Universitat Autònoma de Barcelona

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Land use change in the era of reflexive modernity

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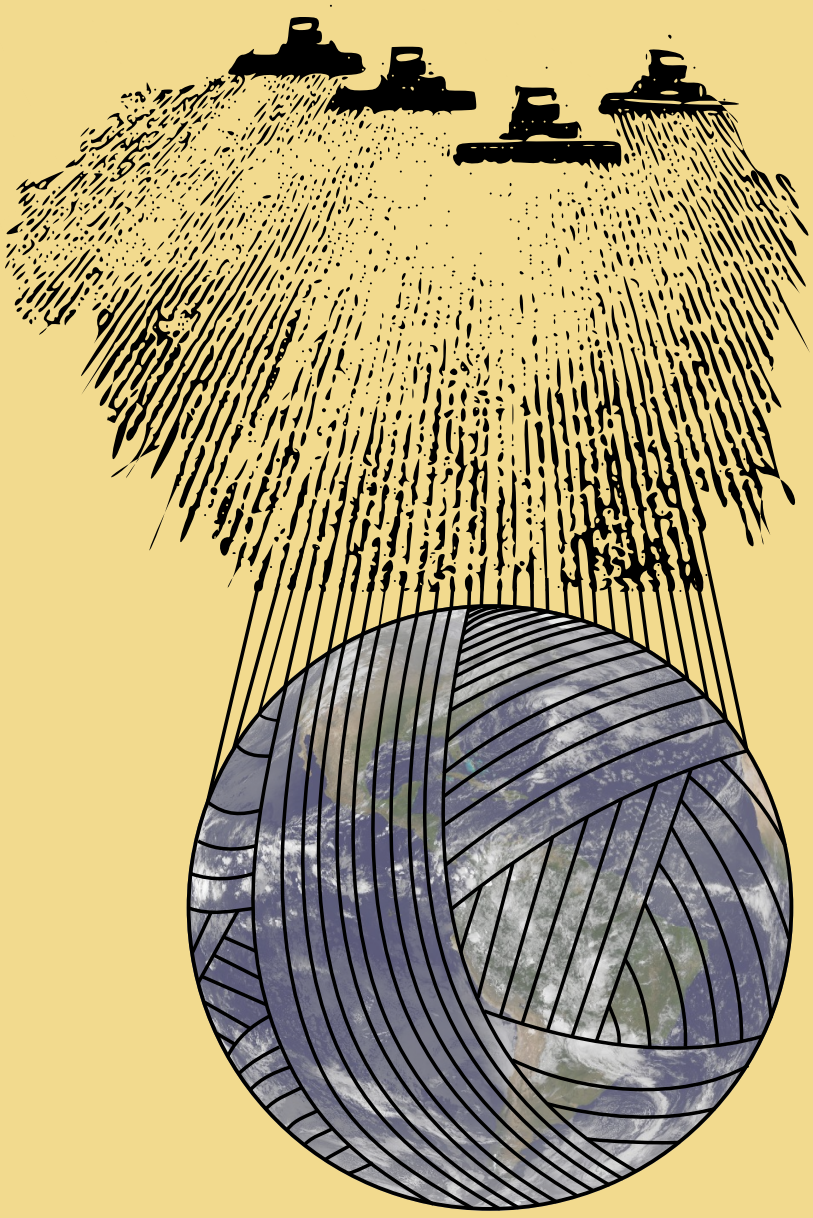

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Ph.D. dissertation

Directors: Esteve Corbera & Beatriz Rodríguez-Labajos

Ph.D. programme in Environmental Science & Technology

Institut de Ciència i Tecnologia Ambientals

Universitat Autònoma de Barcelona

2022

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Barcelona

October 2022

Summary

This dissertation explores the global soybean complex within the context of land use change in the age of reflexive modernity. This age is characterized by processes of self confrontation, radicalizing the core values of modernity by scrutinizing unintended side-effects of earlier modernization projects. The emergence of a global agenda for sustainability and interdisciplinary socio-ecological impact sciences are examples of such processes. Land system science as a discipline has developed tools and conceptual approaches to trace impacts and policy outcomes in a globalizing world with increasingly diffuse spillover effects. This thesis analyzes what it identifies to be three blind spots or research gaps in this literature.

Firstly, due to a reliance on neoclassical theory, land system science often conceptualizes economic processes as universally valid phenomena rather than socially and historically embedded. Thereby, studies often follow snapshot-like representations, where an initial demand signal is taken to be the original driver behind land use change dynamics. This thesis provides a reading of historically evolved socio-ecological relations which have shaped the current function of soybeans in the world economy. It thereby turns conventional causal explanations on their head and analyzes how accumulation strategies have inserted land in production processes and thereby funneled soybeans into different provisioning systems, shaping final consumption patterns.

This analysis reveals how the current function of soybeans, dominated by the use of soybean cake in animal feed, is a legacy from the post-war era, which assembled surplus grains, oilseeds and animal bodies in a way to allow for continued accumulation. Further, corporate actors, which control the productive nodes build around this socio-metabolic pathway, will likely resist major transformations, since fixed capital assets lock in current forms of provisioning. Transitions towards sustainable practices may depend on the role governments will play in future governance interventions.

Secondly, tools developed to trace how agricultural items and their associated impacts are embedded in final consumer products so far do not provide nuance at the functional level of constituent chemicals. This would allow observing socio-metabolic patterns for the sourcing and final use of individual substances, as well as trace the impacts of substitutions between items for specific uses. This thesis presents a nutrient-specific multi-regional input-output model for calories, protein and fat and several potential applications.

Thirdly, while land system science has progressively included more perspectives from the social sciences, the role of discourse and deliberation in shaping governance interventions has remained

rather marginal. This dissertation explores how different stakeholders and media have framed problems associated with soybean expansion, analyzing whose concerns and what regions are emphasized or neglected. Employing a text-mining approach, this work shows how news media in importing countries increasingly covered issues relating to soybean production rather than only focusing on final consumers. However, these issues are mostly limited to those impacts clearly relevant for national audiences. Further, impacts such as deforestation can receive very different levels of attention in Western media discourse and be framed in distinct ways depending on where they occur and what popular imaginaries are associated with a given place.

These findings suggest that research needs to understand how specific strategies to accumulation have organized production in a way that shaped current land use practices and entangled them with provisioning systems and modes of consumption. Further, post-sovereign environmental politics at times require public pressure incentivizing corporate actors and government bodies to tackle socio-ecological impacts. However, deliberative processes can create loopholes by emphasizing certain impacts, regions or interests while neglecting others and thereby lead to unintended outcomes.

Acknowledgments

This dissertation is the result of a process very different from what I had in mind when embarking on it and in many ways the past years were the most difficult times I have had. Due to the COVID-19 pandemic, the research process was mostly confined to a desk with few personal interactions, no in-person conference presentations and no fieldwork. This thesis materialized only for the support of a great many people, of whom I can only mention a few here.

Firstly, I am grateful to my parents, *Solveigh* and *Gerhard*, who have always supported me throughout the years and whom I have not had the chance to visit as often as I would have liked. The same goes for my brother, *Lasse*, and my sister, *Jana*, who have seen my face almost exclusively on a screen for years.

Many friends have been there for me over these years. My time in Barcelona would not have been the same without *Bekah* & *Lliure*, *Mônica*, *Eva Planell*, *Sole*, *Aljoša*, *Ale*, *Diana*, *Anna*, *Albert*, *Vero*, *Sohini*, *Borja*, *Fulvia*, *Xiao*, *Santi*, *Felipe*, *Joël*, *Lou*, *Kim* and everyone I have shared lunch or coffee with at ICTA.

Some friends have always remained close despite the many years of long distances and I am grateful to *Stefan*, *Ulli*, *Niko*, *Henning*, *Reinhardt*, *Fynn*, *Esther*, *Janek*, *Linn*, *Jamil*, *Martin*, *Fine*, *Tania*, *Chris* and everyone else who has checked in on me despite my radio silence.

Absolutely nothing would have worked out without the administrative support by *Cristina Durán*, *Montserrat Puigdomènech* and *Laura Sans*.

I am also indebted to all my friends and colleagues from COUPLED, particularly *Kathrin*, who held everything together, *Jonas*, who supported me during my research stay in Berlin and *Louise*, who always encouraged me.

For the great exchanges and collaborations, I want to thank *Francisco Bidone*, *Marion Werner*, *Annie Shattuck*, *Ryan Galt*, *Zackary Dunivin*, *Martin Bruckner*, *Simon Croft*, *Maria Tyldesley*, *Paulina Flores Martinez*, *Anna Frohn Pedersen* and *Edward Challies*.

Last but not least I want to thank my supervisors *Esteve* and *Bea* for their support and feedback.

Thank you!

Funding and institutional support

This research has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 765408.

This research has been supported by the Laboratory for the Analysis of Social-Ecological Systems in a Globalized world (LASEG), Universitat Autònoma de Barcelona and Generalitat de Catalunya (2017-SGR-775).

This research contributes to ICTA-UAB "María de Maeztu" Programme for Units of Excellence of the Spanish Ministry of Science and Innovation (CEX2019-000940-M).

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Background

The story of the soybean's (*Glycine max*) emergence as a major global agricultural commodity is remarkable. Originally domesticated in China about 4500 years ago (Qiu and Chang 2010), today the soybean is the fourth most important crop in terms of area harvested (FAO 2020). But while wheat, maize and rice, which top this list, had all already experienced a global spread of production and trade since the European colonization of the Americas, soybeans still largely remained a regional food item in Eastern and Southern Asia at the onset of the 20th century (Du Bois 2018). After the first shipments of soybeans from Manchuria (a region in Northeast China, at the time firmly under the control of Japanese imperialism) to the industrial centers of Europe in 1907, the "miracle bean" (Prodöhl 2010) spread across the world and ultimately became ubiquitous in the global food system.

In this process, virtually every aspect from production to use has undergone major transformations. The center of global production has since shifted from Manchuria to the United States during World War II and most recently towards South America. Yield per hectare has increased from about 0.7 tons for Manchurian soybean production in the early 20th century (Shurtleff and Aoyagi 2007) to a global average of 2.8 tons today (FAO 2020). Advances in plant breeding and more recently biotechnology have produced soybean varieties for distinct photo-periods, hydrological conditions, soil types and resistant to specifically marketed herbicides as part of technological packages (Vieira and Chen 2021; Wysmierski and Vello 2013; Lapegna 2016). This allowed for the expansion of soybean production in agricultural lands and commodity frontiers across distinct biomes. The evolution of soybean processing and marketing has catapulted both, the oil and protein fractions, into myriads of industrial applications. In the early 20th century soybean cake was mainly exported as fertilizer for rice farms in Japan, while the oil was shipped to Europe to meet demand for vegetable oils to produce goods such as margarine, soap and paints (Mizuno and Prodöhl 2019). Today, soybean cake is used mainly in commercial animal feeds. Further uses of soybean oil include biofuels, inks, adhesives, resins, and detergents (Raghuvanshi and Bisht 2010).

The rapid rise and expansion of soybean production and trade to become virtually ubiquitous exemplifies the cumulative effects of increasing "time-space compression" Harvey (1989), channeling

standardized soybean products from different continents into myriads of industrial pathways across the globe and thereby disembedding associated socio-ecological relations from local contexts. This has been accompanied by conflict and controversy. Soybean cultivation has replaced native vegetation in sensitive biomes, such as the Cerrado, Amazon and Gran Chaco, contributing to biodiversity loss and greenhouse gas emissions through land-use change (Song et al. 2021). Rural dispossession and displacement as well as landholding concentration have further marginalized already disenfranchised indigenous and traditional populations (Russo Lopes et al. 2021). Moreover, the adoption of input intensive agriculture has led to patterns of debt accumulation for producers (Bicudo Da Silva et al. 2020) and raised public health concerns over the increased use of pesticides (Bernieri et al. 2019). The important role of soybean cake in animal feed also links these issues to the growing environmental footprint of concentrated feeding operations (Weis 2013b). Further, the COVID-19 pandemic has highlighted the potential contributions of agricultural expansion in commodity frontiers and monospecies industrial livestock operations to elevated risks of zoonotic diseases (Mishra et al. 2021).

This ambiguous image of soybeans as symbol for both, tremendous progress and grave socio-ecological impacts reflects broader debates on the contemporary era of modern globalization and its way of reorganizing global food systems and land use. The role of science and technology in this process was long confined to what Schnaiberg (1980) defined as "technological-production" science, a production of knowledge oriented toward increased capitalist accumulation, which expanded corporate control over resources. Growing concern over negative impacts from unregulated corporate productivism has led to the emergence of "environmental-social impact" science (Schnaiberg 1980), which came to scrutinize such adverse effects. This was accompanied by the rise of social movements and "post-sovereign" (Pattberg 2007) approaches to environmental governance, such as measures that aim to regulate impacts associated with traded agricultural commodities by including stakeholders along the value chain (Sikor et al. 2013). This is exemplified by the various corporate governance interventions in the soybean sector, including the Soy Moratorium, corporate zero-deforestation commitments and certification schemes such as the Roundtable on Responsible Soy (RTRS) and ProTerra. Environmental impacts of soybean production and other Forest Risk Commodities (FRCs) have also been addressed by national legislation in producing countries, as exemplified by Brazil's Forest Code and in multilateral deliberations, as manifested in the New York Declaration on Forests.

It is widely debated, however, whether current modes of institutional change are adequate to address socio-environmental impacts and conflicts. Ecological Modernization (EM) theorists maintain that current modes of production and development can integrate insights from impact science through market instruments and in fact would benefit from increased resource efficiencies (Spaargaren and Mol 1992). Critics associated with the traditions of political economy and political ecology argue instead that impacts are tied to the fundamental dynamics of capitalism (O'Connor 1988; Schnaiberg et al. 2002). Another major concern is with the nature of deliberative processes through

which problems associated with globally traded commodities, such as soybeans, are identified and solutions envisioned. The arenas of such deliberation would have to include a broad variety of stakeholders and coalitions beyond national boundaries to attain legitimacy (Fraser 2009).

1.2 Aim and scope

The presented thesis invites the reader to explore the contentious issues surrounding land use change and environmental governance through the case of the Global Soybean Complex. Rather than a case study on socio-ecological relations, land use outcomes, or conflicts manifesting in or resulting from soybean production and trade in a particular geographical context, the dissertation investigates the function of soybeans in the contemporary global food system, the processes and historical legacies that have shaped this function and the deliberative mechanisms through which problems have been identified and addressed in the past decades. Specifically, it asks:

1. What processes have shaped the current function of soybeans in the global food system, what practices are promising to transform it, and how can this understanding be integrated in land system science?

2. How can we analyze the role of soybeans in the global food system by tracing their constituent chemical components through different end uses over time?

3. How have socio-ecological problems associated with soybean expansion been framed in transnational public spheres, which issues have been emphasized and which neglected?

4. How do these frames differ between biomes, and how does this relate to disparities in governance interventions and conservation efforts?

The following section introduces the concept of reflexive modernity and explores its relation to research in land system science. It proposes to engage more directly with economic geography and environmental communication to overcome the field's current shortcomings related to its reliance on neoclassical economic theory and it's lack of attention towards processes of signification. Chapter 2 explores the history of the Global Soybean Complex through the legacies of socio-metabolic functions, spatial fixes and technologies. Chapter 3 provides a model to maps global flows of dietary nutrients through production, trade and final use, identifying the role of soybeans within the chemical geographies of agrarian capitalism. Chapters 4 and 5 trace the topics and narratives circulating in transnational debates on soybean expansion and deforestation. Chapter 6 summarizes the findings and explores their relevance in contemporary debates on globalization, agrarian capitalism and land-use change.

1.3 Conceptual foundations

1.3.1 Reflexive modernity and land system science

In the social sciences, there has been an intense debate on the concept of modernity, which constitutes a core element of sociology and its analysis of social evolution. My aim is not to provide a concise overview of this exchange here. Rather, I focus on the emergence of the concept of reflexivity and its relevance to research in land system science, and the soybean complex more specifically.

In the classical understanding, modernization was typically framed as being tied to the emergence of the industrial division of labor, social relations emerging from the capitalist mode of production or a general process of differentiation in the economic, political and cultural spheres (Heiskala 2011). This understanding was fundamentally put into question by Jean-Francoise Lyotard's postulation of modernity as the emergence of meta-narratives, particularly on science and progress, which assume the status of absolute truths and narrow the semantic space for cultural identities (Lyotard 1984). According to Lyotard, the subsequent postmodern condition is characterized by the erosion of these narratives and a new plurality of cultural identity formation. Another response and critique of Lyotard's , which is relevant in this dissertation due to its implications concerning questions on sustainability, is Ulrich Beck's theory of Risk Society and the associated concept of reflexive modernity (Beck 1992; Beck et al. 2003).

According to Beck, the problem-solving rationale in industrial societies, relying on scientific certainty and autonomous nation states, is challenged by an emergent 'risk society', characterized by the social production and distribution of increasingly transnational "techno-scientifically produced risks". In the presence of looming uncertainty and new struggles relating to the distribution of risks, there is a severe legitimacy crisis of the institutions characteristic of modernity due to their inability to deal with unintended side effects (e.g. ecological crisis) of industrial capitalism. Under these circumstances a second modernity evolves, one which is reflexive or, in other words, turns upon itself in a form of self-confrontation. This further radicalizes and universalizes the consequences of modernity. One expression of such self-confrontation is the emergence of the very notion of sustainability, which, according to Torgerson (2018, p.1) "is a remarkable historical event, constituting a reflexive moment that encourages a reconsideration of past developments and future possibilities". This development is also mirrored in what Schnaiberg (1980) describes as an erosion of the dominance of "technological-production" science with the emergence of "environmental-social impact" science. In addition to the understanding of reflexivity as "self-confrontation", the use of this term has also come to encompass the meaning of "reflection", in a sense that "social practices are constantly examined and reformed in the light of incoming information about those very practices, thus constitutively altering their character" (Giddens 1990, p.38). Over the past decades, reflexivity has

found use in many research areas, as evidenced by the proliferation of constructs such as ”reflexive expertise” (Lidskog et al. 2022) or ”reflexive governance” (Voß et al. 2006).

In the realm of land use, agriculture and food systems, this conceptualization of modernization in two phases appears to have a lot of merit. The catastrophism of Malthus (1798), which had predicted population growth to be limited by its overshooting food production capacity, was proven wrong by gains in agricultural productivity following technological developments characteristic of first modernity (e.g. the Haber-Bosch process, modern plant-breeding, synthetic pesticides). These allowed global food output to keep up with and even outstrip unprecedented levels in population growth during the 20th century, while simultaneously significantly decreasing the share of people engaged in agriculture. However, the rise of a reflexive, second modernity began confronting some consequences of the very institutions this process gave rise to, scrutinizing the persistence of hunger and malnutrition even at times of abundant global food supply as well as the socio-environmental impacts of modern industrial agriculture.

Within the past three decades land system science emerged as one field of such reflexive socio-environmental impact science, focusing on the terrestrial component of the Earth system, its anthropogenic uses, transformations and socio-ecological outcomes (Verburg et al. 2013, 2015). The field is characterized by its interdisciplinary, which has included perspectives from physical (e.g. remote sensing), ecological and social science traditions to grasp human-environment interactions in land dynamics and has led to an increasingly complex understanding of drivers and impacts of land-cover and land-use changes, maturing into a set of core empirical, methodological and theoretical contributions (Meyfroidt et al. 2018).

The reflexive nature of the field is highlighted by how a focus on individual regional case-studies and their synthesis in meta-analyses has increasingly given way to a more holistic view in light of the understanding on how land systems are connected over large geographic distances in manifold ways (Meyfroidt et al. 2013). This is exemplified by the recent focus on land-use spillovers, which describe situations where land-use changes or interventions in one place have consequences (often assumed to be unintended) on land use in another place, such as when forest conservation in one country leads to deforestation in another by increasing demand for imported timber (Meyfroidt et al. 2013; Bastos Lima et al. 2019). Given that land system science itself aims to inform future land use interventions, this focus constitutes exactly the kind of infinitely recursive process in which new understandings on unintended side effects of current interventions inform science and policy recommendations for future ones.

The centrality of spillover effects is evident in the emerging telecoupling framework (Figure 1.1), which captures the mutual dependencies and conditionalities of distal socio-ecological systems via material, financial and informational flows (Liu et al. 2013, 2014; Eakin et al. 2014; Friis et al. 2016). The framework consists of key analytical components, which can be applied when studying such

distal interactions. Telecoupling is described as a phenomenon arising when an action triggers a flow (e.g. biomass, information, finance) from a sending to a receiving human-environment system, which leads to a response (e.g. land use change, governance intervention) in at least one of these systems. A spillover system may be affected by this interaction between sending and receiving systems, but does not directly influence the nature of the original flow. With increasing economic globalization, land systems are understood to be integrated into complex hierarchies or nested structures of such telecoupled systems.

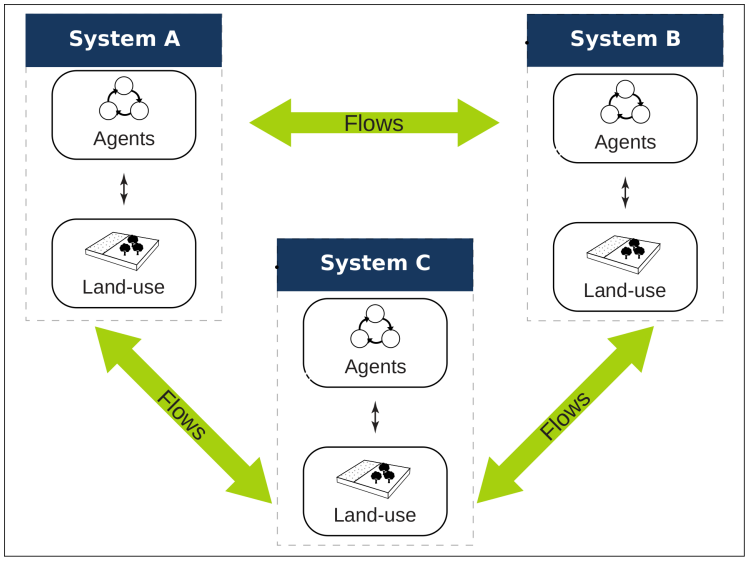

Figure 1.1: The telecoupling framework. Based on Liu et al. (2014).

