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Trade and Land-Use Telecouplings

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1 Introduction

Production of commodities fuelled by global demand for food, fibre and energy is arguably the most important driver of land-use change globally, contributing to widespread land degradation (IPBES 2018). Historically, land use has been tightly linked to local or regional resource demands, but globalisation has led to a sharp spatial decoupling in the production and consumption of land-based products, underscoring the key role of international trade in shaping land use globally.

About 1.5 trillion dollars' worth of agricultural commodities were traded internationally in 2016 (FAOSTAT 2018), about 10% of global trade in that year (WTO 2017). The share of exports in agricultural and other natural resource commodities, as a proportion of total exports, is considerably larger in many developing countries that have a relatively small domestic demand and/or a large agricultural surplus. Trade in land-based resources has boosted the economic growth of many developing

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and emerging economies, whilst also improving global food security by buffering the effects of local shocks (such as drought) on food production, and facilitating the exchange of technology and information (FAO 2003; Clapp 2015). However, global market integration has also exacerbated land degradation and unsustainable levels of resource use at local, regional and global scales (Lambin and Meyfroidt 2010; IPBES 2018). Indeed, the environmental impacts that are embedded in globally traded commodities make it impossible to decouple the economic growth of a country from environmental degradation (Wiedmann et al. 2015). Typically, as countries become wealthier, pressure on the environment is not reduced but rather displaced to other countries—often low-income nations that take the role of cheap producers of raw materials for the global economy (Srinivasan et al. 2008).

Understanding how to identify the role of trade as a driver of land-use change, mitigate its negative impacts and amplify possible benefits is therefore of central importance to tackling the impacts of land-use changes globally. Liu et al. (2013, 2015) define telecouplings as the interaction between social and environmental factors over distance, and in this chapter, we focus specifically on interactions that are mediated by trade—a major channel of telecoupling flows—and have effects on land use.

A combination of the spatial decoupling of production and consumption processes, increasing globalisation and the myriad production, processing and consumption processes that are mediated by trade, has made analysis of the causal relationships between commodity trade and land-use change dynamics extremely challenging, hampering efforts to inform policy decisions. For instance, several alternative land uses are possible in the same unit of land, including from different sectors (e.g. agriculture, urban development, forestry, energy and mining) and within the same sector (e.g. alternative farming products such as soy, maize or cattle ranching). As such, factors affecting one aspect of a given system (such as crop prices, levels of demand or changes in crop productivity) will have cascading effects on the entire land-use system. By the same token, international trade involves a growing number and diversity of supply chain actors, including producers, traders, manufacturers, retailers, consumers and policy-makers, but also intermediary and service providing actors such as transporters and manufacturers of agricultural inputs. As such, changes in the behaviour of one actor, in one stage of a global supply

chain for a specific commodity, can have cascading effects on the behaviour of other actors involved in the production, trade and consumption of the same and other commodities.

We argue that our understanding of the challenges posed by the telecoupling of trade and global land use remains weak due to the inadequacy of current data and approaches for mapping and analysing trade—land-use connections, which were developed at a time when appreciation of these complexities was poor, and key datasets were less accessible and understood. We further argue that while the telecoupling conceptual framework can help respond to this complexity by helping surface hidden causal linkages to underlying drivers of land-use change, it is still limited operationally and needs to be further developed to support practical applications in decision-making in land use and trade. We review new methodological approaches and poorly tapped data sources that can help overcome some of these limitations. Two key limitations of existing approaches are:

1. *Spatial explicitness of trade flow mapping.* Most analyses of international trade rely on national scale databases, whether based on bilateral trade flows from FAOSTAT and COMTRADE (e.g. Kastner et al. 2011) or monetary flow estimations from financial input-output tables between the economic sectors of countries (Bruckner et al. 2015). Therefore, the spatial heterogeneity in socio-environmental conditions within a given country is not considered, with analyses relying on crude national averages of resource use (e.g. land to produce a tonne of a given commodity) and embedded impacts (e.g. deforestation per tonne of traded commodity). This lack of spatial explicitness means that international demand is assumed to affect all areas of production within a country of interest uniformly, whilst embedded impacts are considered to be the same per unit of product for all consumers, regardless of differential sourcing patterns. Moreover, a reliance on national-level data also means that analyses are not commensurate with the scale at which key resource-use decisions are made, which is often within individual subnational regions (Godar et al. 2015).
2. *Nominality of actors.* Most quantitative analyses do not include information on the identity of the actors (e.g. traders, investors, retailers)

involved in the production and trade. This makes it challenging to engage relevant actors, whether they are specific companies or jurisdictional governments, in the design and implementation of interventions, and to strengthen accountability for environmental and social impacts linked to trade (Godar et al. 2016).

