability. As one retailer commented, referring to an environmentally important savannah ecoregion:

> *"There's nothing you can do about it because it's legal deforestation anyway and the only way you are going to stop that is the financial incentive and that's why we made this [. . .] announcement in the Cerrado region in Brazil" (R4)*

Several NGOs agreed with this statement about the importance of financial compensation to reduce deforestation, noting that for as long as *"we still have something that is more profitable than keeping the forests, we will have deforestation" (N1).* However, information is then needed on which regions are best to invest in, as otherwise—as one interviewed consultant warned—*"the unintended consequences might be rather that they [end-buyers] invest in the wrong place" (C4).*

The quotes suggest that, to make landscape approaches effective, there needs to be careful attention paid to ensuring that their pathway to implementation is not limited by the same pitfalls of current commodity certification systems. One of the consultants we spoke to saw landscape approaches—because of similar limitations as certification—only as an intermediate step towards some more effective alternative (C1). Certification is limited by a lack of rigorous enforcement and monitoring but also a scarcity of empirical studies measuring the impact of certification on sustainability outcomes [69]. Likewise, to be able to identify whether some investment leads to sustainability outcomes, more clarity would be needed on how sustainable practices would be encouraged, progress monitored, and performance measured. Providing data to regularly monitor performance at low cost remains a challenge.

4.3. Priority Concerns

4.3.1. Environmental Sustainability: The Need to Balance Complexity and Simplicity

So that data providers and scientists can focus their efforts, priority concerns of supply chain stakeholders need to be understood. The environmental sustainability concerns most frequently mentioned by interviewees linked to commodity sourcing were GHG emissions, deforestation or other forms of ecosystem conversion, biodiversity loss, and water consumption. Opinions on a need to consider multiple sustainability concerns in contrast to focusing on a single concern varied between stakeholders (Table 2). Whereas some interviewed NGOs, retailers, and consultancies argued that out of pragmatism, more simplicity is needed, others thought that multiple sustainability concerns should be considered together to avoid unintended consequences. One consultant stressed the simplification in which sustainability was taken forward by many retailers in Europe:

> *"I think largely to the climate change agenda that's been really simplified, and in terms of environmental sustainability most retailers we work with [. . .], that's now only just collapsed down to deforestation" (C1)*

Besides the interest in carbon and climate change, one NGO representative noted that there is a focus on more visible and fast-changing issues such as deforestation (N3), which can be easily and cost-effectively monitored with satellites. However, in our view, there is a risk that adopting too narrow an approach could have potential consequences on less visible and slower-changing sustainability challenges such as soil degradation or biodiversity loss, which science has been warning about for years [70,71]. Scientists have cautioned about over-simplification [72], which was acknowledged by some end buyers who recognized the need to embrace some complexity, as one retailer stressed:

> *"Any kind of methods that combines several sustainability aspects is good. Because otherwise you sit with different tools for every different type of aspect. So, I also understand that there's a bigger complexity the more aspects you include, but if you manage to do so, it becomes a more valid tool" (R3)*

Most stakeholders who argued for a need for simplicity justified this by the risk of complexity leading to inaction. This challenge of balancing complexity while avoiding inaction was stressed by one retailer:

> *"We are entering sort of an era where we have gone from trying to really make the complex super simple [. . .] just to be able to do something because if we make it too complex then we [. . .] don't dare to do anything. But I think we are entering from that simplification era to actually [. . .] acknowledge that this is a complex situation" (R3)*

Similarly, the influential, science-based initiative, "EAT Lancet", aimed at transforming the global food system, argues that *"We need to become better at embracing complexity while reducing the desire to oversimplify everything."* [1]. However, opinions regarding the level of complexity end buyer companies can handle varied among stakeholders depending on company internal expertise and capacity (M3, R3).

Table 2. Range of opinions on the level of appreciated complexity among different types of stakeholders as illustrated in selected citations.

Actor Type	Complexity
Manufacturer	*"So a tool, if it only did greenhouse gas calculations and land use change, then that might be fine for some, but the more that it can do on top of that the better probably" (M2).*
Retailer	*"If we make it too complex [multiple indicators], then we don't do anything, we don't dare to do anything. But I think we are entering from that simplification era to actually go into and acknowledge that this is a complex situation. [. . .] I do think that there is a lot of here, there is a lot more need for research guidance" (R4).*
NGO	*"I mean ideally absolutely we want people to look at all of these metrics [. . .] but it gets very complicated [. . .]. So, what we need is enough data that guides companies in the right direction without bogging them down in detail, right?" (NGO4).*
Consultant	*"When we use GHG reduction as the sole, or deciding, indicator of a sustainable food system, it leaves us at risk of failing to address other critical aspects of food system sustainability. Soil health and biodiversity are key metrics gaps towards achieving the desired outcome of sustainable food systems" (C3).*
Certifiers	*"I would say try to avoid too comprehensive analyses—it is not worth the effort as there is so much uncertainty" (CB3).*
Scientific expert	*"I like to joke that the Anthropocene, is really the ANDthropocene—that we need to be much better about recognizing the impacts of food on health AND hunger AND water AND biodiversity AND land AND climate. We're not there yet and I find that people are unable to understand multiple issues and their interactions" (Scientific Director, EAT Lancet).*

4.3.2. Beyond the Biophysical Environment: Social Sustainability

When stakeholders were asked which other issues they are concerned about, the majority mentioned social issues. Social sustainability aspects came up in most discussions even though we had stressed at the beginning of the interviews that these would be beyond the scope of our research. One representative of a certification body explained the importance given to social aspects by European end buyers:

"I think there are two big issues when a company starts the process of certification. First, they want to solve the risk of deforestation in their supply chain. After that, they are asking about social aspects, like poor communities' projects, improvement in labor conditions and biodiversity on the farm" (CB1)

Therefore, end buyers of commodities have the desire to consider ecological aspects together with social issues. Indeed, sustainability concerns in producing regions were often considered as interlinked, with, for example, water pollution from agriculture noted as affecting downstream drinking water quality, and poverty and education affecting knowledge and the ability to manage land sustainably. This perspective is illustrative of social–ecological systems thinking, as described by Ahlström et al. [57]. Nevertheless, trade-offs between social and ecological issues can arise. This dilemma was illustrated by one manufacturer:

"The social versus the environmental trade-offs are the biggest ones [. . .] But we find that if we stop doing business with them, the consequence to vulnerable people either working for that business or linked to that business would be so great that we may still have to work with that business. Because if we would stop doing business with them, the vulnerable people would be even more vulnerable" (R4)