The emergence of these new conceptual approaches is much needed in an era of accelerating agricultural trade, highly volatile financial capital and networked configurations in global environmental governance. It represents a reflexive moment in the sense of "reflection", as the increasing awareness of spillover effects refines the conceptual models used and resulting policy recommendations. However, it is questionable whether this tireless effort to uncover and counteract progressively more diffuse impacts is truly reflexive in a sense of "self-confrontation": Understanding the inadequacies of present models in coping with the current wave of economic globalization appears to trigger successive generations of patches rather than a fundamental overhaul of basic assumptions. This concerns, as Munroe et al. (2014) have argued, land system science's continued, almost exclusive, reliance on neoclassical approaches to understanding economic processes. Similarly, Napoletano et al. (2015, p.199) argue that land system science "has not considered the underlying impetus of globalization processes or sufficiently accounted for land change in the evolution of the capitalist world-economy".

Treating economic interactions as expressions of universally applicable rules blurs their socially embedded and historically specific nature, resulting in snapshot-like representations (Friis et al. 2016), in which dynamics are typically analyzed without considering developments in the longue

durée. Further, while the telecoupling framework explicitly highlights the relevance of discursive processes and flows of information, there has been a prioritization of developing methods to trace material flows of biomass or minerals and their environmental impacts (Persson and Mertz 2019). The following two sections shall deal with each of these shortcomings in more detail.

1.3.2 Regimes and transitions: re-embedding the economy

The rather ahistorical, snapshot-like nature of conceptualizing economic processes in the telecoupling framework and related research in land system science may be addressed by engaging with "substantivist" approaches in economic theory. Substantivism was formulated by Karl Polanyi (1944, 1957), who drew from Marxian economic sociology and its analysis of the historical tendencies of capitalism (Stanfield et al. 2015). Polanyi argued against the "formalist" approach of neoclassical economics, which conceptualized the economy as a set of "generally conceptualized activities, such as making 'rational choices' under the constraints of resource scarcity" (Gao 2021, p.4). Engaging with anthropological studies of pre-capitalist economies, Polanyi stressed the importance of historically specific social relationships and institutions in the process of material reproduction. The dominance of neoclassical approaches and models has meant that substantivist thinking has remained rather marginalized in mainstream economics. However, it still has influenced several research lines, which may help to re-embed the understanding of economic processes within broader, historically and geographically specific social structures.

One such research line is the régulation approach (RA), which originated in the 1970s, when then Global North experienced a stagnation and unemployment crisis after several decades of post-war economic stability. It is a radical critique of neoclassical economic theory based on the postulation of the self-regulating character of market economies (Aglietta 1979). Unlike it, the RA does not seek to provide a general, transhistorical account of economics (Jessop and Sum 2006). The notion of régulation rather allows studying how despite its inherent contradictions and crisis tendencies, there remains a permanence of the capitalist mode of production. Hence, RA is centrally concerned with analyzing geographical and historical variations in the institutional arrangements of capitalist economies (Boyer and Saillard 2002). It does so by periodizing relatively stable accumulation regimes (e.g., pre-fordist, fordist, post-fordist/neoliberal) between moments of crisis, and identifying the stabilizing institutionalized compromises, which emerged from crisis and social struggles (Boyer 1990; Lipietz 1986). Typically, in its analysis of such compromises the RA has focused on five distinct "institutional forms" (Boyer and Saillard 2002): the monetary regime, the wage-labor nexus, form of competition, insertion in the international regime, and the nature of the state.

While the RA originally largely ignored environmental issues, land system science can build on new approaches evolved over the past decades, which have brought the RA in conversation with ecological modernization theory, political ecology and other scholarship analyzing nature-society relations (Schuldt 2022). To incorporate socio-ecological perspectives into the RA and overcome what

was perceived as an "ahistorical normative discourse" (Gandy 1997, p.338) in much of environmental research, Gandy and others built on O'Connor (1988, 1991) and his "second contradiction of capitalism", which suggests that capital tends to undermine its own conditions of reproduction by degrading ecological systems. This can be conveniently fitted in the RA by treating nature as another inherent crisis tendency in the capitalist mode of production. However, Gandy and others thereby conceptualized an environmental dimension as extra-economic and thus to be treated on a separate analytical level (Gibbs 2006; Huber 2013; Schuldt 2022). Huber (2013) advocates for transcending the nature-society dualism by siding with Moore (2011, p.34) and his suggestion that "capitalism does not have an ecological regime, it is an ecological regime." In his analysis of petro-capitalism and oil-dependent consumption patterns, Huber therefore insists that ecology can be understood through the RA's institutional forms (Huber focuses on the wage-labor nexus).

Another approach to periodization that extensively draws on the RA and world systems theory in the realm of agrarian political economy is the concept of "food regimes", proposed in the seminal publications by Friedmann (1987) and Friedmann and McMichael (1989). The food regimes concept rejects the exceptionalism of agriculture (analytically separating it entirely from industry) as well as linear representations of agricultural modernization. Rather, it provides a "structured perspective to the understanding of agriculture and food's role in capital accumulation across time and space" (McMichael 2009, p.140). The initial work focused on identifying an emerging international food system with the first food regime (1870 - 1930s), which appeared with the rise of nation-states and was characterized by European imports of grains and meat from settler-states as well as tropical crops (e.g., sugar, tea, coffee) (Atkins and Bowler 2001). In the post-war era, a second food regime emerged, following a model of national agro-industrialization with large surplus production from the United States re-routed to Europe and postcolonial states according to strategic efforts in the Cold War (McMichael 2009).

Since the publication of the seminal work, debate has ensued over the periodization of a third, neoliberal or corporate food regime, which shows increasing consolidation in production networks under transnation corporations, the rise of flex crops and phenomena such as green consumerism. The strong influence of the RA and world system theory in food regimes literature has meant that environmental issues have not been central. However, Krausmann and Langthaler (2019) show that the approach is compatible with socio-ecological perspectives and that empirical analysis of agricultural trade flows and societal metabolism confirms the periodization suggested by the food regimes literature.

Finally, another productive engagement for land system science in its effort to untangle the implications of different forms of distant interactions is with the various conceptualizations of "spatial fixes" in economic geography. In his seminal work *The limits to capital*, David Harvey (1982) analyzed the spatial patterns of past and present capitalist economies. Harvey introduced the spatial fix as a

way to make sense of how crises of overaccumulation can be deferred by switching capital between geographically distant regions, for example by finding outlets for excess capital in built environment, by opening new markets or by sourcing raw materials from expanding commodity frontiers. Beyond the use of this concept to understand geographical expansion as a temporal remedy for crisis tendencies, recent scholarship has analyzed how such fixes involve the reconfiguration and appropriation of nature. The "socioecological fix" (McCarthy 2015; Castree and Christophers 2015; Ekers and Prudham 2015, 2018) is thus conceptualized as "something that directly engages with and resolves, mitigates, or postpones a structural impediment -including any environmental one- to sustained capital accumulation" (McCarthy 2015, p.11).

Engaging with these conceptualizations may enrich land system science by putting the contemporary phase of modern globalization into perspective. The seminal publications on spillover effects and the telecoupling framework often explain the increasing entanglement of land use within distant interactions mainly with technological innovations, which allow for faster transactions, larger trade volumes or virtually instant long-distance communication. While these developments are certainly relevant, they do not alone explain what function these interactions have in broader socioeconomic contexts, how they evolved and how they differ from former phases of globalization.

In other words, starting the analysis from a signal (e.g., increasing meat demand in China) and tracing the implications through resulting flows and spillovers (e.g., meat exports from Europe with embedded land use from soybean production in Brazil) means ignoring path-dependencies and turning a blind eye to how and why these metabolic pathways, demand structures and trade relations were historically produced. In this dissertation, chapter 2 will take up these ideas by tracing the evolution of the global soybean complex according to accumulation strategies and socio-ecological fixes. The chapter argues that the contemporary soybean complex inherits defining properties from the past, particularly the postwar strategy of using industrial animal farming to add value to surplus grains and oilseeds. Expanding soybean production is therefore not merely a result of increasing demand, but rather the outcome of different provisioning systems' continued dependence on soybeans.

Further, chapter 3 develops a physical multi-regional input-output model of agricultural production, trade and use for calories, protein and fat. Disaggregating agricultural commodities into nutrients enables analyzing the dynamics of sourcing biomass products for certain functional components of societal metabolism and to explore the shifting role of various flex-crops and their derivatives over time. The chapter explores in various applications how the model can illustrate processes, such as the restructuring of sourcing patterns and final uses of fats under the agenda of the bioeconomy or the socio-metabolic pathways and (in)-efficiencies of protein use from primary products in dietary transitions. The model thus allows to quantify and analyze phenomena referred to in chapter 2 and highlighted by an emerging chemical turn in geography (Romero et al. 2017).

1.3.3 Engaging with environmental communication

The availability of detailed trade data, large-scale multi-regional input output tables, remote sensing products and increasing computing capacity has led to immense methodological innovation and abundant empirical studies tracing land use and associated impacts through transactions in the global economy. However, arguably this potential has not yet been sufficiently explored when it comes to discursive processes. While the role of communication and information in shaping land use decisions and governance interventions is acknowledged, these are less often the focus of empirical inquiry, are under-theorized and methodological advances in handling big-data are not incorporated. Here, we suggest that land use science can benefit from engaging with conceptual developments in environmental communication and with methodological approaches to studying text originating from computer science.

Engaging with communication in this context means taking serious the "politics of signification" (Hall 1982) in the realm of transnational environmental governance. In other words, processes of defining and giving meaning to environmental concerns, which may legitimize or challenge governance interventions, become part of the analysis. The rapid rise of attention toward the environmental domain, which emerged as an arena of political contestation in the postwar era, has given rise to the field of environmental communication, which consolidated in the 1980 (Cox and Depoe 2015; Pezzullo and Cox 2018). When incorporating insights from the field, environmental problems become conceptualized as socially constructed through claims-making and contestation by different stakeholder and mediated through various arenas of communication (Hansen 2015a). The field offers a rich repertoire of theoretical, conceptual and methodological developments to build on, that cannot be grasped here. Instead, we will focus on public sphere theory, the concepts of environmental discourse and framing as well as the possibilities offered by text-mining approaches.

Public sphere theory was initially developed by critical theorist Jürgen Habermas (1989) in his attempt to trace the evolution of communicative processes characteristic of modern societies and how they relate to understandings of democracy. His seminal work was originally published in German in 1962, but received a much broader international reception after its translation into English in 1989. Habermas understood the public sphere as a net of communicative processes, situated between the private and political realms, through which citizens within a nation state debate the issues of concern. Through the public sphere, debates can be carried from the periphery into the centers of political decision-making, thereby providing an important counterbalance to authorities. Thus, the notion of a public sphere is intimately tied to the theory of deliberative democracy and - as is characteristic of critical theory - contains a strong normative element in relation to its inclusiveness and effectiveness.

Public sphere theory only becomes relevant in the context of global environmental governance when considering its further developments and debates. This concerns primarily the original "West-

phalian" character of the theory, which anchored the public sphere firmly within the nation state (Fraser 2009). This methodological nationalism is a clear limitation, when considering the "post-sovereign" (Pattberg 2007) character of networked governance processes, which are not situated in bounded political entities but neither truly global (Lenschow et al. 2016). Thus, since "the legitimacy of political decisionmaking is dependent on the inclusion and empowerment of all potentially affected parties through public debates and deliberations" (Salvatore et al. 2013, p.2), it is imperative to study communicative processes that spill over national boundaries in transnationalizing public spheres (Fraser and Nash 2014).

Studies in environmental communication can engage with text (or other media) on several levels of analysis. On the textual level, an important concept is that of framing. A frame is a "schema of interpretation" (Goffman 1974) which selects "some aspects of a perceived reality and make them more salient in a communicating context, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/ or treatment recommendation for the item described" (Entman 1993, p.52). Snow and Benford (1988) distinguish between three types: diagnostic frames, which identify problems and attribute responsibility; prognostic frames, which suggest solutions and strategies; and motivational frames, which provide the rationale for action by stressing moral considerations or urgency of impacts.

Individual framing devices are not employed in a historical void and when analyzing text on a contextual and sociological level, they can be linked to broader discourses. A discourse can be defined as a "specific ensemble of ideas, concepts, and categorizations that are produced, reproduced, and transformed in a particular set of practices and through which meaning is given to physical and social realities" (Hajer 1995). While there have been previous efforts to trace the evolution of different types of environmental discourse (e.g., Herndl and Brown (1996)), the most applied typology is probably that introduced by Dryzek (2013), which groups discourse into four main categories: survivalism, environmental problem-solving, sustainability and green radicalism.

Just as much of these theoretical and conceptual framworks in environmental communication have been inherited to a large extent from the broader social sciences, so have the methodological approaches. While text analysis has developed heterogeneous methodologies in qualitative modes (e.g. discourse analysis), quantitive modes (e.g., content analysis) and mixed method approaches, these have relied on a similar workflow, including careful reading and manual coding of selected materials. However, with the availability of large volumes of digital content (e.g., news databases, press releases, digitized archives, social media platforms), these traditional approaches can become very time-consuming and costly.

Text-mining approaches, which were pioneered in computer science but have gradually found their way into the methodological repertoire of social scientists, offer a remedy to this dilemma. Further, when used in fields such as land systems science, where positivist approaches to science

based on hypothesis testing may be dominant, the use of computer algorithms for text analysis may counter some of the concerns related to human bias. However, as Grimmer and Stewart (2013) have pointed out, text-mining approaches have their own biases and should be thought of as complementing rather than replacing traditional approaches to text analysis.

Methods in text mining can use linguistic or probabilistic models of text to extract relevant information. Typically, a text-mining analysis involves many different methods in its workflow or "pipeline" from gathering relevant content to pre-processing, analysis and visualizations. There are manifold opportunities for various research objectives, such as text classification, sentiment analysis or metaphor detection (Ignatow and Mihalcea 2017). Here, we will focus on two such applications: Topic modeling and automated quantitative narrative analysis.

Topic models, popularized with the groudbreaking work of Blei et al. (2003), are one of many approaches to text classification. They classify texts into categories that are not known a priori and belong to the class of unsupervised algorithms, hence they do not rely on separate training datasets with pre-coded categories. Further, topic models are mixed membership models, since they do not classify each text into a single category, but rather determine the prevalence of each category (topic) for a given text. Topic models such as latent Dirichlet allocation (LDA) (Blei et al. 2003) or structural topic models (STM) (Roberts et al. 2014) are based on the assumption that documents in a given collection are generated by drawing words from a fixed number of topics according to underlying probability distributions. In other words, each document contains the topics in different proportions and each topic is more strongly associated with certain words. Probabilistic topic models thus reverse this generative process and thereby infer the hidden ("latent") variables (e.g., topic distribution over documents and word assignments to topics) (Blei 2012).

Topic models can be used to analyze the evolution of themes in a given collection over time, or to observe the co-occurrence of topics. However, they do not penetrate more deeply into the narrative structure of text. This is largely due to the fact, that the probabilistic model of text generation at the heart of topic models is completely oblivious to the actual order of words. The *bag-of-words* (BoW) approach in topic models is only concerned with word frequencies and allows users to eliminate words that occur very frequently independent of topics (*stop words*) in order to reduce memory use and processing time.

However, text-mining also provides methods which allow analyzing narrative structures of large collections by taking into account semantic relationships. For this purpose, language-specific linguistic models are applied to determine the grammatical structure of individual sentences (*dependency parsing*). This functionality is provided by modern natural language processing (NLP) software packages, such as the Python library *SpaCy* (Honnibal and Johnson 2015). One such approach to extracting narrative structures as introduced by Sudhahar et al. (2015a) is the automation of Quantitative Narrative Analysis (QNA). This method analyzes the "story grammar" of texts by extracting

all subject-verb-object (SVO) triplets to identify important actors and their relations (Franzosi 1987, 1998). This approach can be combined with network analysis and - if verbs are further classified into negative and positive relations through specific dictionaries - visualized in signed networks as demonstrated by Sudhahar et al. (2015a,b).

In sum, by engaging with theoretical development in environmental communication and different methodological approaches from traditional text analysis as well as text mining, land system science can deepen its understanding of the claims making and contestation in the process of defining relevant socio-ecological problems and formulating governance interventions. In this dissertation, chapters 4 and 5 will engage with the politics of signification in framing socio-ecological problems associated with soybean expansion and deforestation in different biomes. Both chapters employ various text-mining approaches to demonstrate their usefulness in the context of land system science.

Chapter 4 analyzes communication on soybean expansion from different media platforms and stakeholders and shows that while European public spheres appear to become more receptive to issues related to impacts in sourcing regions, there remains a narrow focus on specific problems and regions, which reflects a fundamental asymmetry in different stakeholders' ability to shape transnational deliberations and resulting governance processes. Chapter 5 analyzes how Western media have addressed and framed deforestation in the Brazilian Amazon and Cerrado biomes. The findings provide a methodologically innovative and empirically grounded case for the often raised concern over a relative invisibility of the Cerrado biome and its traditional populations, which may help explain observed disparities in governance interventions.

1.4 Self-reflexivity and positionality

Addressing positionality is common in disciplines which are fieldwork-intense and rely mostly on qualitative methods, in which the researcher "directly confronts those who are researched" (England 1994, p.81). However, I recognize that in any discipline to some extent one's background and position "will affect what they choose to investigate, the angle of investigation, the methods judged most adequate for this purpose, the findings considered most appropriate, and the framing and communication of conclusions" (Malterud 2001, p.483-484). I believe this to be true particularly in interdisciplinary settings, where researchers commonly juggle findings from a multitude of fields and methodological approaches and simultaneously have to limit their engagement with each as to not fall into some sort of holism trap. Therefore, before continuing with the empirical chapters of this dissertation, I will reflect briefly on my own background and how it may have shaped the research process.

As a German citizen and white male born into a middle-class household, I have to acknowledge the privilege that has allowed me to pursue my education and the relative material stability and comfort I have enjoyed. This background necessarily means that some of the phenomena mentioned

in this dissertation remain abstract concepts removed from lived experience. This is important to mention, as I decided to cancel all fieldwork due to the COVID-19 pandemic and this dissertation contains no primary data collected through direct engagement with stakeholders. Some of the methods employed in the empirical chapters, particularly relating to the handling of big data, are available mainly to an "urban based, formally educated, instrumentally orientated elite" (Atkins 2004). Results produced via complex algorithms and presented in elegant graphs often appear objective and convincing, but don't necessarily reflect the uncertainty inherent in most large datasets and the bias of said algorithms. Missing the opportunity to conduct fieldwork was therefore not only immensely frustrating for me personally, but also resulted in a rather detached birds-eye perspective, capturing only large-scale processes.

With respect to my academic background, I graduated in Environmental and Resource Management and then continued to pursue a Master's degree in Ecohydrology. My interests have always taken a conflicting path between the natural and social sciences. While the thesis work for my first degree was mainly based on interviews with community-organized water suppliers in Colombia, I later worked on statistical modeling of weather extremes and remote sensing applications for monitoring marine macroalgae. Maybe due to this disciplinary homelessness, I have felt uncomfortable with apolitical ecological reductionism, as much as with postmodernist scientific relativism, social reductionism and self-declared scholar-activism. In this dissertation I try to navigate a space, in which both, the material base and the social construction of socio-ecological issues are relevant.

Lastly, a few words on my personal motivations and my ideological convictions. I consider myself politically progressive and subscribe to the general idea of a socialist project, in the sense that I imagine a future, in which democratic control and accountability expand to the realm of how resources, labor and social surplus are allocated. In that sense, I see the current social organization of the global food system as an example of how corporate control leads to a multitude of perverse outcomes. That being said, I do believe in evidence-based, factual argumentation and do not see a need to challenge any evidence of progress only on the basis that it occurs within a social arrangement that I consider fundamentally flawed. Further, I do not engage in the demonization of specific commodities or technologies, but believe that it is the social relations under which these are deployed or produced which matter. In other words, soybeans do not possess magical properties that allow them to go berserk and clear forests or displace people. I can imagine bright futures both with and without large-scale soybean production, GMOs or cultured meat from bioreactors.

Part I

Re-embedding land use change

"Industrial civilization will continue to exist when the Utopian experiment of a self-regulating market will be no more than a memory."

Karl Polanyi


Land Use Change

Chapter 2

From railroad imperialism to neoliberal reprimarization: lessons from regime-shifts in the global soybean complex

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This chapter presents work currently under review:

Mempel, F., Corbera, E., Rodríguez-Labajos, B., and Challies, E. (2022). From railroad imperialism to neoliberal reprimarization: lessons from regime-shifts in the global soybean complex. *Manuscript in review*

Abstract

Soybeans are ubiquitous in the global food system. As a major forest risk commodity, they are also at the heart of efforts to untangle the dynamics of land use change and associated impacts resulting from distant drivers. However, land system science has so far largely ignored the historically and socially embedded nature of these entanglements. This results in snapshot-like representations relying on neoclassical approaches to production and consumption. Here, we trace the evolution of the global soybean complex (GSC) since the late 19th century. We analyze how in the context of external developments soybeans have been channeled into different provisioning systems. This has occurred in a series of socio-ecological fixes, facilitated by socio-technological innovations and public sector interventions, motivated by different impediments to capital accumulation. Today, several emerging socio-technological practices promise to transform the GSC towards sustainability. We argue that the contemporary GSC inherits defining properties from the past, particularly the postwar strategy of using industrial animal farming to add value to surplus grains and oilseeds. The expanding GSC is therefore not merely a result of increasing demand, but rather the outcome of different provisioning systems' continued dependence on soybeans. Future transitions will depend on public interventions and the influence of vested interest in current socio-metabolic patterns.

2.1 Introduction

Soybeans are an integral part of the global food system. They are the fourth most important crop by area harvested and the seventh by production output and are currently the most traded agricultural commodity by volume (FAO 2020). The rise of the soybean has however come with its share of controversies as the expansion of soybean monocultures in Brazil, Argentina, Paraguay and Bolivia has led to major social and environmental transformations and impacts. The crop is often characterized as a forest risk commodity, with about 9 percent of the forest lost across South America over the past two decades having been converted to soybeans (Song et al. 2021).

The case of the soybean and its socio-ecological impacts is no stranger to environmental advocacy groups, academics, policymakers, and corporate sustainability managers. Since the early 2000s, the commodity has been the center of successive waves of NGO reports, corporate governance interventions (e.g., Amazon Soy Moratorium, Roundtable on Responsible Soy, zero-deforestation commitments), and research into embedded impacts in traded soybean products (Escobar et al. 2020) or the effectiveness of corporate commitments and other governance interventions (Garrett et al. 2016; Kastens et al. 2017).