The chapter is structured into three more sections. In the second section, we examine the causes and effects of trade and land-use telecouplings, using examples to demonstrate how often unexpected, remote drivers can override the influence of local drivers on land-use and hence environmental change. We identify both the underlying properties, such as the increasing volume of trade and increased market integration that predispose many systems to be affected by trade and land-use telecouplings, as well as the more specific causes and effects of such telecouplings. In the third section, we illustrate the methodological challenges that have hampered attempts to understand trade and land-use telecouplings. We identify opportunities to advance this understanding by using hitherto untapped, granular data on both material and financial flows in international supply chains, providing with examples from recent work of the Trase initiative (www.trase.earth). We argue that a key step towards improved understanding of trade and land-use telecouplings is to use spatially explicit and nominal data to link international supply chains and demand to specific landscapes and land-use changes, as well as to specific actors. In the final section, we discuss ways in which research on trade and land-use telecouplings may change in the near-future in the face of a rapid shift towards greater transparency and open-data access in public, private and civil society sectors, and reflect on how a new level of understanding of existing institutional and policy contexts can provide with relevant and actionable information for policy-makers.

2 Globalisation and the Causes and Effects of Trade and Land-Use Telecouplings

In an ever-more globalised world, land and resource use in one place is increasingly shaped by drivers originated on the other side of the planet, and are mediated by trade. Globalisation can both amplify and attenuate

drivers of land-use change by breaking down regional barriers and strengthening global connections and influences, such as trade tariffs and restrictions, global prices, legal conventions and access to information over local factors, such as regional markets, extension services and local governance regimes (Lambin et al. 2001; Liu et al. 2013).

2.1 Trade Telecouplings and Emerging Properties of a Globalised Economy

A number of key emergent properties of an increasingly globalised economy set the stage for trade-related telecouplings, and have an increasing influence on land use.

Increasing global demand for internationally traded commodities. Cross-border trade in agricultural and forestry commodities increased threefold between 2000 and 2016, rising from c. 500 billion to 1.5 trillion US dollars' worth (COMTRADE data, as of November 2018 <https://resourcetrade.earth>). Rapid growth of major emerging markets over the last 20 years has boosted global demand for commodities, with Brazil, China, India, Indonesia, Mexico, Russia and Turkey accounting for 39% of the increase in global food consumption (Baffes et al. 2018). For example, China has rapidly emerged as the biggest global importer of soy. Exports of soy from Brazil to China have risen by 300% over the last decade, with much of the trade being in raw beans that are processed into animal feed on arrival. As shipments to China have grown to comprise two-thirds of Brazil's soy exports (and nearly 80% of its raw beans exports), major traders have shifted their patterns of operation and investment accordingly, with implications for land use and deforestation (Fig. 8.1). It has also spurred the entry of new companies, often from Asia such as COFCO, into the market.

Increased market integration. Increasing market integration and cross-scale interdependencies in how land and natural resources are managed can have a significant, if not over-riding, effect in mediating local drivers of land-use change. The most evident example of this is in the shift of many smallholder farmers from the production of staple crops to cash crops, such as palm oil in Indonesia, cocoa in West Africa, maize across much of sub-Saharan Africa, or banana plantations in Central America, to name but a few (Bryceson 2002; McCarthy 2010).

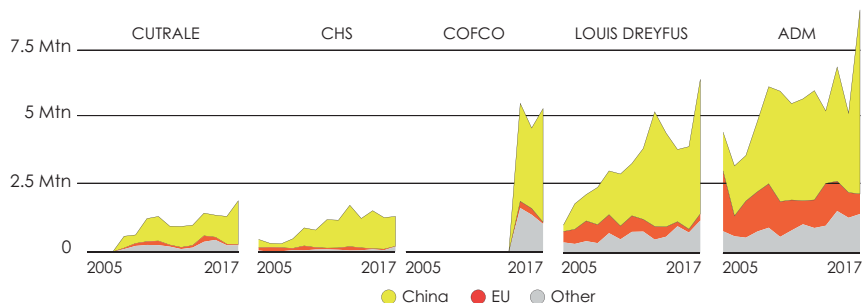


Fig. 8.1 Response of different traders to China's emergence as the world's largest soy importer, 2005–2017. Values in soybean equivalents, exports of soy cake and soy oil are included and converted to their raw commodity equivalents. Redrawn from Trase (2018a)