4.4. Limitations of Existing Science and Tools to Advance Sustainability

4.4.1. Scale: Focus on Own Supply Chain vs. Change at Scale

Once the priority concerns of stakeholders have been understood (Section 4.3), science and tools need to link these to the spatial scale relevant to actors. Here, the focus of chosen activities by companies varied. In contrast to representatives from manufacturers, who were focused more on efforts to change practices in their own supply chains, interviewed retailers showed less focus on their own supply chains but instead rather focused on collaborative efforts to reduce deforestation (R5). Retailers are more distant from producing regions than manufacturers, and thus, traceability data on producing regions is harder to obtain. Therefore, a focus to affect change through collaborations is pragmatically more feasible. The manufacturers' emphasis on their own supply chain allows them to provide evidence and report progress on the environmental commitments they set themselves. A statement from one manufacturer supports this:

"Being able to prove to the world that you are actually eliminating deforestation from your supply chain that there is actually stuff going on there that you can measure and count and report against" (M4)

Consequently, what some of these companies "*end up doing is buying all their palm oil from concessions that were cleared 20, 30 years ago: So of course there is no deforestation*" (N4). However, this would not reduce the overall deforestation in the world as other companies with different priorities might buy commodities grown on recently deforested land. Therefore, some NGOs we interviewed do not believe that a focus on companies' own supply chains alone is an effective solution to tackle a challenge like deforestation (N3). Other NGOs ask end buyers to provide evidence of no deforestation in their entire supply chain, as highlighted by a comment from an NGO:

"So, it's a really, really tricky balance for companies who we are asking two things: You have to be squeaky clean but you also have to work in tough places you can't just [buy from long deforested places]. So, what should they be doing: they should be doing both: making sure that their supply chain is clean and driving clean suppliers" (N4)

A focus on a company's own supply chain requires much more detailed traceability data and segregation in supply chains. However, ensuring traceability and segregation is costly and ultimately, financial resources should be directed to where the sustainability outcomes can be maximized. However, providing cost-effective evidence on the outcomes of actions seems to be a challenge, as one manufacturer explained:

"There's generally a total lack of evidence in terms of impact and performance. I don't find that difficult to understand because the cost of these sorts of things is enormous" (M2)

Therefore, as long as some NGOs ask end buyers to both provide evidence of their own supply chain and also contribute to affecting change at scale, science needs to support both of these purposes.

Another knowledge gap that was brought up in the interviews was the interaction between different spatial scales. Manufacturers mentioned that they would like to better be able to understand how interventions at the farm or plantation scale would relate to landscape-scale changes and ultimately, to impacts at global scale (M2). In an ideal world, methods would be able to sum up how interventions at the farm scale would stack up with changes at landscape scale and ultimately, at global scale, as many companies' supply chains and commitments are global (M3). This would help to identify which interventions at which scale would be most effective in meeting their environmental targets (for example, potential alternatives such as improving agricultural practices at farm scale, land use planning at landscape scale to reduce ecosystem conversion, or invoking changes in the design of products).

4.4.2. Temporal Scales

The dynamic nature and complexity of supply chains provides a challenge for data providers to generate reliable information that is available quickly enough to inform current decisions. Many trade flow datasets, for example, are subject to data lags. In the context of commodity-linked sustainability, this limitation of providing recent enough trade flow data was pointed out by multiple end buyers and consultants. As one consultant explained,

"A lot of the information and the metrics that are available have [. . .] issues with [. . .] time-lag: a lot of the data that is used is very static. So, something like Trase is not really that useful to have something that happened last year. You could have accepted hundreds of tons of deforestation associated into your supply chain before the next version of Trase or things that have that sort of slow renewal time come out" (C1)

However, having more recent data is not automatically useful, as one NGO representative pointed out:

"They [end-buyers] see in their new real-time monitoring system that in the surrounding of the units where they buy from forest is being cleared. But what do you do with that information? First, it's not linked with your supply base because at the time that the tree is being cut down, there is nothing going there. So, it is not within your supply base. [. . .] And secondly [. . .], as long as there is no one on the ground [from the end-buyer company] to investigate and to do something about it and to understand the drivers, it's impossible to stop deforestation" (N3)

One reason for the time-lag in providing trade flow data is that currently the processing and cleaning to ensure robustness is very time-intensive for researchers (see [73]). However, ensuring the accuracy and reliability of the information provided is important in building trust to ensure uptake by users in their decisions. Analysis by Reis et al. [74] found that the stability and consistency in regional trade flows—referred to as "stickiness"—may vary, with some remaining relatively constant over time and other supply chain relationships changing rapidly. Researchers will therefore need to find the right balance between accuracy and timeliness, depending on the purpose of the intended users for any given information. Additional detailed information is costly, and it is questionable how much detail is needed in an uncertain world as one manufacturer pointed out:

"I can pay vast sums of money and spend huge amounts of time, but will the quality of the answer be any better than a screening type of approach, given the level of uncertainty that exists in the data and the level of changes that are likely to occur?" (M2)

With respect to changes in the future, two interviewed manufacturers (M1, M2) mentioned that they believed that to prove the origin and manage associated sustainability issues, closer and longer-term relationships with producers will become more important, and thus, trade flow stickiness will increase (see [74]). This may also reduce the complexity of supply chains, as there would potentially be fewer intermediaries between manufacturer and producer.

4.4.3. Meaningful Metrics

Several end buyer companies mentioned that they would like to link trade flow information to metrics that they are already using or might use in the future to report on their environmental performance. Since the Paris Climate Agreement, hundreds of companies have committed to Science-Based Targets for climate [5]. For companies in the food sector, most GHG emissions occur during the agricultural stage, and it is therefore expected that the interest in methodologies to measure Scope 3 emissions (i.e., from their supply chains) will increase in the future [17]. This speculation was supported by one retailer's comment that

> *"carbon impact is relevant especially in the future, where more and more companies will be setting Science-Based Targets and clear their Scope 3 emissions in the supply chain. [. . .] I know that some retailers are already doing that, and I imagine that we at some point will as well look into that" (R5)*

4.5. Collaboration to Tackle Systemic Challenges

All manufacturers and retailers we interviewed reported feeling that they have limited leverage to affect and evidence meaningful change through their supply chain commitments because their globalized complex supply chains were outside of their direct control. Examples of commitments (see [7]) are the support of no deforestation, no conversion on peat, and the reduction of GHG emissions in supply chains. Considering their commitments (see [75]) and the responses of companies to our questions, it becomes clear that their ambition is to affect change at the system level. Yet, no actor alone can achieve meaningful change at system level, particularly in globally traded complex commodity systems. Taking a "systems thinking" view requires acknowledging that there are interconnections between the system's different components, dynamic feedback, and no single "solution" [61]. Agri-food systems are complex and characterized by the interactions of multiple actors [76]. Identifying effective partnerships between different actors therefore requires an understanding of their different roles in the system and the relationships between them ([33], see Figure 1). As one international NGO representative commented,