In this context, the case of soybeans exemplifies many of the challenges and the breakthroughs associated with research in land system science and related disciplines. The large volume of global soybean trade is a fundamental aspect of the growing disconnect between places of agricultural production, processing, and consumption. The initial research focus on regional case-studies, and their synthesis in meta-analyses, has evolved into a more holistic view, relating land use change across different regions to global flows of commodities, finance, or information. As a result, increasing recognition of various spillover effects sheds light on displaced impacts that complicate conventional understandings of forest transitions or conservation efforts in a particular place (Bastos Lima et al. 2019; Meyfroidt et al. 2013).

Further, as a "flex crop" (Borras et al. 2016) soybeans and their processed derivatives (e.g., soybean cake, soybean oil, soy lecithin) have a wide range of final applications (e.g., food, animal feed, paints, biofuels). New approaches link the final use of a given derivative with associated land-use or other environmental impacts. These methods use various assumptions for dealing with re-exports at different processing stages, weighing attributions between processing co-products according to different variables (e.g., mass, value, calories) and attributing responsibility to either final consumption, production or value-added (Schaffartzik et al. 2015).

These new conceptual and methodological approaches take advantage of unprecedented detail in many data products, such as remote sensing imagery, land-use maps, and multi-regional input output models. This has undoubtedly led to innovations that allow to trace impacts and evaluate governance mechanisms in the context of a globalizing global economy. However, there is a tendency

to characterize land-use change in "snapshot-like" representations (Friis et al. 2016) as the field "has not considered the underlying impetus of globalization processes or sufficiently accounted for land change in the evolution of the capitalist world-economy" (Napoletano et al. 2015, p.199). Indeed, as observed by Munroe et al. (2014) land system science has relied almost exclusively on neoclassical approaches to economic processes, which tend to neglect their socially and historically embedded nature.

This shortcoming motivates our work, which traces how land and other resources have been metabolized in different socio-technological arrangements through soybeans as an intermediary commodity form. In doing so, we leverage conceptual approaches from economic geography, transition studies and ecological economics to understand how the contemporary global soybean complex evolved and shaped different provisioning systems according to external circumstances, socio-technical innovations, and socio-ecological fixes. Our final discussion also distills lessons from this for current endeavors in sustainability transitions.

2.2 Provisioning systems, transitions, and socio-ecological fixes

The concept of provisioning systems allows us to understand economic processes as historically specific and embedded within socio-ecological practices as in classical political economy or contemporary substantivist approaches (Jo 2011). Similarly, the "systems of provision" approach evolved as a critique to neoclassical understandings of consumption as the outcome of decisions taken by rational, utility-optimizing individuals (Fine 2002). Building on Plank et al. (2021) and Schaffartzik et al. (2021), we understand provisioning systems as historically evolved relations of production, distribution, and consumption, which are shaped by power relations, technological infrastructures, available resources, and cultural values.

The socio-metabolic dimension of provisioning systems encompasses "the material and energy inputs, their transformation [...], the accumulation and reproduction of materials stocks, and all resulting outputs, involved in societal reproduction" (Schaffartzik et al. 2021, p.1408). It also involves the technological infrastructure through which material transformations take place (Schaffartzik et al. 2021). The evolution of such socio-technological systems is addressed in the transitions literature, drawing from science and technology studies, complex system theory and approaches to governance (Grin 2016). This literature is often guided by the key concept of a multi-level perspective (Geels 2005) or similar approaches, which distinguish between interactions at different levels, such as existing structures, niche experiments and broader external processes at the landscape level.

Further, technologies do not only transform socio-ecological relations but are also conditioned by them. As Hornborg (2016, 2020) has pointed out, technological artifacts are made possible not only by ingenuity and innovation, but by systems of relations, which make energy sources (including land and labor) available for a new socio-technological regime to become practically feasible and

economically viable. As part of capitalist forms of provisioning, soybeans and their derivatives take the commodity form and flow through industrial circuits mediated by technological infrastructures, operated by corporate actors to maximize profit Jo (2011). Their role can then be understood in terms of the "fixes" these arrangements have provided for capital accumulation at different time periods. Originally, "spatial fixes" conceptualized how crises of overaccumulation can be deferred by switching capital between distant places mainly through outlets in built environment (Harvey 1982). Recently, the "socioecological fix" (Castree and Christophers 2015; Ekers and Prudham 2015; McCarthy 2015) has broadened this idea to "something that directly engages with and resolves, mitigates, or postpones a structural impediment -including any environmental one- to sustained capital accumulation" (McCarthy 2015, p.11).

Capitalist forms of provisioning systems are embedded in broader modes of regulation, or geographical and historical variations in the institutional arrangements of capitalist economies (Aglietta 1979; Lipietz 1986). These can be defined through institutionalized compromises, such as the wage-labor nexus, forms of competition, insertion in the international regime, and the role of the state (Boyer and Saillard 2002; Jessop and Sum 2006). Further, relations of competition and cooperation between individual actors in the processes of creating and capturing value through different economic activities in increasingly transnational operations can be conceptualized as Global Production Networks (Coe et al. 2008).

We use these conceptual tools to characterize the evolution of the soybean complex as a sequence of relatively stable regimes. Each regime responds to large scale landscape developments, is marked by accumulation strategies related to specific socio-ecological fixes, as well as configurations of dominant actors in the production network. These dynamics shape the way soybean production metabolizes resources and shapes consumption patterns as part of distinct provisioning systems.

2.3 Regime shifts in the global soybean complex

The following sections outline regime shifts in the global soybean complex. Key characteristics and events are summarized in Figure 2.1.

2.3.1 The rise of a regional commodity: Soybeans before the first era of globalization

The domestication of soybeans took place in China during the Shang dynasty (ca. 1766 - 1125 BCE) (Hymowitz 2008; Qiu and Chang 2010). Despite their high complete protein and fat content, soybeans also have several antinutritional factors, which cause problems with digestion when they are not processed and prepared properly (Liener 1994). Unlike the immature beans (edamame), mature beans require processing for proper digestion, and did not play an important role in local foodscapes (Fu 2018). Soybeans thus initially largely served the purpose of a leguminous cover and fodder crop for animals and only played a minor role in human diets (Du Bois 2018).

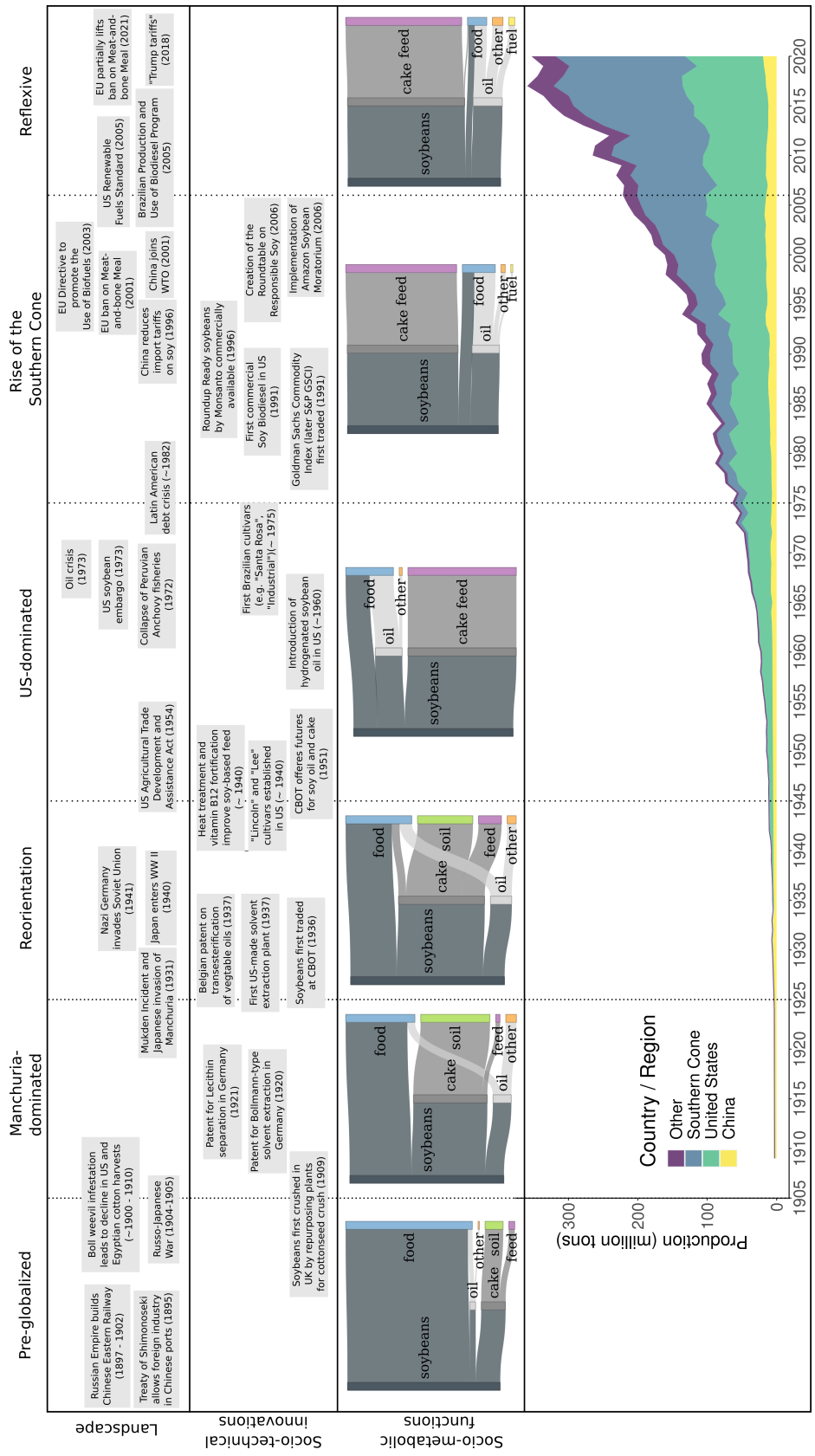

Figure 2.1: Regime shifts in the global soybean complex. Production data taken from Shaw (1911); Stewart (1936); Deasy (1939); FAO (2020); USDA (2020).

Over time, several processing technologies evolved in East Asia, including sprouting, fermentation techniques to yield products such as shi, miso, soy sauce and tempeh, and grinding yielding soybean milk and curd (tofu). Soybean food products and associated socio-technical practices spread across many parts of East Asia, aided by the travels of Buddhist monks observing plant-based diets (Du Bois 2018). The soybean thus evolved into an important staple crop and protein source in the region.

Further, improved mechanical soybean crushing technologies also allowed for other uses. Soybean oil began to be used as a cooking oil, and for lubrication and lighting. Soybean cake was employed as nitrogen-rich fertilizer across Eastern Asia (Mizuno and Prodöhl 2019; Shaw 1911). Northeast China (Manchuria) began exporting significant tonnages of soybean cake for sugarcane plantations in Zhejiang, Guangdong, and Fujian and cotton production in the Lower Yangzi River, particularly after the Qing rulers had lifted restrictions on grain exports in 1772 (Fu 2018).

There were experimental shipments of soybean cake to the coffee plantations in British Ceylon (the former British colony in present-day Sri Lanka) and Hawaii, but in both cases the operations were deemed too costly in these early stages of steam ship technology (Shaw 1911). Since the 17th century soy sauce was also traded as a bourgeois specialty food item to Europe (Du Bois 2018). By fertilizing sugar cane and cotton plantations, soybean cake was also embedded in the Qing dynasty's regional and increasingly inter-regional trade with refined sugar and textiles (e.g., the valued "nankeens"), both of which were among China's first modern industries (Chao 1977; Chen 1971) and played a role in the Qing dynasty's trade surplus with Europe, which drained Europe of its colonial silver and ultimately led to the Opium Wars (Von Glahn 2019).

By the end of the 19th century, soybeans were part of regional provisioning systems as a cover crop as well as a dietary protein source but were also transitioning towards a regional and - to some extent - inter-regional commodity in the form of traded soybean cake as fertilizer. Thus, while the crop was only partially commodified, the early flows of soybean cake from Manchuria can be read as a socio-ecological fix, which brought land in the Manchurian plains into production to prevent soil-depletion -particularly a concern in cotton cultivation-, in other regions, thereby enabling the further development of textile and refined sugar industries. A legacy from this early commodification which remains to this day is the construction of soybean derivatives mainly as industrial inputs rather than marketing soybean products as final consumer goods.

2.3.2 Railroad imperialism: Soy exports from Manchuria

The first truly global soybean trade regime emerged at the turn of the 20th century, when Manchuria became the center of imperialist interventions with Russia and Japan struggling for spheres of influence (Hiraga and Hisano 2017; Mizuno and Prodöhl 2019). Several strategic assets in the region fell

under Japanese control. Imperial Japan used these assets to gain access to resources for its rapid industrialization following the Meiji Restoration.

The opening up of the Manchurian commodity frontier was achieved through the South Manchurian Railway Co. (SMR), a major colonial institution, comparable to the British East India Company. Established after the Russo-Japanese War, the SMR was largely funded by the Japanese government. The SMR managed the commodity trading network through the ports of Port Arthur and Dalian, integrating the Southern part of the China Eastern Railway, which Russia had ceded to Japan following the war. The power wielded by the monopolistic control of this railway system as a "tool of empire" (Elleman et al. 2010) was enormous. It served a dual purpose, firstly as military railway network for the fast deployment of troops, rendering the region a Japanese military protectorate, and secondly, as the infrastructure to spur development in the frontier region of the railroad's catchment area to stimulate the export of soybeans and other commodities (Matsusaka 2010).

Through large-scale investments, Japan further evolved to a "co-regimist" in international shipping (Wray 1998), building a fleet of high-speed ships, developing the ports of Yokohama and Kobe, and making use of existing telegraph systems between Europe and East Asia. All these activities were coordinated by a tightly integrated network of shipping companies (e.g., Nippon Yusen), trading companies (e.g., Mitsui) and financing institutions (mainly the Yokohama Specie Bank) with long standing business ties (Kunio 1998; Wray 1998). Through these efforts, Japan developed its own lines to Europe and North America and controlled a significant tonnage of international shipping.

Among the commodities sourced from Manchuria was the soybean. Soybeans became a staple food item in the Japanese diet but were mainly processed to use the protein cake as fertilizer on intensifying Japanese rice fields. This was part of an effort by the administration to make the empire self-sufficient in food (Farina 2017). The nitrogen-rich cake alleviated shortages of fish manure as coastal herring stocks were being depleted (Fu 2018; Mizuno and Prodöhl 2019). Japanese trading companies successfully navigated the geopolitical tensions in the region and also used the Russian controlled railway systems and export hubs for their operations (Mizuno and Prodöhl 2019).

It was the co-product of the nitrogen-rich cake, soybean oil, which was increasingly sought after in Europe for industrial applications. This must be understood in the context of increasing importance of vegetable oils imported into Europe since the early 19th century following shortages of animal fats, particularly with the depletion of whale oil from the arctic (Waibel 1943). Early shipments of soybeans to Britain started in 1907.

Soybeans were originally pressed to yield meal and oil using traditional mechanical crushing with large millstones, turned by mules (Brown 1981). Earlier attempts by foreign entrepreneurs to enter the Manchurian soybean processing business with modern steam-powered equipment failed, partly due to the strength of Chinese guilds and their ability to oppose innovations that would have threatened their influence (Brown 1981). The Treaty of Shimonoseki from 1895, ending the First Sino-Japanese

War, finally allowed foreign-owned industry in port cities and steam-powered technologies were then rapidly adopted by both foreign and Chinese companies (Brown 1981).

Japanese actors, such as the Japan-China Bean Meal Manufacturing Company, concentrated their processing facilities around the port of Dalian. They began operating steam mills from 1909 (Shurtleff and Aoyagi 2004) and would later introduce industrial plants with solvent extraction technologies. Starting in 1907, soybeans began to be crushed in Europe for the first time, when poor cotton harvests in the American South and Egypt led to a shortage of vegetable oil in Britain (Wen 2019). With minor modifications, the technological infrastructure built around the cottonseed flows to the British Empire, mostly located in the cities of Hull and Liverpool, was now used for the newly arriving soybean from Manchuria.

The rising demand for soybeans was met by the expansion of cultivated land and the large inflow of settlers from Southern China (Langthaler 2020). Between 1887 and 1930 cultivated acreage in Manchuria increased five-fold and the population rose from 5 to 31 million, driven by net immigration (Eckstein et al. 1974). Germany became the largest importer of soybeans in Europe, developed new solvent extraction technology, which greatly improved efficiencies, developed a soy-based rubber substitute, and evolved into a major center of soybean crushing, almost equaling the output in Manchuria (Shurtleff and Aoyagi 2016). Other European nations, such as the UK and the Netherlands, continued to rely on other oilseeds (e.g., cottonseed, copra) (Drews 2004).

There are many contemporary accounts of the opportunities provided by the new soybean trade for "the prosperity which it promises to numerous buyers of foreign cottonstuffs, and in its general influence on mercantile exchanges" (Rose 1912, p.103). However, this early soybean frontier also foreshadowed some of the current controversies. The conversion of the Manchurian plains into farmland followed extractive practices with soil fertilities declining rapidly as nutrients were exhausted (Langthaler 2020). Christmas (2019) linked these practices to cases of selenium deficiency disorder in the region. While Chinese farmers flocked to the region in response to the economic opportunities presented by soybean expansion, the industrialization process displayed highly unequal patterns. Development was largely controlled by Japanese monopolists, who tried to cut out local middlemen and paid highly unequal wages, leading (Grajdanzev 1935, p.151) to state that "the future of the Manchurian in Manchuria is to be at the bottom of the social pyramid".

This first global soybean regime constituted a socio-ecological fix for rapid Japanese industrialization during the Meji Restoration by providing a cheap nitrogen fertilizer, which replaced scarce fishmeal fertilizer and allowed for more intensive rice cultivation. Through its characteristic as a nitrogen-fixing leguminous plant, a few decades before the spread of synthetic nitrogen fertilizers, soybean cake became to Japan what the guano deposits had been to Europe in the 19th century. For Europe, soybean oil was a fix for its struggle to meet demand for lipids used in manifold consumer

products, after depleting animal fats from the Artic and when other oilseeds were expensive and scarce due to poor harvests.

2.3.3 Reorientation: Interwar period and World War II

During World War I and the interwar period, Manchuria remained the global center of soybean production and export, while European demand for vegetable oils soared, fueled by applications in nutrition, soaps, detergents, and machinery. New efforts to cultivate the crop in other world regions began, notably in Egypt, where Britain increasingly pushed for soybean production (Wen 2019) and in the US, where the plant was initially used as a cover crop for forage and to enhance soil fertility. There was increasing investment in soybean processing by Western corporate actors, particularly in the margarine industry. Rather than a stable regime, this period constitutes a time of experimentation with different final uses and of attempts to start soybean production in other regions to decrease dependency on trade routes from Manchuria.

The invention of a process to separate soy lecithin, patented in Germany in 1921, further diversified the applications of soy products (Shurtleff and Aoyagi 2016). A Belgian patent for the transesterification of vegetable oils in 1937 was a breakthrough moment for research into the use of soybean oil and other vegetable oils as fuel (Guo et al. 2015). Many processing plants were using solvent extraction technology by 1930. The world's largest soybean crushing plant at the time, operating in Hamburg, Germany, had a capacity of 1,089 tons per day (Shurtleff and Aoyagi 2004). European nations preferred imports of raw beans, which led to a decline in Manchurian crushing. In 1929, Unilever was founded through a merger of a Dutch margarine company and a British soap maker, who shared a need to source soybeans and other oilseeds as raw materials.

At the outset of World War II, the global soybean complex began to be transformed radically. Attempts by Chinese warlords to push Japanese companies out of the soybean business helped trigger the Japanese invasion of the region following a false-flag attack on the railway system. However, with the creation of Manchuko as a Japanese puppet state, the Manchurian soybean rush began to fade. The region experienced severe flooding (Grajdanzev 1935), the Second Sino-Japanese War began, and Japan entered World War II on the side of the Axis powers (Kung and Li 2011). At the same time, the war industry itself became thirsty for soybean oil, which was used in machine lubricants and the production of nitroglycerin, while soy protein became an important ingredient in army provisions (Du Bois 2018). An early foreshadowing of the present role of soybeans appeared in Denmark, where soybean meal in animal feed played a significant role in the country's shift from a grain-based economy towards a major exporter of animal products by 1930 (Shurtleff and Aoyagi 2004).

In Nazi-Germany massive but ultimately unsuccessful research efforts sought to develop soybean varieties that could be grown domestically. Meanwhile, the industrial conglomerate IG Farben spearheaded the expansion of soybean production in South-Eastern Europe, at times relying on

forced labor (Drews 2004). Supply was to be secured as a safeguard against the scenario of collapsing trade routes to East Asia. Germany established a core-periphery trade relationship consisting of the exchange of soybeans and other primary goods from Southeastern Europe for German machinery and manufactured industrial products (Drews 2004). The soybean played an important role in the regime's efforts to maintain availability of protein and fats, which had long been dependent on imports and thereby were threatened during wartime. The beans initially found applications in the margarine industry (oil) and as animal feed (protein cake). However, the state attempted to increase its direct use as a food item to reduce losses in animal metabolism. While the general population was reluctant to adopt soybean products in their diets, these played a key role in army rations and in meals provided at workplaces. Production in Eastern Europe and Germany was never sufficient to break the dependency on Manchurian soybeans however, and shortages ensued after Germany's invasion of the Soviet Union led to the collapse of trade routes (Drews 2004).

The most radical transformation began in the US in the late 1920s, when soybeans were increasingly cultivated for oil and meal, rather than for hay or soil improvement as they had previously been. The US government encouraged soy cultivation over other crops under the New Deal, when earnings from cotton and maize had stagnated due to oversupply and financed further botanical research expeditions to acquire material for public plant breeding operations (Prodöhl 2013; Roth 2018). The use of novel hybridization techniques greatly improved yields, producing the dominant "Lincoln" cultivar in the Midwest and the "Lee" cultivar in the South (Vieira and Chen 2021).

The soybean further became a focus of attention for the Chemurgy movement, a political force in the US that sought to replace raw material imports by using domestically available biomass sources and gained government support in the form of financing for research on soybean applications in the face of wartime shortages in tropical oils (Finlay 2004; Prodöhl 2013). In the 1940s, soybean oil was increasingly used for margarine, as there was a shortage in butter (Prodöhl 2013). Soybeans thus became crucial in the American wartime economy. They provided farmers with a new source of income and patched holes in the vegetable oil and dietary fat supply, while also using the byproduct, protein meal, in livestock production to supply the army with protein-rich provisions and - to a lesser extent - market soy meal protein for direct use in civilian diets (Prodöhl 2013; Roth 2018).