Changes in the number, diversity and specialisation of actors involved in global trade. Globalisation has given rise to increased competition that is altering the structure of international supply chains and entire sectors of the economy (Gereffi and Lee 2012). Supply chain operations have become more complex, with different actors specialising in different stages of production, trade, processing and retail, as well as on indirect roles such as inputs supply (e.g. seeds, fertilisers), transport, financial services and capital investment. In 2009, global export of intermediate goods exceeded the total export value of final and capital goods (IDE-JETRO and WTO 2011). Moreover, many of these actors operate in different places, responsible only for specific sections of the supply chain, and often with very limited engagement with all other supply chain actors. In parallel to this increased specialisation, increasing demand and a deepening of global interdependencies in the supply chains of many products has also driven a process of capital accumulation and consolidation of assets and market share into fewer, larger actors. For example, more than 1000 companies exported soy from Brazil between 2005 and 2016, but no more than 40 have held a significant share of the market—over 1% of total exports—in any given year (Trase 2018a). In 2016, the six largest traders—Bunge, Cargill, ADM, COFCO, Louis Dreyfus and Amaggi—accounted for 57% of all soy exports from Brazil (Trase 2018a).

Increased importance of the private sector. The rising importance of international trade in land-based commodities has dramatically raised the

importance of private sector actors and market processes over state-orientated governance in shaping patterns of natural resource use (Rudel 2007). This is particularly visible in deforestation frontiers across the tropics where well-capitalised and market-integrated farmers and loggers have become more important than local population growth dynamics in driving deforestation (Rudel et al. 2009).

2.2 Drivers of Trade and Land-Use Telecouplings

The drivers of trade and land-use telecouplings are typically manifold and interacting, often involving a combination of social, economic and political changes in consumer economies that can mediate or override the influence of local drivers of land use in production regions. Land-use impacts are often exacerbated by changes in production systems associated to the influence of global markets and trade dynamics. For example, Liu et al. (2013) analysed the soybean trade between Brazil and China, showing that a superficial analysis identifies the strong demand for soybean products, including animal feed (mostly pigs) in China as being the dominant cause of land-use dynamics in the Brazilian soy sector. However, political considerations of the Chinese government in pursuing foreign investments and securing future supply, as well as the Brazilian government's interest in developing its export market also play a strong role. Strong cultural preferences for products that demand soybeans underpins the economic demand from China, whilst landmark developments in agricultural technology by Embrapa, Brazil's agricultural research institution, were important drivers enabling soy planting under difficult biophysical conditions of the Brazilian Cerrado.

Despite this complexity of interaction effects, it is instructive to separate the important role that a number of key factors can play in causing trade and land-use telecouplings.

Economic factors. Economic factors are often the dominant drivers of trade and land-use telecouplings, and can be both exogenous, such as related to overall economic growth or currency exchange volatility, and endogenous, such as changes in productivity or logistic efficiency. For example, Yao et al. (2018) assessed the importance of different drivers of

telecouplings in the global soybean complex and found that China's macroeconomic growth played the most important role in shaping soybean production and exports in both Brazil and the US. In addition, they found that Brazil's rapid growth in soy productivity (endogenous factor) contributed towards reducing the dependence of the Chinese market on US exports and reducing overall growth of soybean output in the US—demonstrating the complexity of two-way interactions between supply and demand that can occur via international commodity trade.

Market regulatory factors. Regulatory factors in consumer countries, including different forms of trade barriers, tariffs and embargoes, can have a profound effect on land use in production countries. For example, the Amazon cattle industry was barred from many international markets due to the presence of foot-and-mouth disease (FMD), but the subsequent eradication of FMD from the main producing states in the early 2000s stimulated beef production and contributed towards a marked rise in prices (Kaimowitz et al. 2004), as well as access to new markets that accepted Brazilian beef at the time, and that continue to be strong trade partners today. Conversely, the lack of regulations on the environmental impacts of imported commodities in most consumer countries is often a key factor that facilitates unsustainable practices in producer countries.

Investment factors. Changes in financial markets can catalyse telecoupled effects on land use via changes in international commodity trade. For instance, through price volatilities that are often driven by trading in complex derivatives and ultra-rapid, algorithm-based trading technologies, including through speculation on futures trading (Galaz et al. 2015). In 2010, a British hedge fund, Armajaro, purchased instruments worth 7% of the world's cocoa supply, betting that prices would rise in face of poor weather conditions and pushing prices to a then all-time high (Futures Magazine 2010). The impacts of financial trading of farming commodities on global land use are amongst the most poorly understood drivers, yet if better quantified and analysed, it could deliver the most substantive sustainability gains (Scholtens 2017).