> *"The way at least I see it [. . .] is that the more clarity we have on each supply chain actor responsibility and capability, the easier it will be to attribute and to share the responsibility across a supply chain" (N1)*

Most of the interviewed retailers, manufacturers, and NGOs saw producer-country governments as having one of the most influential roles in setting regulations and enforcing compliance around the sustainable use of natural resources ("regulator", Figure 1). This is in line with previous research by Seymour and Harris [77]. However, they also saw this as subject to change, depending on the priorities of the producer country's government. One of the European retailers we interviewed was cautious and saw their only possibility of reducing legal deforestation through providing financial incentives to compensate for the loss of economic opportunity:

> *"We are not prescriptive in terms of saying 'here is the solution', because of their country and their own industry. But we recognize we have a role to play as a company that ends up using the soy in our supply chain. We can be part of the solution, [and] help fund the solutions, even though they are the ones that need to take ownership of it locally, because we can't be seen as dictating the terms, and because countries—especially Brazil—are very sensitive about their sovereignty" (R4)*

This illustrates that, within the system, goals need to be negotiated between different actors (e.g., producer-country governments and consumer-country retailers). In this sense, actors such as those in academia and think tanks can play the role of "guardians" (see Figure 1) to bring multiple stakeholders together to identify common goals and effective solutions to achieve them.

Finally, when taking a systems approach, providing evidence on unintended consequences is crucial but also seems harder to provide for end buyers. A desire to better understand unintended consequences of collaborative efforts was brought up by multiple stakeholders. A frequently mentioned example of unintended consequences was the spillover of land use changes to other ecosystems, as one retailer pointed out:

> *"We have the Amazon Moratorium that drives leakage to the Cerrado. If you do the Cerrado Conservation Mechanism, is that gonna drive leakage to the Gran Chaco? And then if you're saying your soy is deforestation-free within the specific geographic bounds where it's happened, but is it in the wider sense?". (R5)*

5. Discussion

5.1. Implications for Science

Our findings point in the direction of certain priorities to bridge the gap between science and implementation for sustainability in global agricultural supply chains. Regarding the role of science, we argue that research could become more relevant through more collaboration across different disciplines as well as with stakeholders outside of academia. As multiple manufacturers and retailers would like to have more guidance from experts on how to deal with the trade-offs between different sustainability challenges, experts from different disciplines need to work together to develop consistently applicable methodologies that allow joint consideration of issues such as biodiversity, GHG emissions, water and soil impacts, and social considerations. In this sense, our findings corroborate the need for more scientific interdisciplinarity to help tackle sustainability challenges (e.g., [78]). Here, we go beyond previous studies to add a qualitative layer that also includes the views of end buyers that are distant from producing regions.

As expressed by our interviewees, some end buyers are keen to know what actions they can take to meaningfully address sustainability within globalized agricultural supply chains. To better contribute to system transformations, Nielsen et al. [79] argued that land systems science should better acknowledge the normative aspects which could be incorporated through co-production. A challenge here can be a conflict in norms between different stakeholders, but that is part of the governance process [59]. For instance, some actors may be ready to accept some level of tropical deforestation for the sake of agricultural production while others (e.g., some end buyers) want to see none of it—differences in underlying norms could explain this. More dialogue between different stakeholders guiding end buyers (e.g., NGOs, consultancies, scientists) on feasible solutions could help.

This study also underscores the need for a co-production approach in science, characterized by a process of mutual learning between researchers and other actors in society [80] to identify the research gaps that are most pressing in practice. That said, a challenge for multi-stakeholder engagement is that it is a time-intensive process, and the question is how this could be made more economically viable. Increasingly, funding organizations and research programs (e.g., the Global Land Program, Future Earth, Horizon2020; [81]) are asking for co-production approaches to tackle complex real-world challenges [82]. This also requires researchers to be better trained in engaging with non-academic stakeholders. However, given the limited time researchers have available for engagement processes, it might be important to have non-academic organizations involved in regularly updating data as well as in providing more user-friendly and engaging formats for scientific information. In this respect, consultancies or think tanks could become "impact extenders" [83] focusing on communicating credible scientific information to non-experts.

To bridge the gap between science and implementation, Guerry et al. [55] argued that robust evidence is needed that clearly link decisions to impacts on the environment. Improvements in the traceability of trade flow data could help to identify the origin of commodities [20]. However, as interviewees in this study reported, end buyers would like to understand the consequences of their decisions on the environment and, therefore, more forward-looking approaches are also needed. This aligns with what O'Rourke et al. [35] pointed out in their review about the science of sustainable supply chains, that instead of a "policing" of supply chains, more focus should be on how data and tools could be used to be more predictive and avoid unsustainable practices before they happen. Additionally, to prevent unintended consequences, a more holistic approach to sustainability is required. Interviewees in this study pointed out that there is a focus on more visible and faster-changing sustainability challenges such as deforestation. Yet, data collection efforts could focus on currently less visible and slow-changing issues rather than improving the detail of already visible issues.

Finally, to reduce barriers to adoption, there is also a need to harmonize and align different approaches as well as to reach some level of consensus among researchers about the "best" approaches, data and methods depending on the intended purpose. For example, standards have been agreed on how corporations can calculate and report science-based targets on GHG emissions (e.g., [84]). However, as the agri-food sector contributes considerably also to other sustainability challenges such as biodiversity loss, water scarcity or water pollution, methodological advances are needed to allow actors to quantify and report science-based targets for other major sustainability challenges as well (see [5]). Initiatives are underway to develop science-based targets for some issues, such as land or biodiversity [85], led by the Science-Based Targets Network [86]. Without agreed and standardized methodologies, there is the risk of confusing decision-makers and practitioners, leading to inaction or even a loss of trust in scientists [87]. Still, as science in this field is rapidly advancing and new data are becoming available, the developed methodologies also need to be flexible enough to incorporate science and data developed in the future. This requires continued exchange between scientists, practitioners and tool developers.