2.3.4 Redirecting agricultural surplus: Soybeans under US hegemony

In the mid-1930s, the US evolved into a net-exporter of soybeans and by 1942 had overtaken Manchuria as the world's center of soybean production (Du Bois 2018). Soybean trading started on the Chicago Board of Trade in 1936 (Turkish 1961). At the same time, the domestic soybean crushing industry took off with major players like ADM and Cargill entering the business. An American-made solvent extraction process replaced German imports of that technology and publicly funded research developed methods for soybean-oil refinement to further diversify its uses and increase its acceptance as a vegetable oil among the general population (Shurtleff and Aoyagi 2004).

As pointed out by Langthaler (2020), the expansion of soybean production in the US did not follow the pattern of converting natural vegetation into farmland as in the Manchurian plains. Rather, soybeans replaced corn and other cereal crops in the former frontiers of the Mid-West and South, aided by government price support, tariffs on soy imports and new varieties emerging from the breeding efforts following the botanical expeditions. Further, the petrochemical boom transformed farming practices, using tractor-drawn machinery, combine-harvesters, and synthetic agrochemicals. Rather ironically, the rise of petrochemistry allowed for significant increases in soybean yields, but simultaneously ended the Chemurgists' vision of using soybeans and other domestic biomass products to decrease import dependencies, as cheap petroleum by-products became the dominant feedstocks for new synthetic materials (Finlay 2004).

Soybean oil had proven essential in the wartime economy, and experiments with hydrogenation to reduce its linolenic acid content soon further diversified its uses in food processing and made it the dominant fat used in margarine production (Roth 2018). Marketing soybean cake and flour remained difficult, despite considerable advances in promoting their use in human nutrition. This forced the US government to buy up much of the supply (Prodöhl 2013). Thus, after WW2, the US was facing the problem of overproduction of soybeans and in particular an oversupply of soybean cake (Langthaler 2020). However, the increase in livestock production for the war effort and the rise of mixed-feed manufacturers and feed mills for pellet production, had demonstrated the potential of soybean cake in animal nutrition (Roth 2018), particularly after improving digestibility with moistened heat treatment, vitamin B12 fortification and dehulling technologies (Du Bois 2018). Rising wages in the booming postwar economy soon allowed for increasing meat consumption.

The rapid expansion of broiler-type chicken production and the growing importance of soybean exports through the port of New Orleans drove the spread of the soybean industry in the Southern US using new varieties which had been selected for the regional climate (Roth 2018). Breeding high-meat-yielding chickens, providing mixed feeds to farmers, and marketing their products became the burgeoning business of companies such as Tyson foods. This "Southern Model" (Constance 2008) of contract broiler production provided some alternative income for marginalized farmers, who were outcompeted by capital-intensive agriculture. Further, it relied on cheap, unskilled labor in processing plants, typically performed by women, minority groups, and later mostly immigrants from Latin America (Constance 2008).

With Manchuria's economy in turmoil after Soviet takeover, the US soon stepped in to export soybeans to Europe and Japan, and industry associations assisted the efforts to incorporate soybean cake in mixed feeds (Du Bois 2018). As part of a new, US-dominated, global food regime (Friedmann and McMichael 1989), price-depressed soybean products and other grains from the US were part of efforts to use the domestic agricultural surplus in geopolitical instruments to secure partners in the fight against communism. These were subsidized under the Marshall Plan through the Agri-

cultural Trade Development and Assistance Act. Partnerships between the USDA and agribusiness giants, such as Cargill, helped set up concentrated feeding operations based on cheap animal feed in other countries, which were exported as a model throughout the world (Du Bois 2018). The dominant function of soybeans evolved into a cornerstone of the global "industrial grain-oilseed-livestock complex" (Weis 2013b).

Following its defeat and occupation by the US, Japan lost access to soybeans from Manchuria along with other raw materials from overseas territories. The major trading companies were dismantled, and the country faced an extreme hunger crisis (Hiraga 2018). However, these companies were soon re-assembled in new corporate groups, which played an important role in importing US agricultural surplus (including soybeans) during the economic recovery, developing domestic intensive meat and processed food sectors, and thereby stimulating a dietary transition according to the Western example (Hiraga 2018).

This continued demand for soybean products led to increased output, facilitated by rising yields but mainly by expanding acreage, further replacing cereal and cotton crops as well as cropland pastures, but also native vegetation, as in the Mississippi Alluvial Valley (Siniard 1973). The dependence on agricultural inputs and the increasing shift from labor-intensive to capital-intensive farming practices in soybean production favored larger farm sizes as economies of scale became more important (Langthaler 2020).

As the processing industry progressively moved towards state-of-the-art solvent extraction technologies and the capacities of individual plants increased, the sector experienced rapid horizontal and vertical integration (Roth 2018; Shurtleff and Aoyagi 2004). Processing capacity was consolidated under dominant firms, which also entered the formulated feed and oil refining businesses, and by the mid-1970s the largest two processors, Cargill and ADM, controlled over a third of the soybean crushing in the US (Shurtleff and Aoyagi 2004). The soybean crushing business also became increasingly entangled with futures trading at the Chicago Board of Trade, which started listing futures contracts for soybean oil and cake in the 1950s and drove a widening disconnect between the physical processing of soybeans as a value-adding activity on the one hand and the financial returns from hedging and speculating on the other (Roth 2018).

The US-dominated regime was a defining moment that cemented the dominant socio-metabolic function of soybeans as animal feed, which persists to the present. This pattern constitutes a socio-ecological fix to the overproduction of oilseeds and grains in the post-war period. It constructed industrial animal (particularly broiler) farming as a process of adding value to feed. The animal body was a strategic site of this fix, as associated metabolic losses allowed for the creation of scarcity in soybeans and other surplus grains and oilseeds. This went hand in hand with increasing intakes of meat and vegetable oils in Western diets, facilitated by low prices due to subsidized grains and oilseeds as well as low-wage labor in meat processing facilities.

2.3.5 The making of Soylandia: Reprimarization in the Southern Cone

There had been agronomic experiments with soybean cultivation in Latin America as early as the late 19th century and, as in the US, the crop was initially adopted on a small scale as a cover crop for soil management in Southern Brazil, Paraguay and the Argentinian Pampas, with a small portion of production harvested for export as beans (Brazilian soybeans constituted about 3.5 percent of global output in 1970) (FAO 2020; Oliveira and Hecht 2016; Oliveira and Schneider 2016). Until the 1970s, growing international demand for soybean products had been met by increased output from the US (70 percent of global production in 1970) and - to some extent - China, still the second largest producer and a net exporter at the time (20 percent of global production in 1970) (FAO 2020).

A series of external circumstances led international soybean prices to skyrocket in the 1970s, triggering the emergence of Brazil and Argentina as incubators for subtropical and tropical socio-technical practices in soybean production, which would later be exported to other countries in the region (Oliveira and Schneider 2016). These circumstances included major soybean purchases by the USSR and the historic collapse of Peruvian Anchovy fisheries following El Niño-Southern Oscillation (ENSO) warm events, which decreased international supply of fishmeal and contributed to a shortage of protein sources for animal feed, leading the US to ban exports of soybeans for several months (Du Bois 2018; Turzi 2016). High petroleum prices following the 1973 oil crisis also stimulated new research on the use of soybean oil as biodiesel, which was partly funded by producer organizations in an effort to find new marketing pathways.

The global shortage of protein meal led to major investments in research to increase Brazilian soybean production capacity, carried out by the national agronomic agency EMBRAPA, which was created by the military dictatorship in 1973 as part of ongoing efforts to modernize Brazilian agricultural production (Du Bois 2018; Turzi 2016). Part of the funding came from Japan and Europe, which sought to reduce their dependency on US soybeans, and further support was provided through USAID, much to the outrage of American producers (Du Bois 2018). Emphasis was placed on the Cerrado, a tropical savanna biome in central Brazil, which had long been characterized as unproductive, empty, barren land and which was now to be inserted into the realm of capitalist production. EMBRAPA developed methods which soon turned the highly acidic Cerrado soils into valuable cropland and their plant breeding experiments resulted in new soybean varieties suited to tropical climates (Du Bois 2018). Public funding was not only essential in agronomic research, but also in financing infrastructure projects, that would become the backbone of regional agribusiness. New or improved highways (e.g., BR-163), waterways (e.g., Araguaia-Tocatins) and railways (e.g., Ferronorte) allowed the transport of soybeans from frontier regions in the interior to the port cities on the Atlantic coast (Goldsmith and Hirsch 2006).

In Brazil, as in Argentina, the expansion of export-oriented soybean cultivation developed as the country began to abandon the model of import-substituting industrialization (ISI), which had

been dominant in the region since the 1950s and had diverted resources away from agriculture to prioritize domestic industry (Berndt et al. 2019; Turzi 2016). The shift towards a dominant agro-export sector intensified after the debt crisis in the 1980s and the ensuing trade-liberalization under structural adjustment programs, which eradicated rural credit and price support systems and allowed foreign capital to acquire parts of the formerly subsidized soy industry (Langthaler 2020; Turzi 2016). The reorientation of Brazil's and Argentina's economies from regional industrial powerhouses to major exporters of primary goods has often been referred to as "reprimarization" (Cooney 2021).

Over the following decades, other external circumstances further fed the soybean boom in the Southern Cone. These include the opening up of new export markets with trade liberalization in the former Eastern Bloc, China, and India, increasing meat consumption in many parts of the world, China's relaxing of its policies on grain self-sufficiency (Schneider 2011) and the 2001 ban on meat and bone meal in the EU following outbreaks of bovine spongiform encephalopathy (BSE). Further, new emphasis on renewable energy sources and feedstocks as envisioned by projects such as the bioeconomy and green chemistry revived some of the Chemurgists' earlier endeavors and led to new demand for soybean oil as biodiesel, as promoted by legislation in the EU, US and Brazil in the mid-2000s, and other industrial applications. It is also important to point out the increasing use of soybean products within Argentina and Brazil in meat production for both internal and foreign markets, and for biofuels and cooking oil.

Early technological development, which underpinned the expansion of soybean cultivation to new climates and soil types, was spearheaded by state-owned agronomic research and domestic plant breeding and seed companies. Initially, cultivars developed for the Southern United States were introduced but these were later crossed with other varieties, yielding the first Brazilian cultivars, such as "Industrial", "Santa Rosa" and "Campos Gerais", selected mainly for their long juvenile period (Wysmierski and Vello 2013). However, since the late 1990s the rapid adoption of a new standardized technological package based on transgenic seeds (e.g. Roundup Ready) coupled with specific herbicides and non-tillage soil management, concentrated the market for seeds and agrochemicals in the hands of a few transnational corporations (Oliveira and Hecht 2016). After having produced the genetic basis of virtually all modern soybean varieties, public plant breeding efforts have declined since the introduction of patent rights over living material in the 1980s, and have focused on basic and applied research instead (Kingsbury 2009; Vieira and Chen 2021). However, translating patent rights over transgenic traits into productive capital through collecting rents has faced resistance, particularly in the case of the ambiguous legal status concerning property rights and seed saving in Argentina (Berndt et al. 2019).

The adoption of the new technological package has led to a dominance of low-labor and high chemical-input farming styles (Goldsmith and Montesdeoca 2018) favoring land-concentration in fewer and larger units (Russo Lopes et al. 2021). However, individual farming practices in medium

and large units can still differ substantially depending on access to capital, migratory histories of the farmers and market integration (Mier y Terán Giménez Cacho 2016). Indebted farmers, unable to achieve required economies of scale, often signed lease agreements with national and transnational agribusinesses or agriculture investment funds, which effectively take control of land-management in an asset-light, networked business model ("pool de siembra") (Gudynas 2008; Langthaler 2020).

While the Brazilian soybean sector was largely controlled by domestic companies until the late 1980s, leading US and European transnational agribusiness companies, which had risen to dominance in the postwar economy, began investing in soybean crushing, logistics, and export infrastructure, including acquisitions of regional companies (e.g., Bunge bought Ceval and ADM purchased soybean operations from Perdigão and Sadia). However, several large domestic producers also integrated downstream to manage their own trading operations (Goldsmith et al. 2004; Oliveira and Hecht 2016; Wesz 2016). Whereas Argentina has focused on exporting processed soybean products and stimulated domestic crushing capacity as an upgrading strategy, Brazilian exports are dominated by unrefined soybeans, following the exoneration of raw material exportation (Wesz 2016). According to Medina (2022), Brazilian corporate actors now hold relatively small market shares in most inputs such as seeds (16.5 %), fertilizers (33.1 %), pesticides (4.3 %) or machinery (1.9 %) and control about 30.7 % of trade.

The increasingly dominant role of China as an importer further changed the dynamics in the global production network with Chinese actors now operating among the main players in all nodes. This includes COFCO as one of the dominant grain traders for soy from Brazil and ChemChina operating in seeds and agrochemicals (the company purchased Syngenta in 2015). Further, Dabeinong Group developed a herbicide-tolerant GM soy cultivar, which is now licensed for use in Argentina (Wilkinson et al. 2022). However, taking advantage of a crisis in the Chinese soy crushing sector in 2004, the ABCDs (ADM, Bunge, Cargill and Louis Dreyfus) also bought up a segment of crushing capacity in China (Oliveira and Schneider 2016). Chinese dependence on Brazilian soybeans further increased when China imposed tariffs on US soybeans in retaliation for the "Trump Tariffs" on Chinese manufactured goods (Fuchs et al. 2019).

The rise of the Southern Cone as the new global center of soybean production thus provided a socio-ecological fix by putting new commodity frontiers in the Cerrado, Amazon and Gran Chaco into production to sustain the penetration of industrial concentrated feeding operations and Western dietary transitions, especially in East Asia. It allowed dominant TNCs to sink capital into the technological infrastructure in these frontiers. It also provided governments in Brazil and Argentina with a way to acquire hard currency and equalize the trade balance after the debt crisis, the collapse of domestic industries and increasing imports of manufactured goods from East-Asia.

2.3.6 Transition to sustainability? Soybeans in the age of reflexivity

In the mid-2000s the soybean complex had clearly taken center stage in transnational deliberations on sustainability transitions on several levels. Soybean oil was increasingly being diverted for biodiesel in the US, Brazil, and EU as a strategy to replace fossil fuels with first generation biofuels, which would soon receive widespread criticism for their alleged role in the 2007/2008 world food crisis. In 2006, the Greenpeace report "Eating up the Amazon" (Greenpeace International 2006) detailed soybean-driven deforestation and attracted widespread attention. In the same year, the Amazon Soy Moratorium was implemented, and the Roundtable on Responsible Soy was created as a multi-stakeholder initiative and certification scheme. Meanwhile, soybean food products, some based on traditional East Asian food processing, have been part of renewed interest in vegetarian and vegan lifestyles among Western publics, promoted as an answer to environmental impacts associated with global livestock production. In fact, levels of meat consumption have stagnated and even declined in several industrial core countries in what has been referred to as a "second nutrition transition" (Vranken et al. 2014).

This highlights the ambiguous role of the global soybean complex with respect to potential sustainability transitions in various provisioning systems. On the one hand the crop's high-quality protein and fat content make it an ideal renewable source material for many industrial applications, a substitute for fossil resources and vegetable dietary protein. Second-generation biofuels allow for the conversion of used soybean cooking oil into biodiesel. On the other hand, demand for soybeans has largely been fueled by the application of soybean cake in animal feeds, which is an extremely inefficient pathway for dietary protein considering its massive associated land footprint, greenhouse gas emissions, agrochemical inputs and significant role in the global nitrogen cycle and nitrate pollution (Lassaletta et al. 2014).

Currently, increasing attention to commodity-driven land use change and tropical deforestation coincides with general concern about consumption patterns and impacts along global value chains. In 2014 the New York Declaration on Forests (NYDF), signed by governments, corporate actors, and civil society actors, included the key goal of eliminating deforestation from agricultural supply chains. In early 2022, the EU released a draft directive on corporate due diligence and accountability after several countries had already introduced similar unilateral measures. In 2021, the EU partially repealed the ban on meat and bone meal in animal feeds, citing "the need to reduce the Union dependence on third countries for its protein supply" (Regulation 2021/1372 2021, p.2). China, while absent from most governance interventions in the soy sector, has also signaled its willingness to address sustainability in its supply chains. Further, the current administration is now aiming to boost domestic soy production and even to reduce meat consumption within China (Wilkinson et al. 2022). Such signals of landscape level shifts could transform socio-technological practices.

Table 2.1 summarizes emerging socio-technological practices with the potential to transform the soybean complex towards sustainability. Some practices relate to interventions within the soybean value chain while others would indirectly transform the soybean complex, for example through substitution effects. We have grouped these practices in four distinct categories according to their underlying assumptions.

Table 2.1: Socio-technological practices for transition in the global soybean complex.

Socio-technical practices	**Examples**
Digital agriculture	Sensors, artificial intelligence, drones, robotics
Novel inputs	Enhanced efficiency fertilizers, nanofertilizers, nanopesticides, drip irrigation and -fertigation
Gene technology	Genome editing, genomic selection, RNA interference
Corporate commitments	Zero-deforestation, Amazon moratorium
Land Use Planning	Brazilian Forest Code
Monitoring and enforcement	DETER, IBAMA
Certification	RTRS, ProTerra
Due diligence	Duty of Vigilance Law (France), Due Diligence Act (Germany), Draft Directive on Corporate Due Diligence and Accountability (EU)
Supply-chain mapping	Trase (trase.earth)
Alternative diets	Vegetarianism, veganism
Artificial meat	Cell-based meat, 3D-printed meat
Alternative protein (food/feed)	Insect protein, microbial-based protein, algae-based protein
Agrarian reform	Article 184 of Brazilian constitution of 1988
Social movements	Movimento dos Trabalhadores Sem Terra (MST), Via Campesina
Alternative food networks	Community Supported Agriculture (CSA), Farmers' Markets

- Intensification and land sparing
- Monitoring, Transparency and Accountability
- Functional substitution
- Food Sovereignty

"Intensification and land sparing" strategies define socio-ecological problems in the soybean complex as outcomes of inefficient land use practices and resulting yield gaps, which put unnecessary pressure on marginal cropland. Envisaged solutions involve rational cost-reducing and market-based practices that adopt state-of-the-art agricultural production methods to increase yields and thereby

prevent further conversion of native vegetation and displacement of local communities. Emphasis is placed on win-win solutions, whereby corporate actors can commit to zero-deforestation pledges while still expanding their business. Emerging socio-technical practices that promise to increase yields include digital (precision) agriculture, novel farming inputs and state-of-the-art gene technology.

"Monitoring, Transparency and Accountability" strategies see the main problems with the soybean complex as resulting from a lack of transparency, enforcement, or accountability. From this perspective, compliance with rules defined through land use planning, industry standards, international treaties or general constitutional or universal rights needs to be monitored and enforced. This can be done through state agencies, such as with the real-time satellite observation system DETER and the Brazilian Environmental Ministry's executive organ, IBAMA. Further, independent certification agencies can evaluate compliance with industry standards or certification requirements, and supply-chain mapping data tools can provide transparency to the public or to corporate actors. Due diligence legislation in importing regions can enforce compliance with social and environmental norms through global value chains including suppliers.

Strategies of "Functional substitution" connect the problem to the current primary socio-metabolic function of soybeans as feed within provisioning systems of meat. This constitutes an inefficient pathway for dietary protein with large environmental footprints and numerous other impacts associated with the livestock industry. Alternative plant-based diets have been proposed as a solution and are finding growing adherence in some countries. Further, emerging technologies aim to develop meat substitutes that closely resemble its characteristics, such as cell-cultured meat or 3D printed meat. Other protein sources, which have been proposed to either replace meat in human diets or replace soybean cake as feed, include insect protein, microbial-based protein, or algae-based protein. Some of these approaches would completely substitute new protein sources for the existing uses of soybean cake, while others may employ soybeans or soybean cake in other, more efficient pathways to yield dietary protein. For example, plant-based diets may include traditional soybean products and cell-based meat may use textured soy protein in scaffolds, which provide nutritional value and structural support for growing cells (Ben-Arye et al. 2020).

Finally, "Food Sovereignty" approaches trace the problem to the current social organization of food systems, characterized by increasing commodification, financialization and corporate control in the form of modern agribusiness. This perspective demands a rights-based approach to food in which communities determine their own agricultural practices and food systems and emphasizes the role of peasant and family farmers (Wittman 2011). Advocates demand agrarian reform, which would redistribute control over land, water, and rural biodiversity. In Brazil, as in most of Latin America, agrarian reform has a long history and while article 184 of Brazilian constitution from 1988 prescribes a social function for land ownership, which signifies an obligation to use it in ways that

contribute to the collective or common good, this and other existing examples remain ambivalent and are hardly enforced. Social movements have organized behind the principle of food sovereignty and occupied unproductive land to enact the constitutional social function and to provide access to land for impoverished communities (Wolford 2003). Further, alternative food networks have emerged as parallel niche practices to existing corporate structures, promising to re-embed food systems by strengthening family farmers and their direct links to consumers (Matacena 2016).

2.4 Discussion

The preceding overview reveals drivers of regime shifts as well as long-lasting legacies, which have shaped the current role of the global soybean complex in various provisioning systems and associated socio-technical practices. While arguably the inherent properties of the soybean would have inevitably resulted in its ascendance to a major global commodity, this process was by no means natural or straightforward. Technological innovations opened the doors to new potential applications and socio-metabolic pathways for soybeans, but these innovations did not bring about change by themselves. We have traced how regime shifts depended on external landscape developments (e.g., imperialist interventions in Manchuria, the Latin-American debt crisis, or the collapse of Peruvian anchovy fisheries) and major - often high-risk - public investment (e.g., botanical expeditions, plant breeding and other agronomic research, infrastructure, price support, subsidized credit). These circumstances allowed for soybeans and related technological infrastructure to serve as socioecological fixes for capital accumulation in distinct ways over time.

The current regime relies on the legacy of overcoming postwar surplus production by adding value to feed in animal bodies and thereby using metabolic losses to create artificial scarcity. This model was first exported throughout the industrial core countries and later to parts of the Global South in a process dubbed the "Livestock Revolution" (Delgado et al. 2001). Corporate actors who rose to dominance through consolidation in the post-war period control large shares of inputs, logistics, processing, trade, and finance today and have expanded throughout all major producing and importing countries. In the case of Japanese corporate groups their involvement in the soybean complex even goes back to Japanese imperial expansion in Manchuria (Hiraga 2018). Chinese actors have also gained strong footholds in all major nodes of the global production network over the past two decades.