Buyer preference factors. The impact of increasing demand for Latin American soybeans by consumers in China and Europe on the clearance of native vegetation in the Amazon, Cerrado and Chaco biomes has been well documented. Less well understood is the role of consumer preferences for specific production systems. Garrett et al. (2013) demonstrate

how Brazil's production of non-genetically modified soy has enabled it to better access European markets than its competitors in Argentina and Paraguay, who almost exclusively grow genetically modified soy. Once established, these segregated trade-linkages have further facilitated the upgrading of some Brazilian soy supply-chains to different sustainability certification schemes and access to price premiums (Garrett et al. 2013). On the flip side, there are concerns that sustainability standards can also exclude more marginal, smallholder producers (Brandi 2017), whose activities often lead to more sustainable and diverse landscapes than larger agro-industrial enterprises (Pokorny 2013). At the same time, a lack of government-imposed minimum standards can drive a "race to the bottom" in producer countries, depending on differences in their pool of export markets (Gamso 2017).

Demographic factors. Global demographic changes can shape land-use and trade telecouplings, such as when the agricultural capacity for a given crop is met within a country, leading to increased demand for imports. Demographic factors can interact closely with individual lifestyle choices and buyer preferences, either reinforcing or counteracting the influence of specific preferences.

Environmental shocks and changes in biophysical conditions. There is growing evidence that the ongoing degradation of ecosystem services, as well as increasing shocks related to climate change, urbanisation and pollution, to name a few, are major disruptions to farming systems, and in turn to trade of farming commodities. Examples include from the devastating effects of fires in Southeast Asia on transportation and regional economic development, affecting trade of key commodities such as palm oil from major producing countries (Varkkey 2017), to the melting of Arctic sea ice and the opening up of much shorter trade routes in the polar region (Patel and Fountain 2017).

2.3 Effects of Trade and Land-Use Telecouplings

We argue that trade-mediated telecouplings can have first-, second-, or multiple-order effects on land use. First-order effects have a direct influence on the level of expansion and type of production practices of the

commodity in question—for example, changes in the production of soy and beef in Brazil, as shaped by changes in Chinese demand and European import restrictions.

Second-order effects are those that indirectly influence wider land-use changes beyond those linked to the production of a specific traded commodity, but typically occur within the land-use sector, such as leakage and indirect land-use change effects. For example, the effect of increased demand for biofuels to meet targets set by the EU's Biofuels Directive has likely had, under some analyses, a perverse effect through indirect land-use change that has pushed other commodities (such as cattle ranching) further into forest frontiers (e.g. Lapola et al. 2010; Khanna and Crago 2012). Second-order effects can also occur through other indirect pathways. For example, da Silva et al. (2017) demonstrate how the strong influence of Chinese demand for Brazilian soy had a cascading effect on Brazilian maize farming, consolidating much of the production of the latter as a second-rotation crop in soy farms. This shift in the production of maize increased the volume of maize exports, with a knock-on effect of increasing prices in the domestic market, inflating the internal prices of meat consumption, whilst also leaving maize production as a second-crop more exposed to drought impacts. Similarly, the collapse of the Soviet Union led to a marked strengthening of beef exports from Brazil to Russia, now one of the primary importers of Brazilian beef, following a collapse in domestic production in the early 1990s and a rebound of domestic consumption since the late 1990s (Schierhorn et al. 2016).

The realm of multiple-order effects is much more complex and out of the scope of this chapter, but includes effects that are intrinsically unrelated with, or at least not limited to, the land-use sector. For example, geopolitical decisions related to security and power influence can lead to major changes in land use. One example is the Chinese One Belt, One Road initiative (Tekdal 2018), or the recent trade wars initiated by the Trump administration (Reuters 2018), with multiple and uncertain cascading effects and multisectoral ramifications that will have profound impacts on land use in different regions worldwide. Other multiple-order effects can occur through displaced, biophysical impacts of production and trade. For example, the production and trade of farming commodities impacts water use and scarcity, which changes moisture recycling pat-

terns, with cascading impacts on precipitation patterns in production areas elsewhere (Keys et al. 2017). In turn, this can lead to variations in the suitability of competing crops and land uses, but also on socio-environmental conditions that can have further rebound effects, including via other trade telecouplings, to the regions that were originally subjected to water scarcity and to other regions, which in turn may be telecoupled with each other in diverse ways. Second- and multiple-order effects of trade and land-use telecouplings are inherently more unpredictable and complex with increasing globalisation and socio-technological complexity.