5.2. Implications for Practice

The dynamic interactions between different sustainability challenges illustrated in this study highlight the complexity of decision-making within sustainable production and consumption systems. As globalization of traded commodities increases the spatial distance between them [24], it is challenging for end buyers to understand the local contexts in which the farmers producing their commodities operate. Therefore, it is difficult to understand local socio-economic drivers of sustainability concerns as well as the risks of unintended consequences resulting from demand-side policies. Crucially, what is a priority for local stakeholders will depend on their regional context [32]. This context dependency helps explain why stakeholders often disagree on solution pathways. Indeed, mismatches in priorities are typical of "systemic" environmental management problems [88]. Our study suggests that to achieve meaningful progress on sustainability challenges, more collaboration is needed across different companies (e.g., traders, growers, processors, and retailers) but also between companies and different types of organizations (e.g., NGOs, governments, and researchers). Especially for complex global supply chains where companies rely on many geographically or culturally distant suppliers, partnering with other organizations such as NGOs might be an effective approach to achieve meaningful sustainability outcomes on the ground [89].

The perception discussed in this study of the limited leverage of end buyers in supply chains and limited capacity to engage with other stakeholders demonstrates the challenge end buyers face in affecting meaningful change. Therefore, for some companies, it might be more effective to join industry initiatives (e.g., RSPO) to collectively have more power in the market. Industry leaders [90] and researchers (e.g., [91]) have been calling for some time for importing governments to better regulate environmental and social standards in supply chains. The UK, EU, and several of its member states have embraced human rights and environmental due diligence laws restricting the import of commodities linked to deforestation [92,93]. These kinds of regulations may help ensure that it is not only leading companies who are requiring their suppliers to ensure commodities are not associated with deforestation. However, as illustrated in this study by the responses of NGOs, the traceability of imported "embedded" commodities would need to be improved so that companies can monitor and report compliance with this law. Additionally, the European Parliament [94] has highlighted that this law should be extended to also include other, non-forest but carbon-dense and biodiversity-rich ecosystems to avoid conversion pressure on these areas. To be able to implement this policy successfully, existing data providers may need to broaden their current focus, which will likely require additional investment in research and knowledge co-production.

A lack of evidence has been mentioned as one reason for the limited implementation of approaches aiming to improve sustainability at a sub-national scale [95]. To identify whether and to what extent science-based evidence leads to changes in practice, the monitoring of outcomes is essential [96]. There is also a remaining question about who along the supply chain would have the burden of gathering data and proving the sustainability of practices. Is it the responsibility of manufacturers, their suppliers, their sub-suppliers, governments, or traders? Efforts to increase data transparency on supply chains and their impacts can help to identify responsibility of different actors and thus, leverage points (e.g., actors or regions) to improve the sustainability of the entire system [97]. Furthermore, from the perspective of end buyers, it can also help to identify actors with common goals with whom to work in partnership.

5.3. Limitations and Further Research on Supply Chain Stakeholder Needs

While this study offers valuable insights for academia and practice, this research is also characterized by some limitations which future research could focus on. First, in this study we only interviewed actors distant from producing regions. Future research could extend the interview sample to include additional stakeholders linked to the supply chain such as traders, investors, producers (both large and smallholder), and governments. In this study, we used NGOs to represent the "voice" of Western consumers and, to some extent, to represent the opinions of farmers "on the ground", but future research should include those actors more representatively.

Second, it is likely that those individuals that were willing to share their time and knowledge in our interviews were likely part of leading organizations who are already relatively well-informed, set relatively ambitious sustainability targets, and are motivated to act on sustainability challenges. We chose these organizations based on their in-depth knowledge, which they likely gained through years of practical experience aiming to improve their organizations' impact on sustainability. We believe our sample of manufacturers and retailers is representative of leading organizations, as they will likely have similar information needs. However, in the future, the sustainability performance expectations of end buyers' stakeholders (e.g., investors, consumers, producing governments) will increase and, therefore, organizations who are not currently as interested in these concerns will likely need this kind of information. Stakeholder-led research to understand the needs of these non-leading end buyers will be needed.

Third, our interviews were limited to European and North American stakeholders. However, little is known about consumer preferences in developing and emerging markets such as India and China, where demand for agricultural commodities is projected to increase and where the import of animal feed linked to tropical countries has grown rapidly. Our study focused on societies where the demands to improve the sustainability of food systems is currently largest, yet future research should also try to understand the motivations of actors in emerging and developing markets.

6. Conclusions

Our findings reveal the complexity of sustainability challenges linked to demand for forest-risk commodities in global supply chains. Consumer-country societies are linked through retailers and manufacturers not only to their counterparts in countries of production but also to the natural environment in which those commodities are produced.

As providing detailed data can be costly, research needs to ensure that new data generation is focused on aspects where it can lead to better sustainability outcomes. Here, an iterative approach to identify demand-side actors' knowledge gaps together with NGOs, data providers, business representatives, and other relevant stakeholders could be helpful to ensure that science supports decisions with enough information to avoid unintended consequences and maximize co-benefits towards sustainability. Guidance towards environmentally sustainable production therefore requires careful evaluation of possible unintended consequences on other geographies and people, to avoid burden shifting. A key challenge is to provide guidance to navigate this complexity while avoiding overwhelming concerned actors, at the risk of inaction. More dialogue is required between actors in producing countries and those in consuming countries to negotiate common goals and align monitoring as well as actions. All stakeholders involved in these complex supply chain systems should ideally be given a "voice", to ensure successful implementation. Academia might also benefit from closer collaborations with "impact extenders" like NGOs or think tanks who could help them to translate science to a non-academic audience.

Additionally, our findings highlight that mandatory supply chain due diligence regulations such as those adopted by the EU [29] need to consider, besides deforestation and forest degradation, other sustainability challenges such as water consumption, soil degradation, and social aspects to avoid unintended consequences.

Author Contributions: Conceptualization, C.M., C.W. and B.D.; methodology, C.M.; software, C.M.; validation, C.M., C.W. and B.D.; formal analysis, C.M.; investigation, C.M.; resources, C.M. and C.W.; data curation, C.M.; writing—original draft preparation, C.M.; writing—review and editing, C.W., M.G.B.L. and B.D.; visualization, C.M.; supervision, C.W. and B.D.; project administration, C.M.; funding acquisition, C.W. and B.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the UK Economic and Social Research Council (ESRC) Doctoral Training Partnership [ES/P000746/1] (CM), the Global Challenges Research Fund Trade, Development and the Environment Hub project (ES/S008160/1)] (CW). BD and CW were funded by the IKnowFood project, funded by the UK Global Food Security program (Project BB/N02060X/1). M.G.B.L was funded by the Swedish Research Council for Sustainable Development (Formas, grant 2020-00970).