The perspective here presented creates new potential for land system science and associated disciplines in studying land-use change as well as evaluating its implications in terms of desired societal transformations toward sustainability (Nielsen et al. 2019). Firstly, instead of focusing on particular impacts of soybean expansion resulting from a given external demand structure, our work turns this relation on its head. Our perspective understands consumption patterns as influenced by the way in which land and other resources have been metabolized through soybeans as an intermedi-

ate commodity to sustain capital accumulation. When looking at provisioning systems of meat (or dietary protein in general), this perspective is supported by heterodox analyses that identify the political economy of agricultural production as the key driver for "meatification" (Weis 2013a,b) along with cultural signifiers, growing affluence, and urbanization processes (Hansen 2018).

Secondly, this study positions deforestation as one among several interrelated impacts of an expanding soybean complex. These include dynamics of violent conflict (Walker et al., 2011), alterations to the global nitrogen cycle (Lassaletta et al. 2014), concerns over animal welfare, oligopolistic corporate control (Clapp and Purugganan 2020), and the embeddedness of the soybean complex in global unequal relations of exchange in terms of resources and labor embodied in trade (Hickel et al. 2022). Thus, the way in which land is brought into capitalist production through soybeans gives rise to problematic socioecological issues. In this sense, deforestation represents a type of "formal subsumption" (Boyd and Prudham 2017), or an extensive strategy of appropriating nature (Werner 2021) through soybeans. Combating deforestation in isolation through land-sparing measures does not only leave these other issues unaddressed but it may even exacerbate some via "real subsumption" (Boyd and Prudham 2017), or intensive strategies to appropriate nature, for example by further concentrating land ownership at the expense of family farmers (Thaler 2017).

Thirdly, our historical account of socioecological fixes shows how the transformation of a given socio-metabolic aspect of provisioning systems can render previous functions of soybean-derivatives completely irrelevant over time. For example, after the widespread adoption of synthetic nitrogen fertilizers, soybean cake has played no important role as an input to soil management. Hence, the transformation of socio-technological practices in the provisioning systems that soybeans are fed into has the potential to lead to major shifts in the soybean complex. Technological innovation is only one factor in such change. The Chemurgists' dream of a bioeconomy and the early experiments with transesterification for biofuels were delayed for almost a century due to the dominance of cheap oil and the petrochemical industry. Likewise, the sunk costs in current technological infrastructures will make dominant actors resistant to any radical changes in the socio-metabolic function, as "fixed capital assets play a crucial role in locking-in specific forms of provisioning" (Schaffartzik et al. 2021, p.1411).

This directly leads to a fourth observation. At critical points, the regime changes described above relied on major public interventions in the form of botanical expeditions, plant breeding, infrastructure, price support or subsidized credit. The successful marketing of soybean oil as cooking oil, for example, relied on publicly funded research and even industrial espionage, which helped to improve its palatability in Western countries (Roth 2018). What role public institutions will play in sustainability transitions remains to be seen. At present, interventions seem mostly limited to providing incentives or obligations for corporate actors to eliminate certain problems (e.g., deforestation) from their supply chains. After initial publicly funded research, socio-technological innovations related

to functional substitution (e.g., alternative meat) are now also largely funded by corporate actors (Dolgin 2020). This means that new products at the development stage are often marketed as completely "de-materialized", but their actual resource footprints or processing pathways are obfuscated through patents and trade secrets (Guthman and Biltekoff 2021).

These insights can be useful for land system science and related disciplines beyond the contemporary soybean complex. While much work has been done to uncover the diffuse propagation of remote drivers and impacts through increasingly interconnected socio-ecological systems, there is a need to understand socially and historically embedded nature of such interactions. For example, rather than conceptualizing demand as a one-way signal driving land-use change, we propose to understand the way in which land is put into production in terms of accumulation strategies, which have the potential to shape consumption patterns and thus manufacture demand along with other factors. In other words, through specific modes of accumulation certain provisioning systems have become "addicted" to soybeans much in the way in which this has happened with oil in the postwar period (Huber 2013).

Similarly, the embeddedness of agricultural commodities in different provisioning systems makes it difficult to evaluate sustainability criteria by examining production of any one commodity in isolation. Take soybean cake as feed, for example. Even as soybean yields have increased dramatically, their circulation through animal bodies still makes this provisioning system of dietary protein rather inefficient or wasteful. Moreover, the way land is metabolized through these soybeans is connected to a myriad of other issues, from the contamination of water resources by animal wastes (Schneider 2017) to the exploitation of marginalized workers in meat processing.

Research addressing deforestation linked to expanding soybean production often refers to population growth, rising affluence and thereby increased demand for food as direct or indirect drivers. Thus, the industry narrative that soybeans grown in areas such as the Brazilian Cerrado are feeding the world is reinforced. Rather, we suggest reconsideration of the soybean complex as a means by which land is metabolized according to certain accumulation strategies. Thereby soybeans will enter various provisioning systems, such as primary energy or dietary protein and fat. Certainly, there are important nutritional benefits from increased intake of animal products, particularly in East Asia. However, these concerns have not been the main driver behind soybean expansion, and nor are provisioning systems characterized by the grain-oilseed-livestock complex the only possible pathway for such benefits. In fact, soybeans flow around rather than into most regions with higher risks of protein or micronutrient deficiencies, which typically have not experienced a Livestock Revolution so far (e.g., South Asia, East and Southern Africa) (Pica-Ciamarra and Otte 2011). Further, as Wilkinson et al. (2022) argue, projections of soybean demand tend to neglect the possibility of radical shifts in provisioning systems (e.g., through functional substitution) in the mid to long term.

In sum, the dynamic evolution of the soybean as a global commodity shows how the crop's embeddedness in various provisioning systems can be understood as the result of accumulation strategies against the backdrop of external landscape developments, technological innovations, and public policies. Interventions for sustainability transitions may involve strategies of land-sparing, accountability, functional substitution and rethinking of social relations in agri-food systems. The nature of such interventions may depend on the degree to which public institutions are willing to get involved, since dominant corporate actors have vested interests in maintaining current forms of provisioning. Outcomes of such interventions cannot be reduced to the degree of further loss of native vegetation but rather include a myriad of socio-ecological relations across spatial scales. For land system science and related disciplines this perspective may change the focus from analyzing the consequences of a given demand signal to understanding the socio-ecological relations associated with a given strategy in which land is put to work and what this means in the context of associated provisioning systems.

2.5 Conclusions

Socio-ecological impacts of soybean expansion are often conceptualized as driven by external demand structures and considered in isolation from broader provisioning systems and their social and historical embeddedness. This "snapshot-like" representation is linked to the reliance on neoclassical economic theory in land use science and related disciplines. Here, we followed the historical evolution of the soybean complex to problematize such narrow representation, focusing on how through soybeans land has been metabolized according to accumulation strategies and inserted into different provisioning systems, providing successive socioecological fixes in the context of external landscape developments and socio-technological innovations.

We have shown how soybean expansion developed through successive distinct socio-ecological fixes (e.g., overcoming scarcity of nitrogen fertilizers and lipids, adding value to agricultural surplus through feed). This has happened in the context of broader landscape developments (e.g., imperialist interventions in Manchuria, neoliberal deregulation in Latin America) and socio-technological innovations (e.g., solvent extraction, moistened heat treatment), often catalyzed by public interventions (e.g., infrastructure, plant breeding, subsidized credit). The current regime is largely shaped by a specific accumulation strategy characterized by its dependence on industrial animal farming to add value to surplus grains and oilseeds, exemplified by the "Southern Model" of broiler production. This model was exported throughout the industrial core and later parts of the Global South along with corresponding dietary transitions.

Today the widespread concern over socio-ecological impacts associated with the soybean complex (dominated by debates over deforestation) signifies a new shift with different prospective socio-technological interventions promising sustainability transitions on the horizon. In this context, studying the possibilities of decoupling the expanding soybean complex from further deforestation

represents just one specific research pathway, isolated from other concerns (e.g., land concentration, violent expulsion, water pollution, exploitation of marginalized workforces, global relations of unequal exchange). The way that soybeans and other commodities are embedded in different provisioning systems (e.g., food, feed, fuel) may radically shift along with associated socio-ecological outcomes. The nature of such transitions will depend on the type of interventions (e.g., land-sparing, monitoring, functional substitution, food sovereignty), the vested interests of dominant actors and the role of public institutions. Land system science can and should play a role in untangling these dynamics and informing much needed public debate.

Chapter 3

Mapping chemical geographies of global agricultural trade

This chapter presents preliminary results from work in preparation:

Mempel, F. & Bruckner, M. Wasteful efficiencies : Mapping chemical geographies of global agricultural trade. *Unpublished work in preparation*

This chapter further includes references to work currently in press:

Castro-Vargas, M. S. and Mempel, F. (in press). Latin America in the Chemical Vortex of Agrarian Capitalism. In Bustos-Gallardo, B., Ojeda, D., López, G. G., Milanez, F., and Di-Mauro, S. E., editors, *Handbook of Latin America and the environment*. Routledge, Oxford

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Abstract

This contribution introduces nutrient specific multi-regional input-output tables for global biomass production, trade and use. We demonstrate potential applications by calculating global nutrient flows, regional socio-metabolic profiles, nutrient efficiencies and commodity-specific socio-metabolic pathways. Specifically, we show how considering embedded primary products significantly increases the scope of traded nutrients, particularly for protein, when compared to final consumer products. We show how nutrient-specific metabolic profiles reveal the mechanisms of shifting allocation of protein between plant-based and animal based products in China, or the relevance of the bioeconomy for sourcing patterns of fats in Europe. Further, we demonstrate how increasing feed conversion losses can more than compensate for yield gains when considering overall nutrient efficiencies and how nutrients from soybean production have been allocated over time to play an increasingly important role in many regions. These applications showcase how the use of an explicitly chemical lens to socio-metabolic processes in the global food system can disaggregate larger dynamics and provide more nuance to our understanding of coupled socio-ecological systems. Future applications may involve the calculation of energy return on investment for different regional socio-metabolic patterns, inter-regional nitrogen flows or impacts from functional substitution in different economic sectors.

3.1 Introduction

Global food production and trade feature among the most prominent issues discussed in relation to human development and sustainability, with food security and sustainable agriculture being enshrined as the second of 17 United Nations' Sustainable Development Goals (United Nations 2015). The increasingly diffuse panorama of where primary production, processing, final consumption and all associated impacts occur, has motivated innovative methods that trace the propagation of material matter and impacts through the global economy at ever-increasing spatial- and product resolutions (Schaffartzik et al. 2015). Using assumptions and matrix calculations related to those typically applied in input-output analysis (Leontief 1986), Kastner et al. (2011) traced embedded primary production and associated impacts of final food products consumed in a given country. Bruckner et al. (2019) developed a multiregional input-output (MRIO) model for agricultural items in physical units (biomass), with unprecedented product resolution when compared to models based on economic sectors reported in national accounts. This model can be integrated with process-specific databases to calculate embedded emissions, land use, water use or other impacts using environmentally extended input-output analysis (Kitzes 2013).

Here, we are interested in developing a more detailed account of the global food system's social metabolism, by incorporating a chemical geographies lens (Romero et al. 2017). When examining contemporary food and agricultural systems through the lens of chemical dynamics, we find ourselves at a peculiar interface between the biosphere and the technosphere. On the one hand, food is at the heart of those metabolic processes, which have always connected humanity to all other life on earth via the circulation of chemical energy, nutrients and atmospheric gases through photosynthesis and cellular respiration. On the other hand, as a technological species, ever since the deliberate use of fire, humans have entered a new form of metabolic economy. Food processing, domesticated animals, mineral fertilizers, synthetic pesticides, fuel-powered farming equipment and global shipping networks are all examples of how "countless substances, whether the simplest or the most complex, are mobilized, altered chemically, and in this form fed into existing or newly initiated metabolic cycles" (Steininger 2019). The evolution of food and agricultural systems can then be read through the way in which metabolic cycles related to agricultural production have been initiated, altered, or rearranged over time, as pointed out by Castro-Vargas and Mempel (in press).

This conceptualization requires us to trace not only individual items, but also their functional components to understand how different ways of sourcing, for example, protein feed, biofuels or vegetable oils in cosmetics translate into land use change and associated impacts. The versatility of final uses for contemporary flex-crops (Borras et al. 2016) and their derivatives as well as the creative remaking of processing wastes as new products (Landecker 2019) requires research into how individual nutrients travel through industrial pathways and what wider repercussions these arrangements have. Existing research has quantified and traced dietary nutrients through production and processing to

estimate potential supply under different socio-metabolic uses (Berners-Lee et al. 2018) or to calculate measures of inequity for various scenarios (Wood et al. 2018). However, these approaches have not been able to trace these flows, considering the various layers of embedded primary products and their complex spatial arrangements. Here we present a way to untangle the socio-metabolic pathways of nutrient allocation and use, but also to combine this analysis with that of different environmental impacts.

In this contribution, we present 3 additional versions of the Food and Agriculture Biomass Input Output model (FABIO), originally developed by Bruckner et al. (2019). These versions of the model trace flows of dietary calories, protein and fat through agricultural production networks for 125 primary and processed items, covering 191 countries (and an additional rest of the world region) from 1986 to 2013. Allocating inputs to final products according to nutrient content allows us to separate the pathways taken by different functional elements, which can be used to calculate nutrient-specific land footprints or other impacts. We demonstrate this by analyzing the evolution of nutrient flows in different world regions through metabolic pathways.

The article is organized in the following way: The consecutive section presents the assumptions and approach used to build the new versions of FABIO and the methods used for the subsequent applications. We then present the results for the various applications and discuss these findings, future applications and shortcomings of our model. We then end with preliminary conclusions.

3.2 Methods

3.2.1 Building the model

Figure 3.1 illustrates the main steps for building the multi-regional input-output tables based on calories, protein and fat. For the approach taken to build national supply and use tables from data provided by FAOSTAT (FAO 2020), Comtrade (United Nations 2019), IEA (2019), EIA (2019) and BACI (Gaulier and Zignago 2010) we refer to Bruckner et al. (2019), who describe this process in detail. The following account explains all additional steps necessary to build the versions for calories, protein and fat.

For each item we gathered information on calorific value as well as protein and fat contents from food composition tables used in the FAOSTAT database (FAO 2001) and, where not available, from the USDA's FoodData Cental database (USDA 2019) and from supplementary data provided by Berners-Lee et al. (2018). We balanced nutrient compositions (mostly for sugar crops and oil crops) to match their profiles with technical conversion factors for processed items provided by FAO (2000).

We used the composition tables for each item to translate supply, use and final demand data from biomass (tonnes) to each nutrient and calculate multi-regional supply and use tables for calories, fat and protein separately. This step is crucial, since the allocation of a given nutrient from a primary

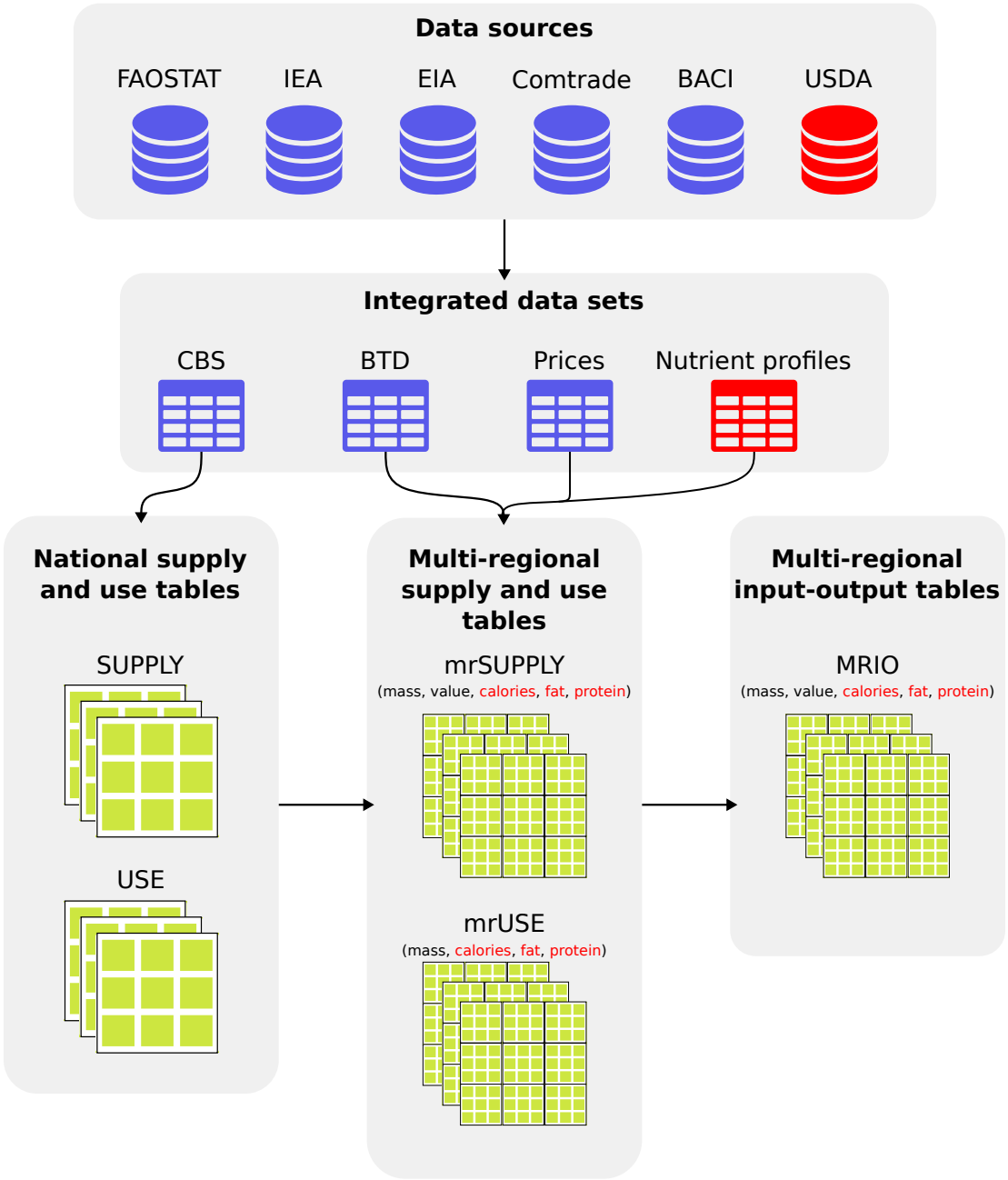


Figure 3.1: Flow diagram illustrating major components of data acquisition and processing. Components marked in red illustrate deviations from the original FABIO model. Adopted and modified from Bruckner et al. (2019).

product to a processed item may differ quite substantially from that of the overall biomass. If this were not the case, nutrient flows could simply be calculated by either creating an extension analogous to those for land-use or greenhouse gas emissions, or by directly translating the final input-output tables to nutrient equivalents.

A good example to illustrate this is that of cotton (see Figure 3.2). Three production processes in the FABIO model are associated only with cotton products. Seed cotton production refers to the pri-

mary production of seed cotton, which is harvested raw cotton, containing seed and lint, that has not been ginned. Cotton production refers to the first-level processing of raw cotton (ginning), which separates cottonseed from fiber (lint). Finally, cottonseed oil extraction is the second-level processing of cottonseed (crushing), which yields oil and cake. According to FAO (2000), cotton production yields about 63 percent of the original biomass as cottonseed and the remainder as cotton lint (35 percent) and processing wastes (2 percent). However, calories, protein and fat will be allocated entirely to cotton seed. Cottonseed oil extraction yields more cake than oil in weight, but almost all fat will be allocated to cottonseed oil. As fats are more energy-dense, the oil will also be allocated a higher share of the calories than that of biomass. Conversely, protein from cottonseed is only allocated to cottonseed cake. This clearly demonstrates that multi-regional input output tables for these nutrients have to be built separately, as the propagation of nutrients differs from that of overall biomass along the chain of production processes.

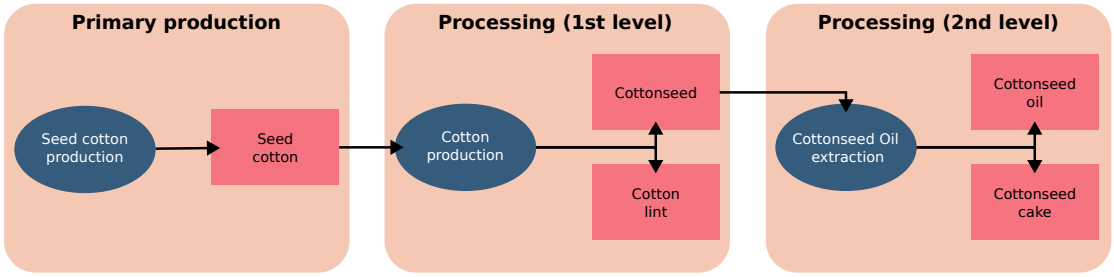


Figure 3.2: Processes and products related to cotton

The nutrient-specific supply and use tables are then assembled to build final input-output tables. Multi-output processes (e.g. cottonseed oil extraction as illustrated above) are dealt with as described by Bruckner et al. (2019) for each nutrient separately. This means that process inputs are allocated to their respective outputs according to the supply shares for each nutrient. Hence, in the case of cottonseed oil extraction, the protein version will allocate all inputs to cottonseed cake, while the fat version will allocate most inputs to cottonseed oil (as the cake still contains some fat).

Finally, out input-output tables show a higher degree of linear dependency between columns than in the original FABIO model. This is likely due to the reduction of output products, which do not contain nutritional value (e.g. fiber products). Linear dependency impedes the invertibility of a matrix, which is a crucial step in calculating the Leontief inverse for further analysis. We dealt with this problem by identifying dependent columns and making minor incremental changes to the respective production vectors.

3.2.2 Applications

We calculated nutrient flow profiles and land footprints separately for all 191 countries and for the years 1986 and 2013. We further aggregated countries into 11 regions (we excluded results for the rest of the world region) as illustrated in Figure 3.3. Regions were selected in a way that their borders re-

mained the same across the study period (hence the former Soviet Union is conceived as one region) and that major dynamics are reflected in the results in sufficient detail (hence China is treated separately from the rest of Eastern Asia). Population data was taken from World Bank estimates (World Bank 2022) and aggregated by region for both selected years as shown in Table 3.1.