3 Methods and Data for Linking International Trade to Specific Land-Use Changes and Associated Effects

To date, methods for linking international trade and land-use change include partial equilibrium models, agent-based and systems dynamics models and environmental-economic export-import accounting, physical accounting and hybrid approaches (Bruckner et al. 2015; Millington et al. 2017). Inputs for these methods are typically based on national-level data. For instance, environmental-economic accounting relies on input-output economics applied to depictions of global financial flows between different sectors of the economy and different countries. Environmentally extended multiregional input-output approaches have been used to track embodied environmental impacts from production to final consumption (Corong et al. 2017; Stadler et al. 2018). By contrast, physical accounting of trade flows does not rely on monetary data but on information on exports, imports, production and consumption, measured in physical units such as kilogrammes, cubic metres or cattle heads. The vast majority of physical accounting approaches have relied on bilateral national trade statistics (e.g. Kastner et al. 2011), as compiled, for example, by the UN (COMTRADE and FAOSTAT) or other supranational organisations (e.g. EUROSTAT). Hybrid approaches have sought to combine economic modelling and physical accounting approaches (e.g. Weinzettel et al. 2014). They recognise that while physical account-

ing is appropriate for trade of raw and simple commodities and/or for the initial stages of a given supply chain (e.g. production to countries of import), economic modelling and environmental-economic accounting is more appropriate for assessing impacts of complex, derived products.

These methods and datasets are used for calculating overall environmental footprints and for assessing certain aspects of trade-related telecoupling dynamics, including the importance of different market-mediating factors as drivers of both land-use and market change in international trade (e.g. Yao et al. 2018), and the assessment of economic and environmental spillover effects that impact third parties outside of bilateral trade relationships (e.g. Xiong et al. 2018).

However, methods based on national-level data are not well-suited to assess and inform subnational and landscape level interventions in production systems, or to assess specific causal linkages between individual trade flows, actors and associated direct and indirect impacts on the land-use system, the role of different supply chain actors in shaping differential sourcing patterns, or the effects of multilevel governance on the telecoupled system (Godar et al. 2015, 2016). There are several reasons for these limitations. First, the lack of spatial explicitness in subnational sourcing of trade flows in almost all economic models and accounting approaches means that spatial variability in productive, environmental, physiographic and socio-economic conditions within producer countries is not captured. This can lead to large oversimplifications and errors, especially for large, heterogeneous producer countries (Fig. 8.2). For example, analyses that depend on national-level data require that all deforestation in Brazil is allocated to all the exports of a given commodity, regardless of whether some are produced in areas with no recent deforestation, or if they are produced under strict safeguards, for example, under the Amazonian Soy Moratorium. As a consequence, current country-to-country assessments of social and environmental impacts embedded in international trade assume an average impact per unit of primary product, thus attributing embedded impacts to consumer countries proportionally to the amount of product they source from each country, not affected by differences and preferences in sourcing strategies (Godar et al. 2015).

This lack of spatial explicitness in accurately describing production, trade flows and supply chain connections also means that most studies of

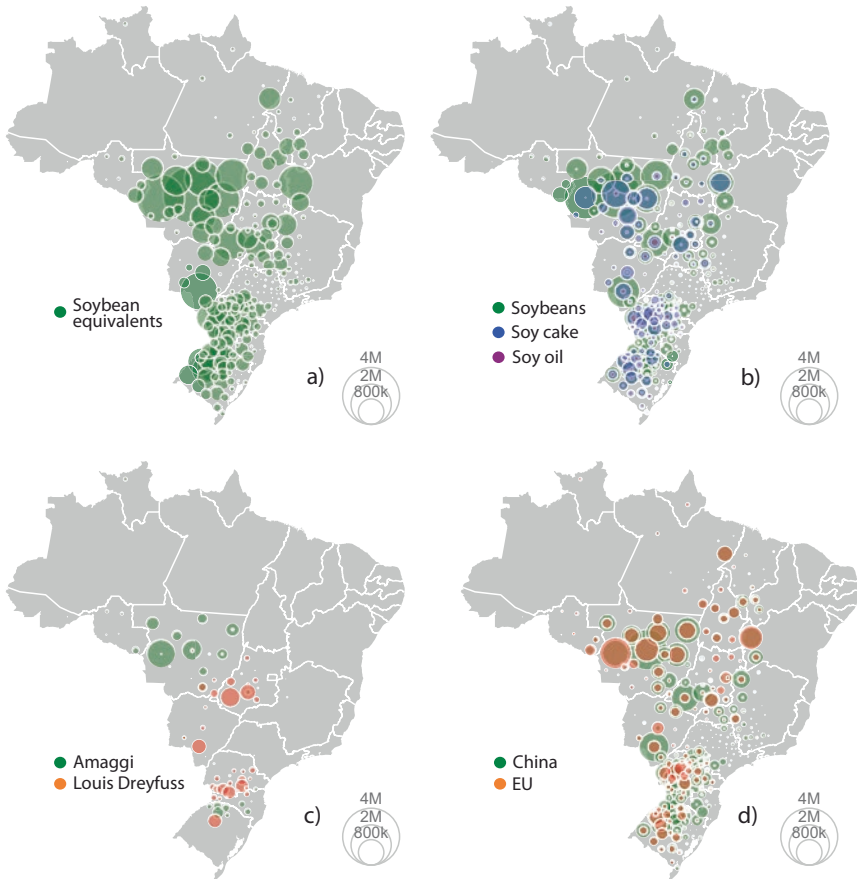


Fig. 8.2 Spatially explicit exports and sourcing of selected traders and countries, Brazilian soy supply chain 2016. Panel (a) represents the volume of Brazilian soy exports per municipality of sourcing; (b) volume of Brazilian soy exports per soy product type (beans, cake, oil) and municipality of sourcing; (c) volume of Brazilian soy exports for two of the main exporter companies, Amaggi and Louis Dreyfuss; (d) volume of Brazilian soy imports for the two largest Brazilian soy importers, China and the EU. The size of the bubbles represents total volume exported, see scales. Data from www.trase.earth