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Department of Environment and Geography at the University of York (20 June 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the participants to publish this paper.

Data Availability Statement: The data presented in this study are not publicly available due to confidentiality reasons.

Acknowledgments: The authors are thankful to all interviewees who agreed to share their valuable knowledge and experience to contribute to this research. We are also grateful for the support and insightful comments at various stages of the research provided by Christopher Lyon (University of York).

Conflicts of Interest: We are not aware of competing interests, including financial or personal relationships with organizations within the two and a half years before starting this work which could appear to have influenced the work. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Willett, W.; Rockström, J.; Loken, B.; Springmann, M.; Lang, T.; Vermeulen, S.; Garnett, T.; Tilman, D.; DeClerck, F.; Wood, A.; et al. Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet* **2019**, *393*, 447–492. [CrossRef]
2. IPBES. Chapter 2.3. Status and Trends—Nature's Contributions to People (NCP). In *Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*; Brondizio, E.S., Settele, J., Díaz, S., Ngo, H.T., Eds.; IPBES Secretariat: Bonn, Germany, 2020; pp. 309–385.
3. Pimentel, D.; Burgess, M. Soil Erosion Threatens Food Production. *Agriculture* **2013**, *3*, 443–463. [CrossRef]
4. Hess, T. How can we avoid eating ourselves out of water? *Nat. Food* **2021**, *2*, 225. [CrossRef]
5. Rockström, J.; Edenhofer, O.; Gaertner, J.; DeClerck, F. Planet-proofing the global food system. *Nat. Food* **2020**, *1*, 3–5. [CrossRef]
6. 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.; et al. The role of supply-chain initiatives in reducing deforestation. *Nat. Clim. Chang.* **2018**, *8*, 109–116. [CrossRef]
7. Donofrio, S.; Rothrock, P.; Leonard, J. Supply-Change: Tracking Corporate Commitments to Deforestation-Free Supply Chain. Available online: https://www.forest-trends.org/publications/supply-change-tracking-corporate-commitments-to-deforestation-free-supply-chains-2017/ (accessed on 29 March 2021).
8. SBTi. Meet the Companies Already Setting Their Emissions Reduction Targets in Line with Climate Science. Available online: https://sciencebasedtargets.org/companies-taking-action/ (accessed on 17 August 2020).
9. Purvis, B.; Mao, Y.; Robinson, D. Three pillars of sustainability: In search of conceptual origins. *Sustain. Sci.* **2019**, *14*, 681–695. [CrossRef]
10. UN. Transforming our World 2030 Agenda for Sustainable Development. Available online: https://sustainabledevelopment.un.org/post2015/transformingourworld/publication (accessed on 26 March 2018).
11. Virah-Sawmy, M.; Durán, A.P.; Green, J.M.; Guerrero, A.M.; Biggs, D.; West, C.D. Sustainability gridlock in a global agricultural commodity chain: Reframing the soy–meat food system. *Sustain. Prod. Consum.* **2019**, *18*, 210–223. [CrossRef]
12. Sharma, R.; Shishodia, A.; Kamble, S.; Gunasekaran, A.; Belhadi, A. Agriculture supply chain risks and COVID-19: Mitigation strategies and implications for the practitioners. *Int. J. Logist. Res. Appl.* **2020**, 1–27. [CrossRef]
13. Jagtap, S.; Trollman, H.; Trollman, F.; Garcia-Garcia, G.; Parra-López, C.; Duong, L.; Martindale, W.; Munekata, P.E.S.; Lorenzo, J.M.; Hdaifeh, A.; et al. The Russia-Ukraine Conflict: Its Implications for the Global Food Supply Chains. *Foods* **2022**, *11*, 2098. [CrossRef] [PubMed]
14. Melas, K.D.; Michail, N.A. The relationship between commodity prices and freight rates in the dry bulk shipping segment: A threshold regression approach. *Marit. Transp. Res.* **2021**, *2*, 100025. [CrossRef]
15. Imbiri, S.; Rameezdeen, R.; Chileshe, N.; Statsenko, L. A Novel Taxonomy for Risks in Agribusiness Supply Chains: A Systematic Literature Review. *Sustainability* **2021**, *13*, 9217. [CrossRef]
16. Anderson, J.D.; Mitchell, J.L.; Maples, J.G. Invited Review: Lessons from the COVID-19 pandemic for food supply chains. *Appl. Anim. Sci.* **2021**, *37*, 738–747. [CrossRef]
17. Tidy, M.; Wang, X.; Hall, M. The role of Supplier Relationship Management in reducing Greenhouse Gas emissions from food supply chains: Supplier engagement in the UK supermarket sector. *J. Clean. Prod.* **2016**, *112*, 3294–3305. [CrossRef]
18. Kareiva, P.M.; McNally, B.W.; McCormick, S.; Miller, T.; Ruckelshaus, M. Improving global environmental management with standard corporate reporting. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 7375–7382. [CrossRef] [PubMed]
19. Pendrill, F.; Gardner, T.A.; Meyfroidt, P.; Persson, U.M.; Adams, J.; Azevedo, T.; Bastos Lima, M.G.; Baumann, M.; Curtis, P.G.; de Sy, V.; et al. Disentangling the numbers behind agriculture-driven tropical deforestation. *Science* **2022**, *377*, eabm9267. [CrossRef]
20. Gardner, T.A.; Benzie, M.; Börner, J.; Dawkins, E.; Fick, S.; Garrett, R.; Godar, J.; Grimard, A.; Lake, S.; Larsen, R.K.; et al. Transparency and sustainability in global commodity supply chains. *World Dev.* **2019**, *121*, 163–177. [CrossRef]
21. Guerrero, A.M.; Jones, N.A.; Ross, H.; Virah-Sawmy, M.; Biggs, D. What influences and inhibits reduction of deforestation in the soy supply chain? A mental model perspective. *Environ. Sci. Policy* **2021**, *115*, 125–132. [CrossRef]
22. Lyons-White, J.; Knight, A.T. Palm oil supply chain complexity impedes implementation of corporate no-deforestation commitments. *Glob. Environ. Chang.* **2018**, *50*, 303–313. [CrossRef]
23. Liu, J.; Hull, V.; Batistella, M.; DeFries, R.; Dietz, T.; Fu, F.; Hertel, T.W.; Izaurralde, R.C.; Lambin, E.F.; Li, S.; et al. Framing Sustainability in a Telecoupled World. *Ecol. Soc.* **2013**, *18*, 26. [CrossRef]
24. Liu, J.; Mooney, H.; Hull, V.; Davis, S.J.; Gaskell, J.; Hertel, T.; Lubchenco, J.; Seto, K.C.; Gleick, P.; Kremen, C.; et al. Sustainability. Systems integration for global sustainability. *Science* **2015**, *347*, 1258832. [CrossRef]
25. Godar, J.; Persson, U.M.; Tizado, E.J.; Meyfroidt, P. Towards more accurate and policy relevant footprint analyses: Tracing fine-scale socio-environmental impacts of production to consumption. *Ecol. Econ.* **2015**, *112*, 25–35. [CrossRef]
26. Zu Ermgassen, E.K.H.J.; Ayre, B.; Godar, J.; Bastos Lima, M.G.; Bauch, S.; Garrett, R.; Green, J.; Lathuillière, M.J.; Löfgren, P.; MacFarquhar, C.; et al. Using supply chain data to monitor zero deforestation commitments: An assessment of progress in the Brazilian soy sector. *Environ. Res. Lett.* **2020**, *15*, 35003. [CrossRef]
27. Zu Ermgassen, E.K.H.J.; Bastos Lima, M.G.; Bellfield, H.; Dontenville, A.; Gardner, T.; Godar, J.; Heilmayr, R.; Indenbaum, R.; dos Reis, T.N.P.; Ribeiro, V.; et al. Addressing indirect sourcing in zero deforestation commodity supply chains. *Sci. Adv.* **2022**, *8*, eabn3132. [CrossRef] [PubMed]