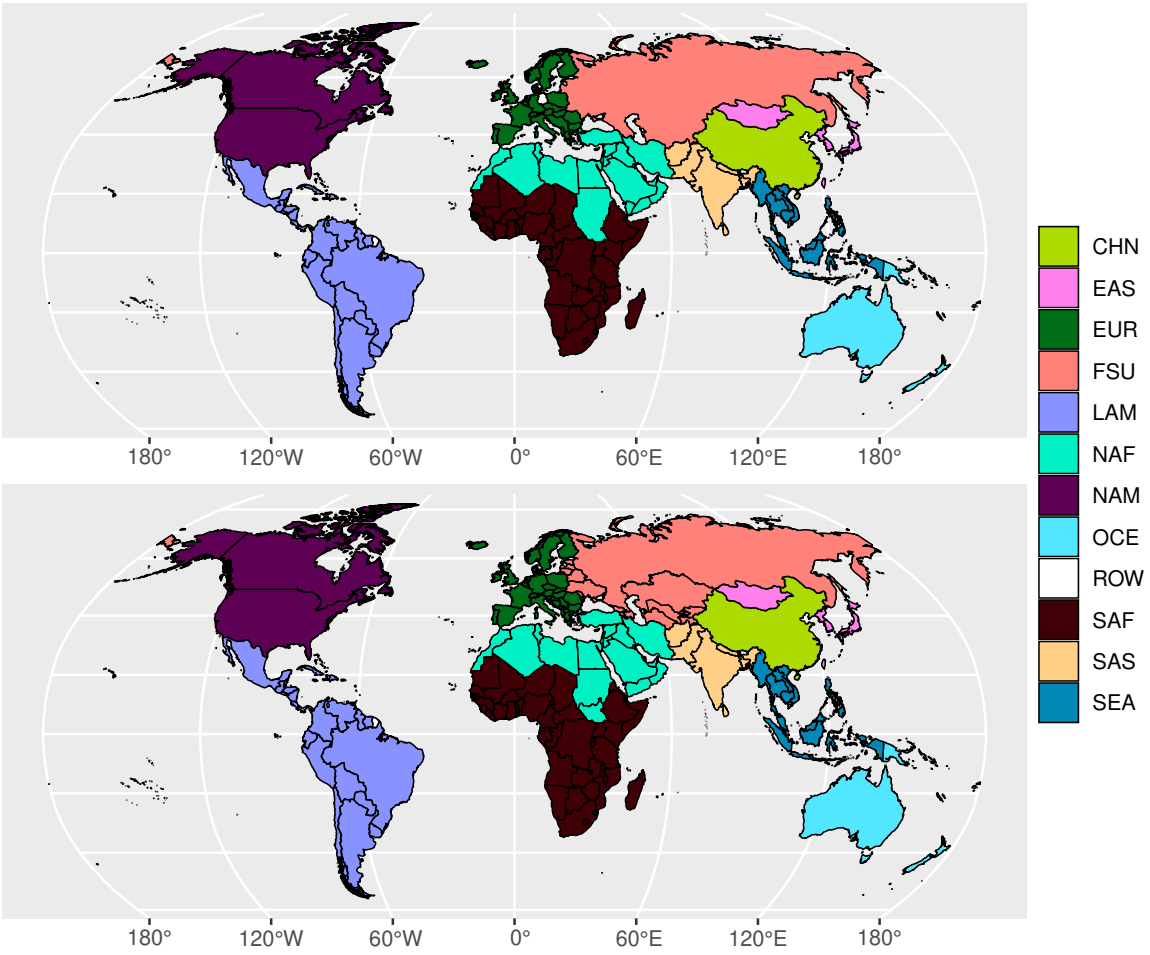


Figure 3.3: Regional division used in data analysis with country borders for 1986 (upper figure) and 2013 (lower figure), respectively. The color coding is maintained for all results presented in this chapter.

To calculate global nutrient flows between regions, we summed all inter-regional flows for both, embedded nutrients and final products, separately. Embedded flows include all nutrients from primary products (e.g., soybeans), which may be processed to intermediary items (e.g., soybean cake) and then serve as inputs to final products (e.g., pig meat). Flows from final products include only the nutrients constituent of final consumer items.

To generate regional nutrient profiles, we grouped primary products in edible crops and grazing or fodder crops. We then classified their further use into direct use (final product is plant-based) or feed (final product is animal-derived). We further calculated three categories of losses: Those related to storage and transportation of primary products (calculated through final demand category available in FABIO), those related to processing of plant-based final products (the difference between

Table 3.1: Regional classification and populations.

Region	Full Name	Population 1986	Population 2013
CHN	China	1066790000	1357380000
EAS	Eastern Asia	209420760	236771743
EUR	Europe	445544837	530101200
FSU	(Former) Soviet Union	278676770	290765954
LAM	Latin America & the Caribbean	409335773	609590332
NAF	Northern Africa and Western Asia	296967558	527948056
NAM	Northern America	266233278	351140681
OCE	Oceania	25146886	37884771
SAF	Southern Africa	431403900	894603827
SAS	Southern Asia	1035959200	1705061812
SEA	South-Eastern Asia	409536992	619421764
ROW	Rest of the World	-	-

nutrients in final products and the sum of all inputs) and those related to feed conversion losses (the difference between nutrients in animal products and the sum of all feed items). Consumer losses and pre-harvest losses are not considered in the model so far but will be in future iterations. Finally, the final use of both, animal products and plant-based products is allocated to either food or other (industrial uses) through the final demand categories available in FABIO. In future iterations, the model will be coupled with the hybrid EXIOBASE MRIO model (Stadler et al. 2021) to further disaggregate the latter category into different economic sectors.

To calculate nutrient-specific land footprints, we develop an approach that allocates land to nutrients based on their share of weight in the respective primary product. For example, of the land necessary to produce a tonne of a given cereal crop, only 4 percent would be allocated to protein if the protein content of said item is 4g per 100g. This approach is rather unusual, but allows calculating footprints separately for protein and fat, which do not depend mainly on the density for a given nutrient. It appears intuitive that a larger share of land used for an oilcrop should be allocated to fats than in the case of a citric fruit. An alternative approach would be to use calorie shares, which would increase footprints for fats relatively to protein due to their different calorie densities.

3.3 Results

3.3.1 Inter-regional nutrient flows

Figure 3.4 and 3.5 illustrate inter-regional nutrient flows in the years 1986 and 2013, for final products and embedded primary products, respectively. We want to point out the following observations from these graphs: The spatial disconnect between production and consumption varies quite significantly according to the nutrient in question. This is true of both, flows of final products and embedded primary products. When observing the patterns for final products, fat appears to be the most globalized nutrient, with South-Eastern Asia exporting increasing shares. This is likely the effect of the palm oil boom over the past decades. Considering protein flows, this trend is much more

obvious for embedded primary products. Northern America and Latin America become major net exporters. This is likely a result of the soybean boom over the past decades. Contrary to the fat from palm oil, protein from soybean products is usually not consumed as a final product, but embedded in animal products.

A particularly radical shift is discernible for China: While the country appeared to be hardly integrated into inter-regional trade flows in the mid 1980s, it becomes a major net importer for both fat and protein when considering embedded primary products. Southern Africa remains a region with relatively little integration or participation in global nutrient flows according to all metrics presented. The former Soviet Union evolves from a net importer to a net exporter for all nutrients, both, in the case of embedded primary production and final consumption.

3.3.2 Regional metabolic profiles

Here we present two examples of regional metabolic profiles. Figure 3.6 illustrates that for protein flows in China and Figure 3.7 that for fat flows in Europe. The color coding for regional imports of primary products corresponds that of Figure 3.3. It is important to note that the regional origin of flows corresponds to those from primary products embedded in all further categories. For example, protein flows from animal products to food are categorized by the regions which supply the primary products used in feed for the respective animal husbandry processes. All values are given in grams per capita per day.

Figure 3.6 cleary illustrates how China was largely self-sufficient in protein use in the mid 1980s. Final consumption of protein was dominated by plant products and corresponded to about 65g of protein per capita per day. Total losses corresponded to about 32 percent of protein supply. The profile has shifted dramatically by 2013. Overall protein supply per capita increased more than two-fold, and a significant share of that supply is based on primary production in other region, particularly Latin America and Northern America. More than half the supply derived from edible crops is now allocated to animal feed, and animal products increase significantly in their share of final consumption. Overall per capita protein consumption increases to 97g per day. Due to the larger share of animal products, overall losses increase to about 49 percent of total supply. Primary products sourced from other regions are disproportionately used as animal feed, and hence also constitute a large share of feed conversion losses.

Figure 3.7 illustrates some interesting trends in the dynamics of how fats have been sourced and used in Europe. Overall per capita fat supply increased by 38 percent between 1986 and 2013, largely by a rising share of edible crops sourced from South Eastern Asia (likely due to the palm oil boom) and the Former Soviet Union (e.g., sunflower seed oil). However, per capita fat consumption as food only increases slightly and the majority of additional supply is absorbed in other (industrial) uses, which increase more than three-fold. This trend is particularly visible for those items originally

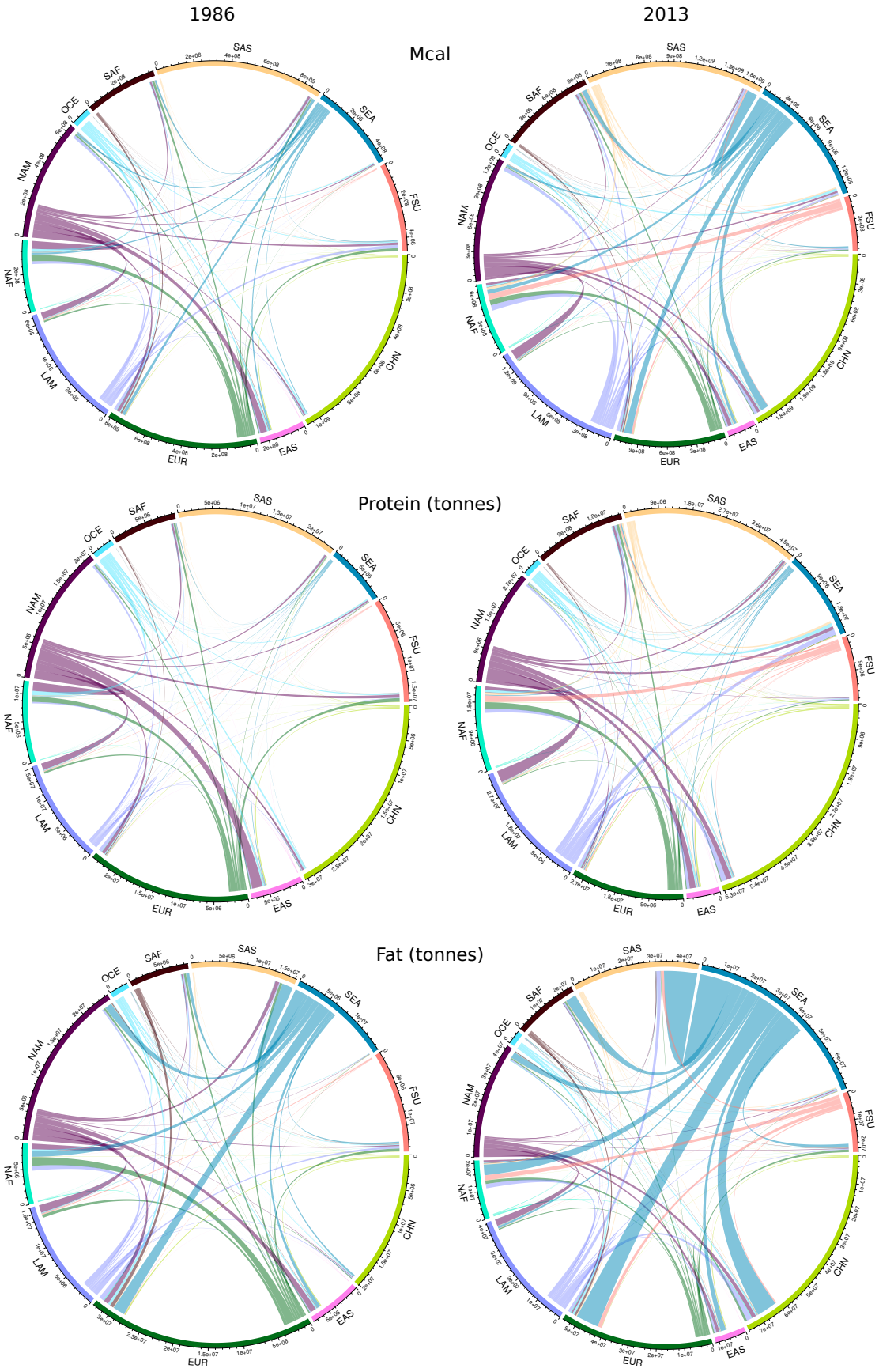


Figure 3.4: Inter-regional nutrient flows for final products.

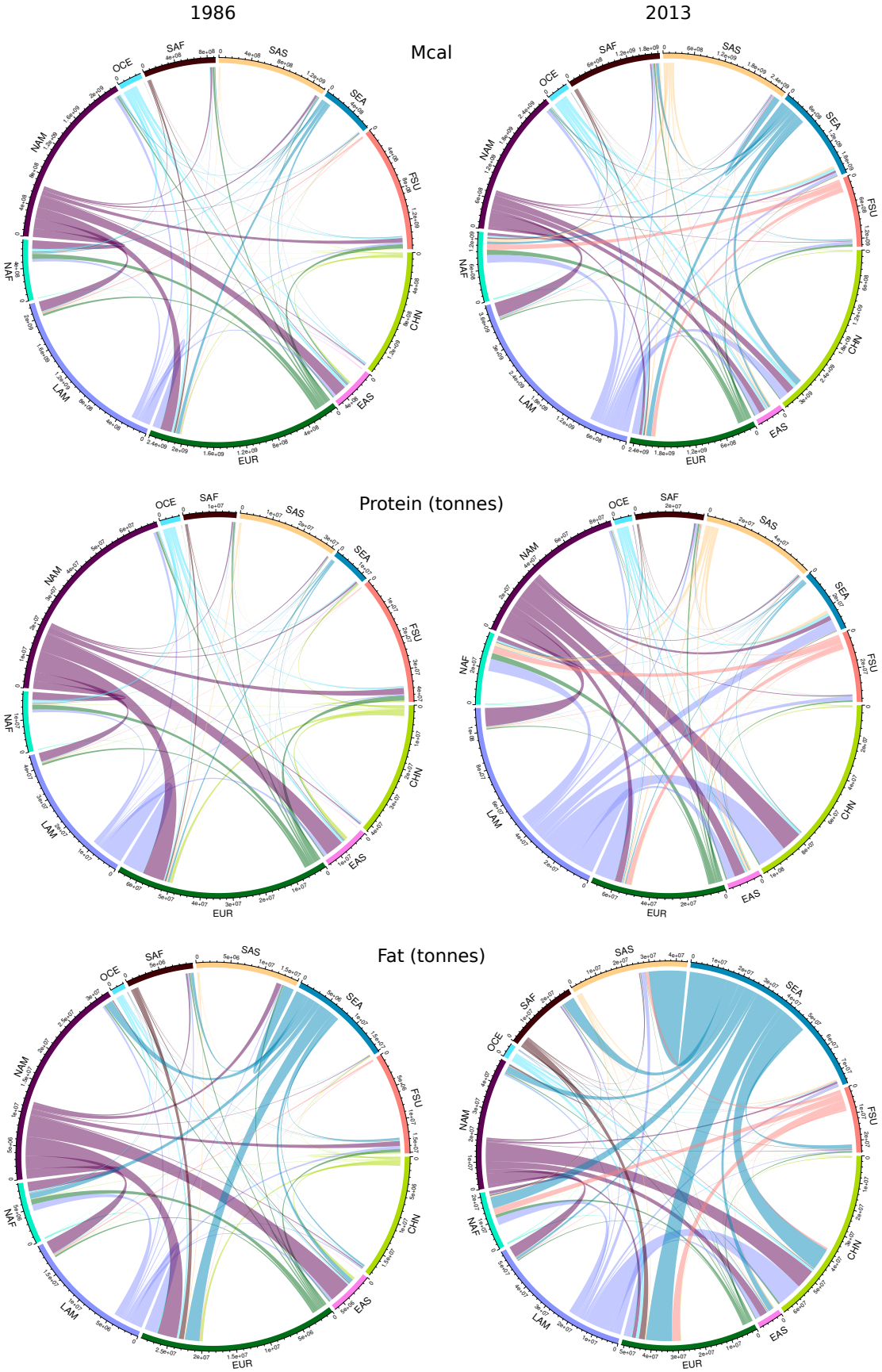


Figure 3.5: Inter-regional nutrient flows for embedded primary products.

Figure 3.6: Protein flow profile for China, 1986 and 2013.

sourced from South Eastern Asia. This trend is likely due to the increasing importance of vegetable oils in biofuels, bioplastics and other sectors influenced by the agenda of the bioeconomy.

3.3.3 Nutrient efficiencies

The previous section outlined regional dynamics in the sourcing and utilization of different nutrients. Here we present some applications on how this can be integrated with an analysis of land footprints. More specifically, we look at how efficiencies of land use have evolved according to how much of a given nutrient are produced per hectare for both, sourced primary products and final products.

Figure 3.7: Fat flow profile for Europe, 1986 and 2013.

Figures 3.8, 3.9 and 3.10 illustrate for the case of China, the amount of protein produced per hectare (based on primary products sourced) both, for the protein available from all primary products and those available for consumption through final products. Figure 3.8 is grouped by the origin of primary products (regions), Figure 3.9 by the product type of primary products and Figure 3.10 by the allocation to final products for consumption. It is important to note that, as mentioned above, only the share of land corresponding to the protein mass share of primary products is considered.

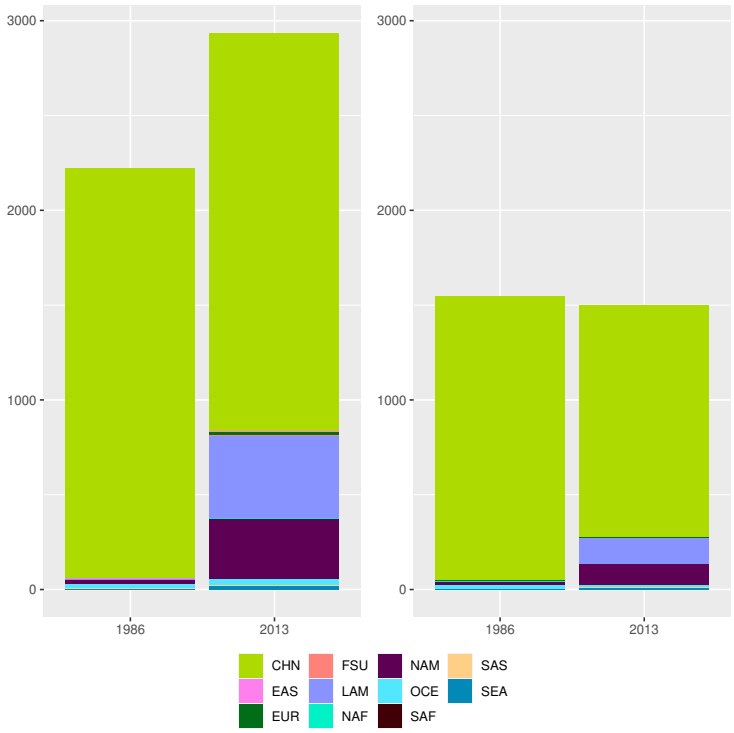


Figure 3.8: Protein efficiency in China. Protein per ha, 1986 and 2013, by region of primary production. Left: Protein in primary products. Right: Protein in final consumption.

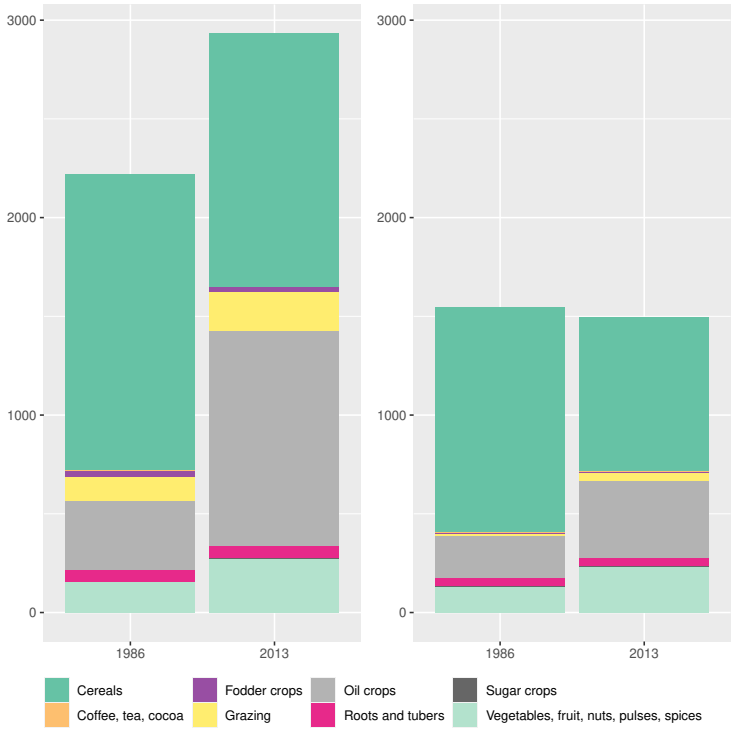


Figure 3.9: Protein efficiency in China. Protein per ha, 1986 and 2013, by product group of primary products. Left: Protein in primary products. Right: Protein in final consumption.

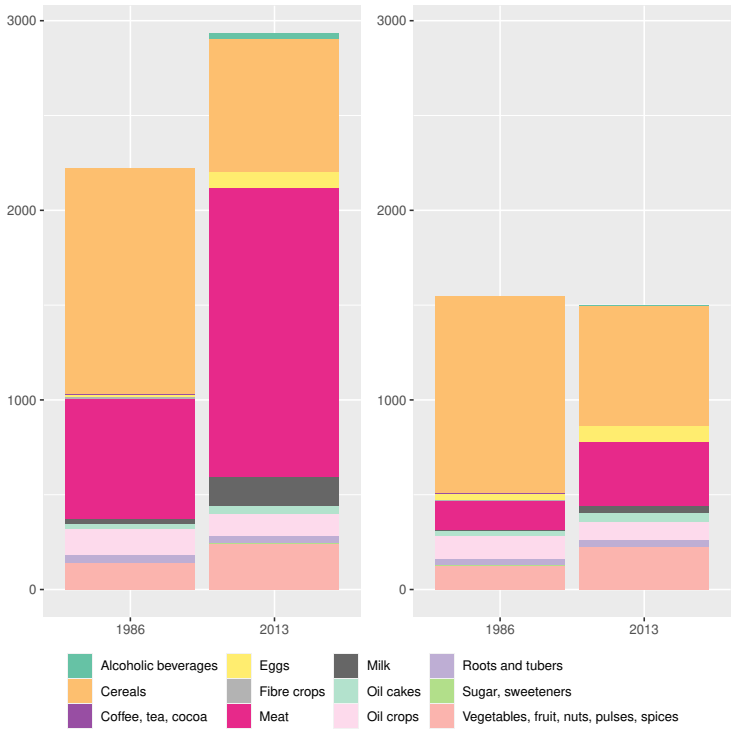


Figure 3.10: Protein efficiency in China. Protein per ha, 1986 and 2013, by product group of final products. Left: Protein in primary products. Right: Protein in final consumption.