trade and land-use telecouplings fail to make good use of the recent revolution in access to fine-scale remotely sensed data (Kwok 2018). For example, the aggregation of per-pixel information on levels of deforestation to inform a country level analysis both trivialises the value of having access to such fine-scale data, whilst also failing to provide the level of analysis that is needed to understand trade and land-use telecouplings in a way that can be operationalised for practical decision-making.

Another major shortcoming of current approaches is a lack of nominality—that is, the identity—of individual actors in trade and production datasets. Differences in the characteristics of key actors involved in the production, trade and consumption of a given commodity can be of fundamental importance in understanding drivers and impacts of trade and land-use telecouplings, as well as the effectiveness of sustainability interventions (see Fig. 8.2b, c, for examples of actor variability in sourcing patterns and therefore risks embedded in export flows). For example, it is important to identify if specific trade flows and associated impacts are dominated by a small group of actors, if the actor-place relationships are persistent—“sticky”—over time (alternatively if relationships are more ephemeral, making accountability for local dynamics more nebulous), or under voluntary measures to improve the sustainability and transparency of their supply chains. These shortcomings are of particular concern when set against a backdrop of increased reliance on private sector actors and supply chain approaches to improve the sustainability of global trade (Lambin et al. 2018), and a diminishing influence of multilateral processes and the role of the national state, paired with an increase in the importance of subnational levels of governance following rising decentralisation in recent decades (Wright et al. 2016).

Recent research demonstrates that new types of data, which remained largely untapped by the sustainability research community, can help overcome some of these limitations (Fig. 8.2). In particular, the use of detailed trade accounts from custom declarations and bills of lading (Godar et al. 2016) and shipping manifests (Schim van der Loeff et al. 2018), as inputs of a physical accounting approach (Trase 2017) provide per shipment information on the exporters and importers of specific products, as well as precise information on total volumes being shipped to specific locations. This information is available for a growing number of countries of export and import. Trade data can also be combined with

spatially explicit information on supply chain nodes in the country of production, allowing for high accuracy in mapping subnational sourcing patterns per supply chain actor. These data include, but are not limited to, taxation records per asset of the companies involved in the production, processing and trade of commodities; sanitary inspections identifying a given commodity volume with a specific location at a given date (Klingler, Richards and Ossner 2018); logistics ownership of traders and producers (e.g. farms, silos, crushing facilities, slaughterhouses); sourcing of certified products; recorded movements of traded goods, for example, vessel trackers using the AIS system (Schim Van der Loeff et al. 2018). By combining these datasets, it is possible to map linkages between commodity buyers and specific production geographies with an unprecedented level of accuracy. This approach has been undertaken by the Trase initiative (www.trase.earth), co-founded by the authors, which by 2020 seeks to map subnational sourcing patterns for entire supply chains for more than 70% of the globally traded volume in tropical forest risk commodities. Figure 8.3 represents three selected illustrative pathways depicting the location of the cargo and its ownership alongside a supply chain, as well as some selected indicators for soy deforestation and shipping emissions. The figure shows the large variability in deforestation risk and international shipping emissions, respectively, per tonne of soy in these three illustrative trade routes. The totality of the exports and a number of other embedded impacts and risks of a given supply chain can be obtained at the Trase home page (<https://trase.earth/flows>), as of November 9, 2018.

These new data-driven approaches allow for a much finer-scale assessment of consumption footprints and actor-specific risk exposure. For example, Flach et al. (2016) and Godar et al. (2015) demonstrated that while China imports more sugar and soy from Brazil than the EU, the fact that the EU preferentially sources from the Amazon and Northern Cerrado in the case of soy, and the dry Brazilian Northeast in the case of sugar, means that compared to China, it has higher levels of embedded deforestation and impacts on local water scarcity per unit of commodity (and see Trase 2018b). A recent study (Schim van der Loeff et al. 2018) suggests that differential sourcing patterns are strongly related with operational and shipping logistics considerations, for example, due to the

simple fact that the EU is closer to the ports in the North and Northeast of Brazil, which in turn are closer to forested areas at risk—a basic observation that is lost in country-level analyses. Figure 8.4 represents the risk per imported tonne of soy of major consumer markets, and of major traders.