28. Godar, J.; Suavet, C.; Gardner, T.A.; Dawkins, E.; Meyfroidt, P. Balancing detail and scale in assessing transparency to improve the governance of agricultural commodity supply chains. *Environ. Res. Lett.* **2016**, *11*, 35015. [CrossRef]
29. EC. Regulation (EU) 2023/1115 of the European Parliament and of the Council of 31 May 2023 on the Making Available on the Union Market and the Export from the Union of Certain Commodities and Products Associated with Deforestation and Forest Degradation and Repealing Regulation (EU) No 995/2010. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R1115 (accessed on 9 June 2023).
30. UN COP. Glasgow Leaders' Declaration on Forests and Land Use. Available online: https://ukcop26.org/glasgow-leaders-declaration-on-forests-and-land-use/ (accessed on 13 February 2022).
31. The Consumer Goods Forum. Forest Positive. Available online: https://www.theconsumergoodsforum.com/environmental-sustainability/forest-positive/ (accessed on 15 March 2022).
32. Bager, S.L.; Persson, U.M.; dos Reis, T.N. Eighty-six EU policy options for reducing imported deforestation. *One Earth* **2021**, *4*, 289–306. [CrossRef]
33. Lyon, C.; Cordell, D.; Jacobs, B.; Martin-Ortega, J.; Marshall, R.; Camargo-Valero, M.A.; Sherry, E. Five pillars for stakeholder analyses in sustainability transformations: The global case of phosphorus. *Environ. Sci. Policy* **2020**, *107*, 80–89. [CrossRef]
34. Schröter, M.; Koellner, T.; Alkemade, R.; Arnhold, S.; Bagstad, K.J.; Erb, K.-H.; Frank, K.; Kastner, T.; Kissinger, M.; Liu, J.; et al. Interregional flows of ecosystem services: Concepts, typology and four cases. *Ecosyst. Serv.* **2018**, *31*, 231–241. [CrossRef]
35. O'Rourke, D. The science of sustainable supply chains. *Science* **2014**, *344*, 1124–1127. [CrossRef]
36. Newig, J.; Challies, E.; Cotta, B.; Lenschow, A.; Schilling-Vacaflor, A. Governing global telecoupling toward environmental sustainability. *Ecol. Soc.* **2020**, *25*, 26. [CrossRef]
37. Wiedmann, T.; Lenzen, M. Environmental and social footprints of international trade. *Nat. Geosci.* **2018**, *11*, 314–321. [CrossRef]
38. Othoniel, B.; Rugani, B.; Heijungs, R.; Benetto, E.; Withagen, C. Assessment of Life Cycle Impacts on Ecosystem Services: Promise, Problems, and Prospects. *Environ. Sci. Technol.* **2016**, *50*, 1077–1092. [CrossRef] [PubMed]
39. Hellweg, S.; Milà i Canals, L. Emerging approaches, challenges and opportunities in life cycle assessment. *Science* **2014**, *344*, 1109–1113. [CrossRef] [PubMed]
40. Lee, E.K.; Zhang, X.; Adler, P.R.; Kleppel, G.S.; Romeiko, X.X. Spatially and temporally explicit life cycle global warming, eutrophication, and acidification impacts from corn production in the U.S. Midwest. *J. Clean. Prod.* **2020**, *242*, 118465. [CrossRef]
41. Chaplin-Kramer, R.; Sim, S.; Hamel, P.; Bryant, B.; Noe, R.; Mueller, C.; Rigarlsford, G.; Kulak, M.; Kowal, V.; Sharp, R.; et al. Life cycle assessment needs predictive spatial modelling for biodiversity and ecosystem services. *Nat. Commun.* **2017**, *8*, 15065. [CrossRef]
42. Escobar, N.; Tizado, E.J.; zu Ermgassen, E.K.; Löfgren, P.; Börner, J.; Godar, J. Spatially-explicit footprints of agricultural commodities: Mapping carbon emissions embodied in Brazil's soy exports. *Glob. Environ. Chang.* **2020**, *62*, 102067. [CrossRef]
43. Verones, F.; Moran, D.; Stadler, K.; Kanemoto, K.; Wood, R. Resource footprints and their ecosystem consequences. *Sci. Rep.* **2017**, *7*, 40743. [CrossRef] [PubMed]
44. Chaudhary, A.; Kastner, T. Land use biodiversity impacts embodied in international food trade. *Glob. Environ. Chang.* **2016**, *38*, 195–204. [CrossRef]
45. Mueller, C.; de Baan, L.; Koellner, T. Comparing direct land use impacts on biodiversity of conventional and organic milk—Based on a Swedish case study. *Int. J. Life Cycle Assess.* **2014**, *19*, 52–68. [CrossRef]
46. Boulay, A.-M.; Bare, J.; Benini, L.; Berger, M.; Lathuillière, M.J.; Manzardo, A.; Margni, M.; Motoshita, M.; Núñez, M.; Pastor, A.V.; et al. The WULCA consensus characterization model for water scarcity footprints: Assessing impacts of water consumption based on available water remaining (AWARE). *Int. J. Life Cycle Assess.* **2018**, *23*, 368–378. [CrossRef]
47. Hoekstra, A.Y.; Mekonnen, M.M. The water footprint of humanity. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 3232–3237. [CrossRef]
48. Stoessel, F.; Sonderegger, T.; Bayer, P.; Hellweg, S. Assessing the environmental impacts of soil compaction in Life Cycle Assessment. *Sci. Total Environ.* **2018**, *630*, 913–921. [CrossRef] [PubMed]
49. Lathuillière, M.J.; Patouillard, L.; Margni, M.; Ayre, B.; Löfgren, P.; Ribeiro, V.; West, C.; Gardner, T.A.; Suavet, C. A Commodity Supply Mix for More Regionalized Life Cycle Assessments. *Environ. Sci. Technol.* **2021**, *55*, 12054–12065. [CrossRef] [PubMed]
50. Green, J.M.H.; Croft, S.A.; Durán, A.P.; Balmford, A.P.; Burgess, N.D.; Fick, S.; Gardner, T.A.; Godar, J.; Suavet, C.; Virah-Sawmy, M.; et al. Linking global drivers of agricultural trade to on-the-ground impacts on biodiversity. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 23202–23208. [CrossRef] [PubMed]
51. Flach, R.; Ran, Y.; Godar, J.; Karlberg, L.; Suavet, C. Towards more spatially explicit assessments of virtual water flows: Linking local water use and scarcity to global demand of Brazilian farming commodities. *Environ. Res. Lett.* **2016**, *11*, 75003. [CrossRef]
52. Harris, N.L.; Gibbs, D.A.; Baccini, A.; Birdsey, R.A.; de Bruin, S.; Farina, M.; Fatoyinbo, L.; Hansen, M.C.; Herold, M.; Houghton, R.A.; et al. Global maps of twenty-first century forest carbon fluxes. *Nat. Clim. Chang.* **2021**, *11*, 234–240. [CrossRef]
53. Global Forest Watch. Global Forest Watch. Available online: http://globalforestwatch.org (accessed on 3 February 2021).
54. WWF. Water Risk Filter: From Risk Assessment to Response. Available online: https://waterriskfilter.panda.org/ (accessed on 20 May 2021).
55. Guerry, A.D.; Polasky, S.; Lubchenco, J.; Chaplin-Kramer, R.; Daily, G.C.; Griffin, R.; Ruckelshaus, M.; Bateman, I.J.; Duraiappah, A.; Elmqvist, T.; et al. Natural capital and ecosystem services informing decisions: From promise to practice. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 7348–7355. [CrossRef] [PubMed]