The overall trends are identical in all graphs: The efficiency in primary production increased significantly between 1986 and 2013 (more protein per ha). However, when taking all metabolic losses into account (see previous section) and considering protein delivered for final consumption, the overall efficiency declined slightly. This means that while yields of sourced primary products increased drastically, the shift in allocation (e.g., between direct use and feed) more than compensated for yield gains. This means that even if China's population and per capita protein consumption had remained the same, the overall land footprint for protein would have increased slightly, due to a different composition in final products (e.g., higher share of animal products).

Figures 3.9 and 3.10 illustrate this even more clearly: The share of protein delivered by oilcrops from each hectare increases drastically for primary production to over a third of the total supply. This share is greatly diminished when considering final consumption. Similarly, the share of primary protein allocated to meat production in 2013 is about halve of total supply while the protein delivered from final meat products is less than that delivered by cereal crops.

3.3.4 The role of soybeans

Our model also allows to trace the propagation of nutrient flows for a single commodity and to calculate its share of total nutrient supply for different components of socio-metabolic processes. Figure 3.11 illustrates the flow of calories from soybeans, aggregated by major producing and importing regions. One can discern the following developments: Between 1986 and 2013 Latin America evolved to

the largest producer, providing more than half of all soybean-based calories. China greatly increased its share of global soybean consumption and evolved from a net-exporter to the most significant importer. In 1986, China used the overwhelming share of calories from soybeans directly through plant-based products, while in 2013 more than half was allocated to animal feed. Finally, by 2013 a significant share of calories from soybeans are allocated to industrial uses in China and Latin America.

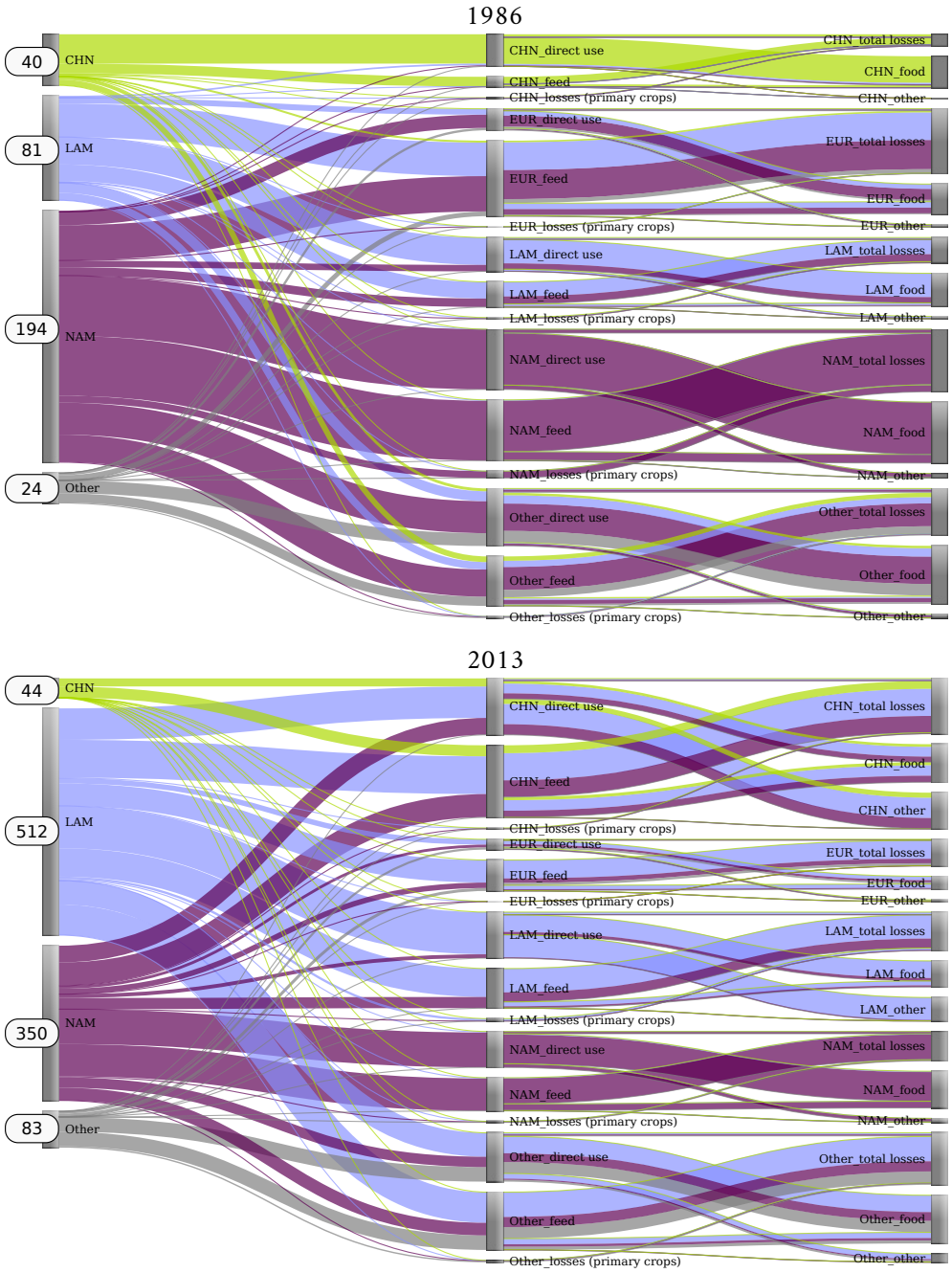


Figure 3.11: Calorie flows associated with soybeans. Values given in peta-calories.

Figure 3.12 illustrates the percentage of protein supply derived from soybeans for all primary products sourced, final food consumption and final industrial uses by region. Soybeans play a much

more important role in protein supply in all regions in 2013. This trend is particularly significant in China, Latin America, Northern Africa and Western Asia and South-Eastern Asia. In regions, where soybeans are increasingly used as feed or more so than other primary products the difference between the share for primary products and that for final food consumption increases (e.g., China, Northern Africa and South-Eastern Asia). In Southern Asia and Southern Africa, soybeans still play a relatively minor role in overall protein supply.

Figure 3.12: Percentage of protein provided by soybeans for total supply of primary production, final demand for food and final demand for industrial uses.

3.4 Discussion

Food and agriculture play a major role in the debate on global ecological crises and sustainability transitions. The increasing spatial disconnect between production, processing and final consumption,

as well as the rising importance of agricultural products for industrial uses have motivated research that traces biomass flows and associated impacts through ever more complex global production networks. Our nutrient-specific global biomass MRIO aims to add more detail to existing approaches and allows for a functional view of socio-metabolic processes related to agricultural commodities. This also constitutes a first step for environmentally extended input-output analysis of agriculture to engage directly with a chemically explicit lens in geography, as proposed by Romero et al. (2017).

Our findings have shown how an explicitly chemical lens to socio-metabolic processes in the global food system can disaggregate measures such a land footprints further to study how changing uses of primary products affect land use in other regions or, rather, how the availability of globally sourced nutrients changes socio-metabolic patterns and final consumption. Efficiency gains from increasing yields for many crops may at times be offset by changing allocation patterns between food, feed or other uses. Flex-crops, such as soybeans, have played a major role in nutritional transitions and transformations in line with the bioeconomy agenda in many world regions.

These findings represent a first step in characterizing and quantifying the way in which different regions engage in an evolving global metabolic economy of nutrients in agricultural commodities. This may help to provide empirical substance for more conceptual and theoretical approaches, such as that provided by Castro-Vargas and Mempel (in press), who analyze how Latin America has historically been embedded in different metabolic networks of agricultural commodities and pesticides, mediated by the chemical industry.

There are many potential future applications of our global nutrient-specific input-output tables for various research questions. Environmental extensions for energy inputs can be combined with our model for dietary energy to calculate estimates for energy return on investment (EROI) and compare the difference between primary production and final consumption for various socio-metabolic patterns between countries. Data on fertilizer use can be combined with our model to estimate nitrogen flows. And, when combining our input-output tables with monetary or hybrid MRIOs for the world economy, the impacts of substituting nutrients sources for one another in specific sectors (e.g., shift from animal fats to vegetable fats in cosmetics) can be analyzed.

There are also a number of shortcomings, some of which may be addressed in future versions of our model. The nutrient specific allocation of production inputs to outputs is intuitive for the processing of primary products, such as in the case of cotton illustrated above. However, nutrient absorption and synthesis through animal metabolism and the production of animal products is more complex. Our model treats these processes in the same way: nutrient outputs are a share of corresponding inputs. One problem with this approach is that the composition and quality of protein or fat derived from animal products may differ quite significantly from that of inputs. For some micronutrients (e.g., Vitamin-A) outputs may even exceed inputs (see also Berners-Lee et al. (2018)).

Even though the product resolution in FABIO is much finer than in most monetary or hybrid MRIO models, different products of the same category may have varying nutritional compositions. This is also true for varieties of the same crop grown for different purposes. Further, the allocation of items of the same category to final uses according to shares of origin may be misleading to some point. For example, soybeans directly used as food items in China are more likely to be of domestic origin than those used for animal feed (Oliveira and Schneider 2016). These shortcomings should be kept in mind, especially when using the model for case studies of individual countries or regions, and, when possible, detailed regional information should complement the analysis.

3.5 Conclusions

While many tools have been developed to trace the fate of primary agricultural products through transnational networks of production, processing, trade and final consumption, these approaches so far did not allow following individual functional components of these products, which may take quite distinct pathways from those of overall biomass. In this contribution we introduced nutrient specific multi-regional input-output tables for global biomass production, trade and use. We demonstrated potential applications by calculating global nutrient flows, regional socio-metabolic profiles, nutrient efficiencies and socio-metabolic pathways of a single commodity (soybeans).

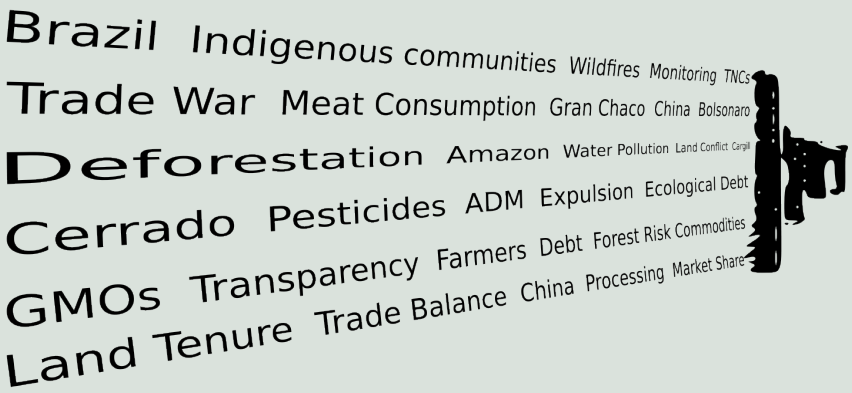
These applications showcase how the use of an explicitly chemical lens to socio-metabolic processes in the global food system can further disaggregate flows of biomass and thereby provide more nuance when analyzing phenomena, such as nutritional transitions, the bioeconomy or the emergence of flex-crops. The assumptions inherent in our model lead to a number of limitations, particularly for applications in country-level case studies, and some of these will be addressed in subsequent versions. Future applications may involve the calculation of energy return on investment for different regional socio-metabolic patterns, inter-regional nitrogen flows or impacts from functional substitution in different economic sectors.

Part II

Land use change and the politics of signification

"Yesterday's deconstructions are often tomorrow's orthodox clichés."

Stuart Hall


Brazil Indigenous communities Wildfires Monitoring TNCs
Trade War Meat Consumption Gran Chaco China Bolsonaro
Deforestation Amazon Water Pollution Land Conflict Cargill
Cerrado Pesticides ADM Expulsion Ecological Debt
GMOs Transparency Farmers Debt Forest Risk Commodities
Land Tenure Trade Balance China Processing Market Share

Chapter 4

Framing the frontier - Tracing issues related to soybean expansion in transnational public spheres

This chapter presents work published in the following journal article:

Mempel, F. and Corbera, E. (2021). Framing the frontier – Tracing issues related to soybean expansion in transnational public spheres. *Global Environmental Change*, 69:102308

Abstract

Rapid soybean expansion in South America has been linked to numerous socio-environmental problems, including deforestation in sensitive biomes. As a major importing region of soybeans, wider public awareness has also put pressure on the European Union. Different governance initiatives involving various groups of stakeholders have sought to address these issues. However, what is identified as a relevant problem, as a region of interest or which actors are mentioned in this context are all matters of claims-making processes between different groups and mediated through various channels of communication. This study uses a text-mining approach to trace the construction of socio-ecological problems related to soybean expansion and the actors and regions linked with these issues in public discourse. The focus lies on print media from the European Union, but several additional sources are included to investigate the similarities and differences between various communication channels and regions. These include newspaper articles from producing countries and interna- tional news agencies, scientific abstracts, corporate statements, and reports from advocacy groups gathered from the mid-1990s to 2020. The results show that European mass media have shifted their focus from consumer labeling, health, and concerns over genetically modified organisms towards more distant or abstract phenomena, such as deforestation and climate change. This has been accompanied with a broader view on different stakeholders, but also with a strong regional focus on the Amazon biome. There has also been much less attention on direct concerns for communities in producing regions, such as land conflicts or disputes over intellectual property rights. We conclude that while European public spheres appear to become more receptive to issues related to impacts in sourcing regions, there remains a narrow focus on specific problems and regions, which reflects a fundamental asymmetry in different stakeholders' ability to shape transnational deliberations and resulting governance processes.

4.1 Introduction

Since the early 20th century, soybeans have evolved from a regional food crop into one of the world's most important agricultural commodities (Du Bois 2018). Within the past 50 years, soybean production has increased almost tenfold and soy now ranks among the four leading crops worldwide in terms of overall area harvested (FAO 2020). The crop's high protein and fat contents make it valuable for a number of different end-uses, but the main driver has been an increasing global demand for livestock feed, particularly in Europe and China (Oliveira and Schneider 2016).

Within the last decades, the expansion of soy production has mainly taken place in South America, where it thrived within a context of structural adjustment policies, deregulation and a general embrace of biotechnology and large agribusiness (Leguizamón 2020; Neiman and Blanco 2020). While applauded as an economic success story by some, this expansion has also been criticized for its negative socio-environmental impacts, as the soybean frontier has expanded into highly sensitive and biodiverse biomes. Studies have pointed to patterns of landholding concentration, rural displacement, deforestation, soil degradation, food insecurity and health hazards (Goldsmith 2017; Leguizamón 2014; McKay and Colque 2016; Pengue 2009).

As media outlets and NGOs from the Global North have increasingly publicized these issues and called on governments, corporations, and consumers to act, political pressure has mounted. New governance mechanisms have been put in place, including many examples of what has been termed "private food law" (van der Meulen 2011), such as certification schemes,private standards or multi-stakeholder round-tables. These often single out individual agricultural commodities and associated social or environmental problems. Further, several international agreements have targeted the issues associated with soybeans among other forest-risk commodities (FRCs) and the European Union (EU) is currently assessing policy options to address tropical deforestation linked to its imports (Bager et al. 2020; European Parliament 2020).

These new governance processes are neither entirely embedded in political entities, nor truly global (Lenschow et al. 2016), they are flow-based rather than territorial(Sikor et al. 2013) and often involve different institutional layers and actors. While the effectiveness of these measures has often been addressed by research (Garrett et al. 2016; Lambin et al. 2018), the role of communication and discursive exchanges in constructing and framing the problems provoking these measures has received much less attention (Persson and Mertz 2019).

Elgert (2012) has demonstrated how certain actors and coalitions have framed issues related to soybean expansion rather narrowly to promote a particular way of addressing them with specific governance instruments, such as certification scheme. Our contribution takes a broader perspective to trace the evolution of how different socio-ecological problems in relation to the surge of global soybean production and trade have circulated in public discourse since the late 1990s. To do so, we

mobilize public sphere theory as a conceptual framework and use a text mining approach to analyze a large text corpus comprised of different sources. Our focus remains on the EU journalistic field as the center of public discourse within one of the primary soy importing regions.

In this article we ask: What differences exist between these fields in terms of the prevalence of certain topics? Which topics prevail at different time periods? How are these topics linked to each other and to the mentions of certain actors and geographic regions? By addressing these questions, we hope to provide insight on how the concerns of different groups in relation to soybean expansion have circulated through public discourse, particularly in importing regions such as the EU, and then shaped the ways in which transnational governance initiatives, such as certification schemes, zero-deforestation commitments, or multi-stakeholder roundtables, have targeted particular problems in sourcing regions. Further, we hope to demonstrate the utility of applying public sphere theory and text mining approaches when studying processes of land use change and environmental governance.

In the following sections we locate our research within the field of environmental communication and introduce public sphere theory as our framework of analysis. We provide an overview of text mining and topic modeling as the toolbox applied in our methods. We then continue to provide a detailed overview of our methods and present our findings.

4.2 Environmental communication, public spheres, and text mining

4.2.1 Environmental Communication and public sphere theory

Studies on the discursive processes shaping public perception of environmental problems can be found in the field of environmental communication (Pezzullo and Cox 2018), which emerged in the 1980s(Cox and Depoe 2015). The field has long studied environmental problems as not merely materially produced, but rather as socially and discursively constructed through processes of claims-making and contestation, mediated through different public arenas or forums, such as mass media (Hansen 2015a).

A useful theoretical underpinning when studying communicative processes and their role in shaping governance mechanisms regulating global commodities is public sphere theory (Habermas 1989). The concept of a public sphere is intimately tied to the theory of deliberative democracy and describes a net of communicative processes, which spans throughout society and through which its members rationally debate the issues affecting their lives.

Beyond its application as an analytical framework, public sphere theory also has a strong normative foundation in relation to the functioning of deliberative democracy. Evolving public spheres can be evaluated according to their inclusiveness to all members and minority groups within a given

polity (legitimacy) and according to their effectiveness at translating public opinion into political debate and binding legislation (efficacy) (Fraser and Nash 2014).

While traditionally applied at the level of individual nation-states, Fraser (2009) has pointed out the need to use these criteria for deliberative processes on a transnational level, since economic globalization has subjected people across individual nation-states to the same governance institutions and rendered them susceptible to the outcomes of the same value chains and decisions taken by the same transnationally operating actors.

In this article, we adopt a conceptualization of issue-oriented, networked, transnationalizing public spheres, which are porous to communicative flows across polities (Fraser and Nash 2014). As in the later revision of Habermas' original theory (Habermas 1996), we consider mass media as crucial to the functioning of modern public spheres. This central role of mass media in deciding on what are being considered key issues in public spheres is also assumed in media effect models such as agenda setting or priming (Scheufele and Tewksbury 2007).

Following Benson (2009) in his mapping of public spheres using Bourdieu's field theory, we understand the journalistic field to be at the center of a given public sphere, interacting with and mediating between other fields, including the academic, the political, the economic and the advocacy fields. It is important to note that the assumed centrality of mass media should not be understood as a normative assessment of its function in public discourse. In fact, many traditions in mass communication theory, such as mass society theory or the critical cultural trend have understood mass media as promoters of hegemonic elitist worldviews (Baran and Davis 2011).

4.2.2 Text mining and topic modeling

Empirical studies in the field of environmental communication have traditionally relied on the same approaches to text analysis (or other forms of communication) as the social sciences more broadly. These differ substantially in their mode of analysis (quantitative, qualitative, or mixed methods) and their level of analysis (e.g., textual, contextual, or sociological), but generally all involve the acquisition, selection, careful reading and manual coding of texts, sometimes using several independent coders.

The widespread use of social media, the ongoing digitalization of archival material, the creation of specialized online databases for news, academic articles and press wires have provided an abundance of available text material about virtually any topic and from a variety of sources. While this provides unprecedented access to texts and other forms of communication, it also represents a major challenge for traditional approaches to text analysis. Manual coding of large volumes of texts is only feasible by applying selective filters and sampling methods or by hiring many additional coders, resulting in high project costs (Grimmer and Stewart 2013). However, the increasing processing capacity available to researchers even on personal computers has enabled the use of novel methods and

applications leveraging computer algorithms, often referred to as text mining (Ignatow and Mihalcea 2017). These had been developed in the field of computer science and are now successively being added to the toolbox of the social sciences, alongside traditional methods of text analysis.

More than just a way of dealing with the challenges of big data, the use of algorithms for language processing and supervised or unsupervised text classification also provides a means to counter the regularly raised issue of human bias in traditional text analysis. However, mathematical models for language and text used in these methods are by nature simplified representations. Text mining should therefore not be seen as replacing but rather as complementing traditional content analysis (Grimmer and Stewart 2013). Further, even unsupervised methods still are susceptible to bias, both, though choices in the selection of parameters or interpretation of output, and the reductionist approach to language ingrained in their algorithms.

Originating with the groundbreaking work of Blei et al. (2003), topic models are a rather popular tool among text mining methods. They are a statistical framework developed in computer science research and used to identify the underlying ("latent") topics in a text corpus (Wesslen 2018). Topic models are unsupervised machine learning algorithms, which do not depend on training datasets, but provide classifications according to patterns identified within the data itself. Topic models typically use a document-term matrix (DTM) as input, which lists relative term frequencies for all documents. This representation of documents ignores the original order of words and is therefore commonly referred to as a bag-of-words (BoW) model.

Topic models treat individual texts as being generated by drawing the distributions of topics in each document as well as the distribution of words in each topic from an underlying probability distribution (Günther and Quandt 2016). By reverse engineering the generation of a given text corpus according to this model, topic models provide the user with a representation of every document as a weighted mix of topics (mixed membership model) and every topic as a weighted mix of words.

It is common practice to perform pre-processing and filtering steps on a text corpus prior to the application of a topic model. Tokenization refers to the process of breaking down text documents into smaller units (tokens), which become the basis for further analysis. In the case of topic modeling, tokens are typically words and compound multi-word expressions. Common processing steps include trimming, lemmatization, named entity recognition (NER) and co-reference resolution. These are further explained in the methods section below.