Data on the role of specific actors in different supply chain stages is key to understanding the nature of existing trade and land-use telecouplings and for designing actionable sustainability interventions, whether to improve corporate decision-making or strengthen accountability processes by governments and civil society. By discriminating sourcing patterns of individual companies or buying countries, it is possible to discriminate differences in embedded deforestation risk among actors. Given differences in total sourcing volumes and links to different deforestation hotspots, different buyers can be exposed to very different levels of risk. For example, Louis Dreyfus exported 6.5% of total Brazilian soy exports in 2006–2016. In this period, it mostly sourced from the south of Brazil, where there has been little recent deforestation for soy. Because of its high volumes and its sourcing from areas with little soy deforestation risk, the company's deforestation risk per exported tonne in the period was about 25 times smaller than that of the joint venture Amaggi & Louis Dreyfus Commodities, who sourced exclusively from the deforestation frontier of Matopiba (see Trase [2018a](#)).

By discriminating sourcing patterns and associated levels of deforestation risk for individual companies and importing countries, it then becomes possible, for the first time, to monitor changes in total deforestation risk exposure over time—whether for individual companies or countries that have made zero-deforestation commitments, or for industry groups (such as the Consumer Goods Forum) or groups of committed countries (such as the EU countries signing the Amsterdam Declaration). In order to assess the net effects of such voluntary commitments overall (rather than the independent effect of a given actor), it is essential to be able to map changes in deforestation embedded in commodity trade for the entire exports of a given country and region, making it possible to discern whether a particular buyer has reduced their risk exposure either by moving their sourcing to regions with no recent deforestation, or by investing to reduce deforestation in hotspot areas.

Relative deforestation risk of soy consumed by major markets (ha/kTon/year)

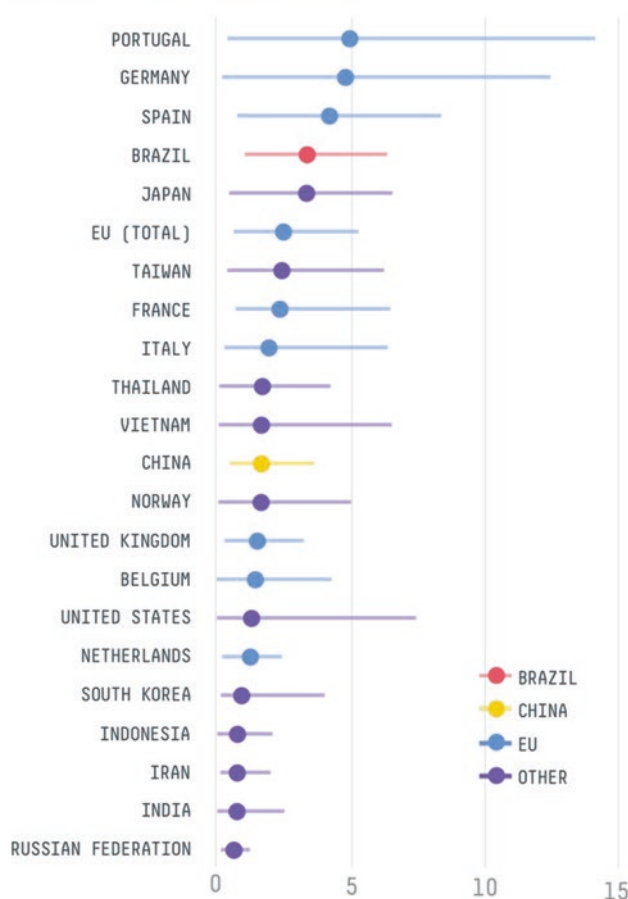


Fig. 8.4 Annual relative deforestation risk, in the Cerrado and Amazon biomes, of soy consumed by major markets, 2006–2016 (ha/kTon/year). Points show the mean relative deforestation risk linked directly to soy expansion per country for the period 2006–2016. The error bars show the minimum and maximum between 2006 and 2016. Amounts of deforestation risk are allocated to different countries in proportion to volumes sourced from each Brazilian municipality. Data from www.trase.earth (retrieved June 2018)

While mapping the different roles of actors directly participating in a given supply chain is a major advance, there are other actors that shape trade and land-use telecouplings more indirectly, whether from the vicinity of a given supply chain (e.g. suppliers of farming inputs, investors, trading operators, regional governments) or from afar (e.g. traders in global commodity futures, trade negotiators). The role and responsibility of these indirect actors is still poorly recognised, and even more poorly assessed and understood. However, recent developments in both data access and processing methods offer options for potentially groundbreaking research in understanding more indirect drivers of land-use and trade telecouplings. These include data mining techniques, Open Access Linked Data (<http://linkeddata.org/>) enabling the linking of datasets that were not previously connected (e.g. via common name or ID matching techniques), Natural Language Programming (NLP) enabling the automated interpretation of complex documents—such as news reports, trading records and public listings of companies, to identify indirect linkages between actors, including financial relationships in the form of subsidiary-parent relationships, joint ventures, shareholdings and equity and debt holdings. Mapping these relationships can greatly facilitate the otherwise overwhelming task of understanding the complex web of dependencies and economic instruments and mechanisms that sustain the global trade architecture and the trade and land-use change telecouplings.