56. Folke, C.; Österblom, H.; Jouffray, J.-B.; Lambin, E.F.; Adger, W.N.; Scheffer, M.; Crona, B.I.; Nyström, M.; Levin, S.A.; Carpenter, S.R.; et al. Transnational corporations and the challenge of biosphere stewardship. *Nat. Ecol. Evol.* **2019**, *3*, 1396–1403. [CrossRef]
57. Ahlström, H.; Williams, A.; Vildåsen, S.S. Enhancing systems thinking in corporate sustainability through a transdisciplinary research process. *J. Clean. Prod.* **2020**, *256*, 120691. [CrossRef]
58. Eakin, H.; Rueda, X.; Mahanti, A. Transforming governance in telecoupled food systems. *Ecol. Soc.* **2017**, *22*, 32. [CrossRef]
59. DeFries, R.; Nagendra, H. Ecosystem management as a wicked problem. *Science* **2017**, *356*, 265–270. [CrossRef]
60. Ghosh, A.; Fedorowicz, J. The role of trust in supply chain governance. *Bus. Process Manag. J.* **2008**, *14*, 453–470. [CrossRef]
61. TEEB. Chapter 2: Systems thinking: An approach for understanding 'eco-agri-food systems. In *TEEB for Agriculture and Food: Scientific and Economic Foundations*; O´Neill, S., Ed.; UN Environment: Geneva, Switzerland, 2018; pp. 57–109.
62. Patton, M.Q. *Qualitative Research & Evaluation Methods: Integrating Theory and Practice*, 4th ed.; SAGE Publications: Thousand Oaks, CA, USA, 2015.
63. Fielding, N.; Thomas, H. Qualitative Interviewing. In *Researching Social Life*, 3rd ed.; Gilbert, G.N., Ed.; SAGE Publications: Los Angeles, CA, USA, 2012; pp. 281–300.
64. Fielding, J. Coding and Managing Data. In *Researching Social Life*, 3rd ed.; Gilbert, G.N., Ed.; SAGE Publications: Los Angeles, CA, USA, 2012; pp. 359–388.
65. Cortner, O.; Garrett, R.D.; Valentim, J.F.; Ferreira, J.; Niles, M.T.; Reis, J.; Gil, J. Perceptions of integrated crop-livestock systems for sustainable intensification in the Brazilian Amazon. *Land Use Policy* **2019**, *82*, 841–853. [CrossRef]
66. Finfgeld-Connett, D. Use of content analysis to conduct knowledge-building and theory-generating qualitative systematic reviews. *Qual. Res.* **2014**, *14*, 341–352. [CrossRef]
67. Baldy, J.; Kruse, S. Food Democracy from the Top Down? State-Driven Participation Processes for Local Food System Transformations towards Sustainability. *Politics Gov.* **2019**, *7*, 68. [CrossRef]
68. Weber, A.-K.; Partzsch, L. Barking Up the Right Tree? NGOs and Corporate Power for Deforestation-Free Supply Chains. *Sustainability* **2018**, *10*, 3869. [CrossRef]
69. Furumo, P.R.; Rueda, X.; Rodríguez, J.S.; Parés Ramos, I.K. Field evidence for positive certification outcomes on oil palm smallholder management practices in Colombia. *J. Clean. Prod.* **2020**, *245*, 118891. [CrossRef]
70. Davies, J. The business case for soil. *Nat. News* **2017**, *543*, 309. [CrossRef]
71. Rockström, J.; Steffen, W.; Noone, K.; Persson, A.; Chapin, F.S.; Lambin, E.F.; Lenton, T.M.; Scheffer, M.; Folke, C.; Schellnhuber, H.J.; et al. A safe operating space for humanity. *Nature* **2009**, *461*, 472–475. [CrossRef]
72. Utrecht University. Interview with Fabrice DeClerck. Available online: https://www.uu.nl/en/research/future-food-utrecht/interview-with-fabrice-declerck (accessed on 5 July 2022).
73. Croft, S.A.; West, C.D.; Green, J.M. Capturing the heterogeneity of sub-national production in global trade flows. *J. Clean. Prod.* **2018**, *203*, 1106–1118. [CrossRef]
74. Reis, T.N.d.; Meyfroidt, P.; zu Ermgassen, E.K.; West, C.; Gardner, T.; Bager, S.; Croft, S.; Lathuillière, M.J.; Godar, J. Understanding the Stickiness of Commodity Supply Chains Is Key to Improving Their Sustainability. *One Earth* **2020**, *3*, 100–115. [CrossRef]
75. Forest Trends. Company Profiles. Available online: https://supply-change.org/#company-profiles (accessed on 20 December 2021).
76. Ingram, J.; Ajates, R.; Arnall, A.; Blake, L.; Borrelli, R.; Collier, R.; de Frece, A.; Häsler, B.; Lang, T.; Pope, H.; et al. A future workforce of food-system analysts. *Nat. Food* **2020**, *1*, 9–10. [CrossRef]
77. Seymour, F.; Harris, N.L. Reducing tropical deforestation. *Science* **2019**, *365*, 756–757. [CrossRef] [PubMed]
78. Padfield, R.; Hansen, S.; Davies, Z.G.; Ehrensperger, A.; Slade, E.M.; Evers, S.; Papargyropoulou, E.; Bessou, C.; Abdullah, N.; Page, S.; et al. Co-producing a Research Agenda for Sustainable Palm Oil. *Front. For. Glob. Chang.* **2019**, *2*, 13. [CrossRef]
79. Nielsen, J.Ø.; de Bremond, A.; Roy Chowdhury, R.; Friis, C.; Metternicht, G.; Meyfroidt, P.; Munroe, D.; Pascual, U.; Thomson, A. Toward a normative land systems science. *Curr. Opin. Environ. Sustain.* **2019**, *38*, 1–6. [CrossRef]
80. Lang, D.J.; Wiek, A.; Bergmann, M.; Stauffacher, M.; Martens, P.; Moll, P.; Swilling, M.; Thomas, C.J. Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustain. Sci.* **2012**, *7*, 25–43. [CrossRef]
81. EC. Responsible Research & Innovation. Available online: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation (accessed on 10 September 2020).
82. Schneider, F.; Giger, M.; Harari, N.; Moser, S.; Oberlack, C.; Providoli, I.; Schmid, L.; Tribaldos, T.; Zimmermann, A. Transdisciplinary co-production of knowledge and sustainability transformations: Three generic mechanisms of impact generation. *Environ. Sci. Policy* **2019**, *102*, 26–35. [CrossRef]
83. Goodman, J.; Korsunova, A.; Halme, M. Our Collaborative Future: Activities and Roles of Stakeholders in Sustainability-Oriented Innovation. *Bus. Strat. Environ.* **2017**, *26*, 731–753. [CrossRef]
84. Greenhouse Gas Protocol. We Set the Standards to Measure and Manage Emissions. Available online: https://ghgprotocol.org/ (accessed on 3 July 2022).
85. SBT. Project Launch: Science-Based Targets for Forest, Land and Agriculture (FLAG) Related Sectors. Available online: https://sciencebasedtargets.org/sbt_events/project-launch-science-based-targets-for-forest-land-and-agriculture-flag-related-sectors/ (accessed on 4 June 2023).
86. SBTN. Biodiversity: Why Set Science-Based Targets for Species and Ecosystems? Available online: https://sciencebasedtargetsnetwork.org/earth-systems/biodiversity/ (accessed on 27 October 2020).

87. Ridoutt, B.; Fantke, P.; Pfister, S.; Bare, J.; Boulay, A.-M.; Cherubini, F.; Frischknecht, R.; Hauschild, M.; Hellweg, S.; Henderson, A.; et al. Making sense of the minefield of footprint indicators. *Environ. Sci. Technol.* **2015**, *49*, 2601–2603. [CrossRef]
88. Larsen, R.K.; Nilsson, A.E. Knowledge production and environmental conflict: Managing systematic reviews and maps for constructive outcomes. *Environ. Evid.* **2017**, *6*, 7. [CrossRef]
89. Koberg, E.; Longoni, A. A systematic review of sustainable supply chain management in global supply chains. *J. Clean. Prod.* **2019**, *207*, 1084–1098. [CrossRef]
90. Anderson, L. Ending Deforestation Is Smart Policy: Officials. Available online: https://www.reuters.com/article/us-foundation-climatechange-forests/ending-deforestation-is-smart-policy-officials-idUSKCN0HI0ZD20140923 (accessed on 13 January 2021).
91. Larsen, R.K.; Osbeck, M.; Dawkins, E.; Tuhkanen, H.; Nguyen, H.; Nugroho, A.; Gardner, T.A.; Zulfahm; Wolvekamp, P. Hybrid governance in agricultural commodity chains: Insights from implementation of 'No Deforestation, No Peat, No Exploitation' (NDPE) policies in the oil palm industry. *J. Clean. Prod.* **2018**, *183*, 544–554. [CrossRef]
92. UK. Due Diligence on Forest Risk Commodities. Available online: https://consult.defra.gov.uk/eu/due-diligence-on-forest-risk-commodities/ (accessed on 31 December 2020).
93. EC. Deforestation and Forest Products Impact Assessment. Available online: https://ec.europa.eu/eusurvey/runner/Deforestation_Impact_Assessment?surveylanguage=en (accessed on 31 December 2020).
94. EC. Legislation with Binding Measures Needed to Stop EU-Driven Global Deforestation. Available online: https://www.europarl.europa.eu/news/en/press-room/20201016IPR89560/legislation-with-binding-measures-needed-to-stop-eu-driven-global-deforestation (accessed on 29 January 2021).
95. Reed, J.; Ickowitz, A.; Chervier, C.; Djoudi, H.; Moombe, K.; Ros-Tonen, M.; Yanou, M.; Yuliani, L.; Sunderland, T. Integrated landscape approaches in the tropics: A brief stock-take. *Land Use Policy* **2020**, *99*, 104822. [CrossRef]
96. Reed, J.; Barlow, J.; Carmenta, R.; van Vianen, J.; Sunderland, T. Engaging multiple stakeholders to reconcile climate, conservation and development objectives in tropical landscapes. *Biol. Conserv.* **2019**, *238*, 108229. [CrossRef]
97. Rueda, X.; Garrett, R.D.; Lambin, E.F. Corporate investments in supply chain sustainability: Selecting instruments in the agri-food industry. *J. Clean. Prod.* **2017**, *142*, 2480–2492. [CrossRef]