While we argue for the need to move from national-level datasets to spatially explicit and nominal trade flow data to help advance our understanding of trade—land-use telecouplings, assessing causality of specific land-use changes, and attributing impacts and thus responsibility to distant actors remains immensely challenging. Robust impact evaluation methodologies are very difficult to design and often require datasets that are not readily available, even for assessing relatively “simple” cause-effect relationships. Assessing the specific impact of more remote drivers includes the fundamental problem of determining how responsibility for impacts of a specific supply chain should best be allocated and shared across multiple actors involved and profiting from that supply chain—including more indirect beneficiaries such as input providers and investors. For example, it is possible to discern, at some level, the relative levels of benefit that accrue to different actors and sectors linked to a specific

supply chain based on differences in income (Godar et al. 2016). However, moving from allocation of financial benefits to allocation of responsibilities for improving the sustainability of production is much harder, and is partly a political rather than a technical problem as it is possible to argue that each stage or sector involved in a supply chain bears responsibility for the entire amount of deforestation embedded in a given supply chain. However, it is also important not to get lost in the complexity and seek to apportion impacts and responsibilities to all participants, given that in an increasingly globalised economy the list of candidate participants can be extremely large. While technical solutions, such as those derived from blockchain technology applied to supply chains and machine learning and big data techniques applied to supply chain intelligence, are postulated as partial solutions to some of these problems, they are fundamentally limited when it comes to disentangling what are inherently co-dependent effects and multiple-order causal pathways. Multiple-method approaches, including both quantitative and qualitative methods, are needed to disentangle causal pathways. The more data-driven (over pure modelling) approaches to mapping commodity supply chains that are advocated for in this chapter, accounting for spatial explicitness and actor nominality, can go a long way towards grounding these analyses closer to the practical needs of decision-makers.

4 Transparency and a Data-Driven Opportunity to Provide Decision-Relevant Information on Trade–Land-Use Telecouplings

In this chapter, we have argued for the research community to adopt and invest in a more granular and data-driven approach to mapping and assessing global commodity trade as a basis for improving our understanding of trade and land-use telecouplings. Specifically, we argue that a focus on spatially explicit and actor-specific data, distinct from the dominant focus to date on national-level data and model-intensive methods, is essential for

providing actionable information to support decisions in specific regions and for specific actors and sectors. Recent breakthroughs in the harnessing of hitherto poorly tapped data sources, including individual-shipment level trade data, as well as advances in methods for processing these and other linked data, open the door to exciting and important new research opportunities on trade-related telecouplings.

Underpinning these breakthroughs is an explosion of accessible, transparent information on how supply chains operate and the environmental and social risks and opportunities they pose (Gardner et al. 2018). Labelled by some as the “Information Age,” the last few decades have given rise to an era where information transparency processes are increasingly capable of supporting entirely new modes of environmental governance (Mol 2015).

Changes in purchasing and investment practices of commodity buyers and financial institutions are driven by a multitude of interests and often contesting agendas that require compromises and trade-offs involving both private and public actors. Recent increases in supply chain transparency, the adoption of ambitious sustainability commitments by an increasing number of actors and the increased involvement of non-state actors have all contributed towards significant changes in the governance of commodity supply chains (Gardner et al. 2018; Lambin et al. 2018). Analyses to help unpick and reveal the roles played by specific downstream actors in shaping distant patterns of land use can help in facilitating both a shift towards more cooperative action, with hybrid governance arrangements and increased precompetitive collaboration among private companies, as well as a strengthening of top-down compliance (Egels-Zandén et al. 2015). Transparency as a means of cooperation can work by helping to equip actors with the information and tools they need to contribute effectively towards collective action problems, including by helping build coalitions of trusted actors who can reduce costs by working together (Boström et al. 2015). By contrast, transparency as a means of compliance works by way of threats. Threats—and associated repercussions—can come from downstream buyers who shift responsibility for improved practice standards to their upstream suppliers, from campaigning organisations seeking to expose unsustainable or illegal practices, or through surveillance operations by governments and voluntary accountability initiatives.

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