Numerous studies have applied topic modeling and other text mining approaches to analyze communicative processes linked to environmental issues, most notably climate change. Topic modeling has been applied to show how media attention to climate change has generally increased but at significantly different rates across countries (Schmidt et al. 2013). It has helped to demonstrate how specific national framings of climate change reflect different countries' specific local contexts, despite it being a global phenomenon (Vu et al. 2019). Further, Boussalis and Coan (2016) show

the persistence of climate change denial among a group of conservative think tanks and Bohr (2020) demonstrates the importance of outlet bias as a contextual factor in U.S. media coverage on climate change.

4.3 Methods

The entire process of data acquisition, processing, topic-modeling, and analysis is illustrated as a flow diagram in Figure 4.1 and described in detail below.

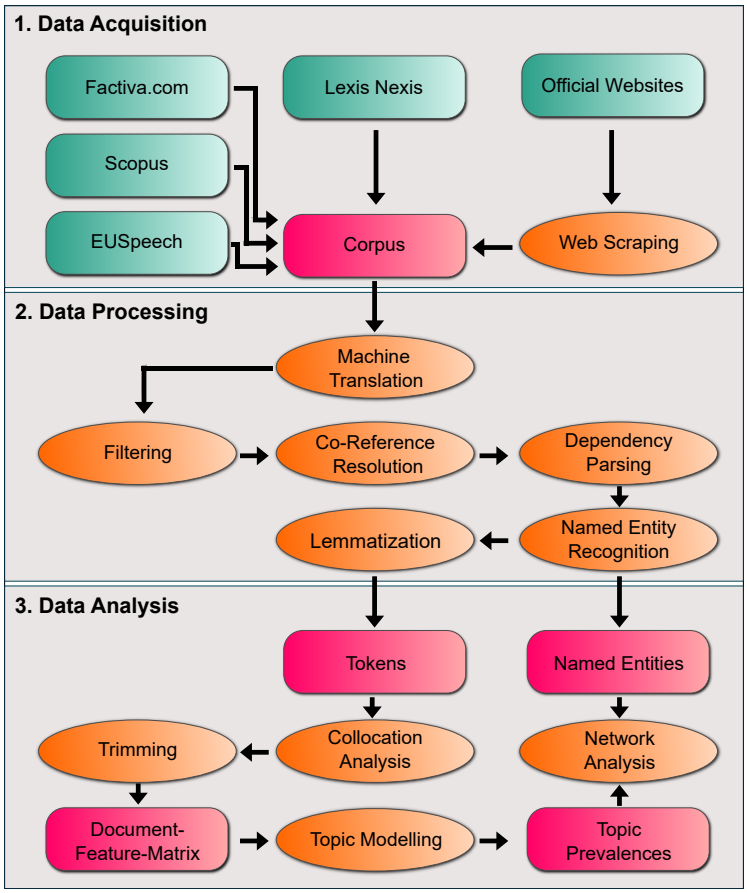


Figure 4.1: Flow diagram illustrating major components of data acquisition, processing and analysis.

4.3.1 Data acquisition – Building the text corpus

Following our conceptualization of networked public spheres, we generated a text corpus by integrating several different types of documents, grouped into a nested categorization as illustrated in Table 4.1. All sources were selected according to availability during our study period (1997-2020). For the journalistic field we aimed to select news media of record with relatively high circulations and preferably national editions. Corporate actors were selected to represent different stakeholders along the soy value chain. For the advocacy field, we aimed to include both, large international NGOs, which have directly collaborated with roundtables and other business initiatives, and movements or organizations working closer with local communities and peasants.

Table 4.1: List of sources, nested according to field and region.

Field	Region	Country	Language	Name	Type
Journalistic Field	European Union	U.K.	English	The Times	News articles
				The Guardian	
				The Independent	
		Germany	German	Sueddeutsche Zeitung	
				Der Spiegel	
				taz	
		France	French	Le Monde	
				Le Figaro	
				Libération	
		Spain	Spanish	El Mundo	
				ABC	
				La Vanguardia	
		Italy	Italian	Corriere della Sera	
				La Stampa	
				La Repubblica	
	Latin America	Brazil	Portuguese	O Globo	
				O Estado de S.P.	
				Folha de S.P.	
		Argentina	Spanish	La Nación	
				Clarín	
				La voz del Interior	
	North America	USA	English	The Wall Street Journal	
				The New York Times	
				The Washington Post	
	Transnational	USA	English	Associated Press	
		U.K.		Reuters	
		France		Agence France Presse	
		Germany		DPA	
		Spain		EFE	
		U.K.		Press Association	
		China		Xinhua Agency	
Business Field	North America	USA	English	Monsanto	Press Releases
				ADM	
	European Union	Belgium		FEFAC	
		Netherlands		ForFarmer Group	
	Latin America	Brazil	Portuguese	Aprosoja Brasil	
Advocacy Field	Transnational	Switzerland	English	World Wildlife Fund (WWF)	Press Releases
		USA		World Resource Institute (WRI)	
		Netherlands		Transnational Institute (TNI)	
		Spain		GRAIN	
		Simbabwe		Via Campesina	
		Netherlands		Friends of the Earth (FoE)	
Political Field	European Union		English	EU Speech Corpus	Political Speeches
		Belgium		Bulletin Quotdien Europe	Print media articles
		Belgium		EU Commission	Press Releases
Academic Field	Transnational	-	English	-	Journal article abstracts

News articles were sourced from Factiva (Dow Jones & Company 2020) and Lexis Nexis (Lexis Nexis 2020). We collected press releases via Web Scraping from the websites of several corporate

actors, NGOs, social movements, and the EU Commission. EU political speeches were taken from Schumacher et al. (2016). We downloaded journal abstracts from scopus.com. Search strings and filtering criteria are listed in the supplementary material. For the year 2020, data collection stopped on May 1st for all sources included.

In total, the text corpus consists of 32,540 documents, which are distributed according to field and region as illustrated in Figure 4.2. The journalistic field represents the center of our analysis and is represented with the largest number of documents (21,831). The other fields mainly serve for comparative purposes and contribute fewer documents. Within the journalistic field, print media from the EU constitute the largest fraction (6,232 Documents). More details are provided in the supplementary material.

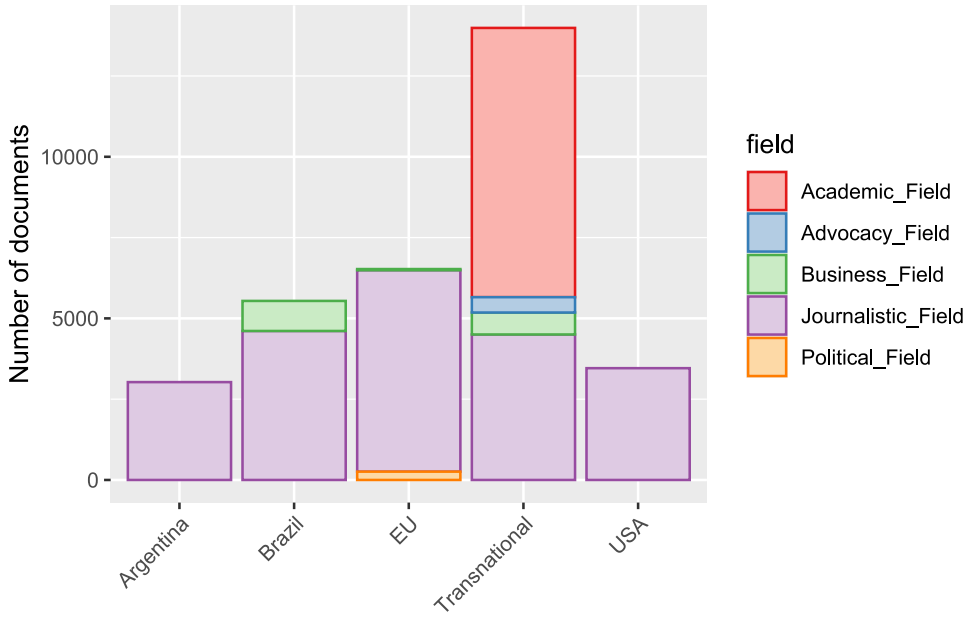


Figure 4.2: Distribution of documents according to region and field.

4.3.2 Data processing

Before computing the topic model, several processing steps were performed. The first step was to translate all non-English documents from their source language into English. We used the ModernMT machine-translation API (ModernMT 2020), which provides a context-aware translation algorithm. While machine-translation is never free of errors, here we mostly rely on the translation of important individual key terms. Grammatical structure is irrelevant for the topic modeling procedure, which does not consider the order of words, but only their frequency. However, this machine-translation approach still introduces an unquantifiable degree of error and may be highly problematic for more nuanced text-mining approaches (e.g., sentiment analysis or metaphor detection).

Subsequently, we applied several filters to the corpus to remove irrelevant documents and duplicates (see supplementary material). We then used the natural language processing (NLP) library SpaCy (Honnibal and Johnson 2015) and the neuralcoref package (Clark and Manning 2016) to resolve all documents for co-references, replacing all mentions referring to the same real-world entity with the entity's name. This is helpful, since an entity may be referred to many times in a text, but only named once.

We also identified and extracted real-world entities using SpaCy's Named Entity Recognition (NER) function. These were removed and collected separately for further analysis. The rationale behind this is to generate latent topics independent of any mentions of organizations or locations. This way, the co-occurrence of topics and these entities can be analyzed separately.

Finally, only nouns, verbs, adjectives, and adverbs were included as input tokens for the topic model. The tokens were lemmatized (transformed to their noninflected dictionary form) with the lemmatizer provided by SpaCy's English language model.

4.3.3 Topic modeling

In our study, we used the Structural Topic Model (STM), based on the work by Roberts et al. (2014). STM is a probabilistic model, in which both the terms associated with topics and topic proportions for each document are approximated as latent variables. We implemented the STM model using the open-source stm package available for the statistical computing environment R (Roberts et al. 2019). When converting our text corpus into a DTM to feed into the topic model, we performed a collocation analysis to represent multi-word expressions (see supplementary material).

An advantage that STM provides over other topic modeling approaches is the possibility to include document metadata as covariates for the topic model. Here, we included field, region, and year of publication as covariates. When computing the topic model, one important consideration is the selection of an appropriate number of topics (the model parameter K). The selection of this parameter will depend on the underlying research aim and the merit of the resulting topics should always be evaluated manually. There are also various metrics designed to automatically find an appropriate range for K. After running the STM with several different setups and comparing the output and a set of test statistics (see supplementary material), we settled on a model with 80 topics, which provided sufficient detail while not overclustering.

Researchers have pointed to the need to validate any use of automated text analysis (Grimmer and Stewart 2013). We establish semantic validity by labeling topics, taking into consideration highly associated words and documents dominated by each topic and by mapping topics via hierarchical clustering. Following Quinn et al. (2010), we introduce a measure of construct validity by comparing the evolution of prevalence of selected topics over time with external events, which would be expected to lead to public debate of the given topics. Further, following the approach introduced by Chang

et al. (2009a), we introduce a supervised element, comparing topic model outputs to the judgement of human coders (see supplementary material).

4.3.4 Data analysis

Presented with the model output, we labeled topics according to a manual inspection of the terms most prevalent for each and the 20 documents with the highest relative share of a given topic. Subsequently, we selected the most relevant topics for our analysis and merged similar topics by summing their prevalence.

We then performed a network analysis based on the co-occurrence between the individual topics and between the extracted entities and topics. For this purpose, we computed cosine similarities between the prevalence vectors of all issues and entities and used the similarity measures as edge weights for the network. Additionally, measures of closeness centrality for all topics are found in the supplementary material.

Lastly, for one key topic ("Deforestation") we selected all documents, in which this topic was the most prevalent one. For each year in our study period we then calculated a measure of "keyness" (Bondi and Scott 2010), i.e. comparing a target group (documents from the given year) to a reference group (documents from all prior years). This approach provides key terms for each year, which are more frequently used than in previous years. We performed this analysis separately for documents from the EU journalistic field, Brazilian journalistic field, and transnational news agencies. We then identified one year, in which this topic appears to be dominated by similar key terms across these three sources. We further identified months which showed peaks in prevalence of the given topic for each source. To analyze the specific content of documents for the selected year and for those months, we calculated co-occurrence networks for each, including both, tokens and named entities.

4.4 Results

4.4.1 Topic model output and validation

The entire output from our topic model, including overall topic prevalence and top contributing terms for all 80 topics are provided in the supplementary material. Labeling of topics provided initial support for semantic validity, as most topics were easily categorized. The results from our manual labeling and grouping of the latent topics identified by the STM are illustrated in Table 4.2, including short descriptions of the selected topics or topic groups, the number of constituent topics, and topic prevalence over the entire corpus. Of the initial 80 topics, 29 were selected and grouped into 20 topics, reflecting relevant issues. The remaining 51 topics were excluded from the analysis. The selected topics represent about 40 percent of the overall topic prevalence across the entire corpus.

Hierarchical clustering of word weight vectors resulted in meaningful clusters around certain topic categories, even though in a few cases related topics form separate clusters, likely due to dif-

Table 4.2: Selected topics and topic groups.

Topic Group	Description	Topics	Prevalence (%)
Diets & Health	These topics deal with different relationships between food items' nutrients and health, such as concerns over different types of fat.	4	4.34
Pest Management	These topics deal with the management of pests affecting soybeans, such as the aphid Aphis glycines Matsumura, pod borers or whiteflies.	3	3.21
Deforestation	This issue is about the loss of forest area in different biomes.	2	2.97
Trade Disputes	This topic deals with protectionist measures, such as tariffs, imposed between different countries and the consequences for trade patterns (e.g. in soybeans), different economic sectors and international relations.	1	2.91
Biofuels	These topics deals with the use of soybeans among other plants as feedstock for biofuels and the implications for direct and indirect emissions from combustion engines.	2	2.7
Harvest & Weather	This topic deals with weather patterns, such as droughts and floods and how they affect yields in various agricultural areas producing soybeans.	1	2.61
Land Use Change & Environmental Impact	This topic deals with land use change and associated environmental impact.	1	2.23
Soil Management	This topic deals with the management of soil structural properties and nutrients through agricultural inputs or cropping practices and the respective impact on soybean yields.	1	2.19
Meat & Animal Feed	These topics deal with concerns over different impacts of meat consumption and the search for different protein meals (e.g. oilseed cakes or fish-meal) for animal feed and the respective trade-offs when substituting between them. Further, there are accounts of consumers' and businesses' attempts to substitute meat products with plant based alternatives.	2	2.09
Climate Change & GG Emissions	These topics deal with greenhouse gas emissions and the threat of climate change.	2	1.85
Economic Crisis	This topic deals with economic and financial crises, inflation, debt and unemployment.	1	1.69
Producers & Landowners	This topic deals with the economic and social environment for farmers and landowners.	1	1.46
Consumers & Food Labeling	This topic deals with consumers' concern concerning various food items and their production, as well as the debate on food labeling.	1	1.4
GMOs	This topic deals with biotechnology applications in agriculture and the various concerns about genetically modified organisms, such as roundup-ready soybeans.	1	1.29
Water Resource Management	This topic deals with water resources, hydrological alterations and issues related to water availability, distribution and quality.	1	1.11
Global Food System	This topic deals with the challenges of global agriculture and food systems, particularly in feeding the world's population, overcoming hunger and malnutrition and preventing food price hikes.	1	1.06
Land Conflicts	This topic deals with conflicts over land as a result of agribusiness expansion. Main themes include the concern over livelihoods and rights of peasants and indigenous populations and the struggles of social movements in defending these rights.	1	1.03
Pesticides & Health	This topic deals with the use of pesticides and associated health concerns, such as cancer and infertility.	1	0.95
Seeds & Patents	This topic deals with farmers' use of patented GMO seed and the legal disputes over intellectual property rights when saving and reproducing seeds.	1	0.78
Wildlife & Biodiversity	This topic deals with threats to wildlife, endangered species, biodiversity loss and the struggle of conservationists.	1	0.68
Other (excluded)	A range of topics excluded from the analysis. These are mainly topics dealing with trade statistics, commodity market updates, but also general "nonsense" topics reflecting the use of specific vocabulary not related to any particular issue.	51	61.43

ferences in vocabulary between fields (see supplementary material). The correspondence found between the judgement of human coders and our topic model is generally encouraging. Mean model precision (comparing assignment of words to topics) was found to be 88.75 percent and the mean topic log odds (comparing assignment of topics to documents) was calculated at -0.52, both at high

significance levels (P ¡ 0.001). When considering only selected topics, model precision increased to 93.1 percent (see supplementary material). With respect to construct validity, section 4.4.6 establishes solid correspondence between selected topics and key real-life events.

4.4.2 Dominant topics vary across fields

The upper graph in Figure 4.3 illustrates topic prevalence for all fields included in our analysis. Topic prevalence varies quite significantly between fields. In fact, the most dominant topic is different for each field. The academic abstracts included show relatively high prevalence values for the topics Pest Management (10.68 %), Soil Management (7.84 %), Land Use Change (7.05 %) and Biofuels (7.04 %). The documents included from the advocacy field are dominated by issues around the Global Food System (19.40 %) and also show the largest relative shares of prevalence for Deforestation (6.06 %), issues around Seeds & Patents (6.47 %), Land Conflicts (5.65 %) and Climate Change & GG Emissions (3.56 %). The Business field shows low prevalence for most of our selected topics, apart from issues dealing with Harvests & Weather (8.90 %), as well as the concerns of Producers & Landowners (3.26 %).

The journalistic field shows a more even distribution of prevalence between the selected topics compared to the other fields. It presents the highest relative prevalence for Diets & Health (4.96 %) and compared to the other fields, it also shows relatively high levels of prevalence for Trade Disputes (4.25 %) and Consumers & Food Labeling (1.77 %). The political field (EU) is dominated by concerns about GMOs (20.91 %) and to a lesser extend Trade Disputes (4.35 %) and Diets & Health (3.07 %).

4.4.3 Topic prevalence varies across print media

The graph at the bottom of Figure 4.3 provides the same information, restricted to the journalistic field and grouped by regions from which print media were collected. The Argentinian print media has a rather unique profile of topic prevalence, being dominated mostly by topics related to Harvests & Weather (15.42 %), Producers & Landowners (9.51 %) and Economic Crisis (4.50 %). The selected newspapers from Argentina also show a relatively high prevalence of issues related to Seeds & Patents (1.83 %), compared to the other regions.

The included Brazilian print media sources show a high relative prevalence of issues relating to Deforestation (9.82 %), Economic Crisis (4.62 %) and Land Conflicts (3.47 %) compared to the other regions. For EU print media, international news agencies and the US print media, topic prevalence shows more comparable patterns: relatively large prevalence values for topics relating to Trade Disputes and Diets & Health. EU print media show the highest relative prevalence shares for Diets & Health (9.30 %) and Climate Change (2.84 %) among all regions. For international news agencies Trade Disputes (8.68 %) dominates and the US print media have the highest prevalence for Consumers & Food Labeling (1.45 %) among all regions.

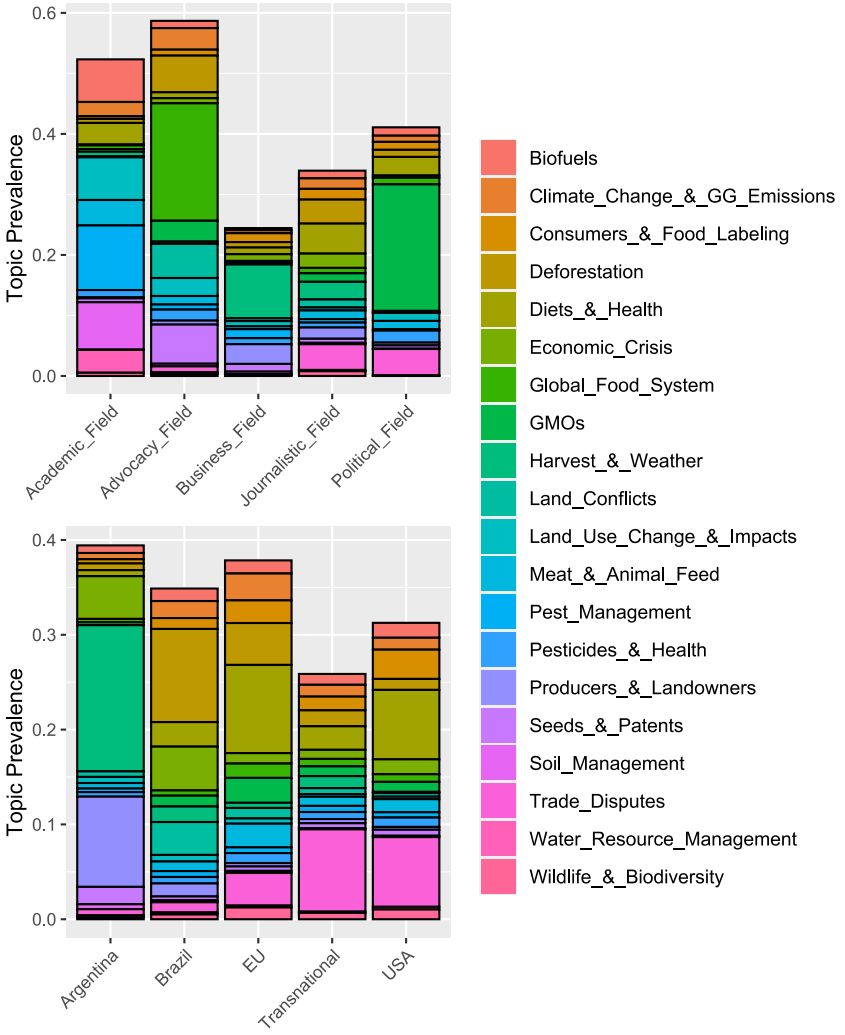


Figure 4.3: Topic prevalence by field (upper graph) and by region for journalistic field (lower graph).

4.4.4 Zooming into the EU print media

Figure 4 illustrates the evolution of the co-occurrence network of our selected topics in the EU journalistic Field through five distinct time intervals between 1997 and 2020, as well as for the entire study period. Further, Figure 5 shows the evolution of prevalence for selected topics by year. One can observe that EU print media articles in the late 1990s, which mentioned soybeans were dominated by topics dealing with Diets & Health, GMOs, Consumers & Food labeling and to a lesser degree, Meat & Animal Feed.

These topics occur in relative isolation and there are only a few strong co-occurrence values between these and other topics (e.g., between Pesticide & Health and Seeds & Patents). Over time, these topics show a declining trend; though Diets & Health remains among the most prevalent topics, GMOs is among the least prevalent in the last time interval. Since the early and mid-2000s, Deforestation and Climate Change & GG Emission gain prevalence, with their highest shown values

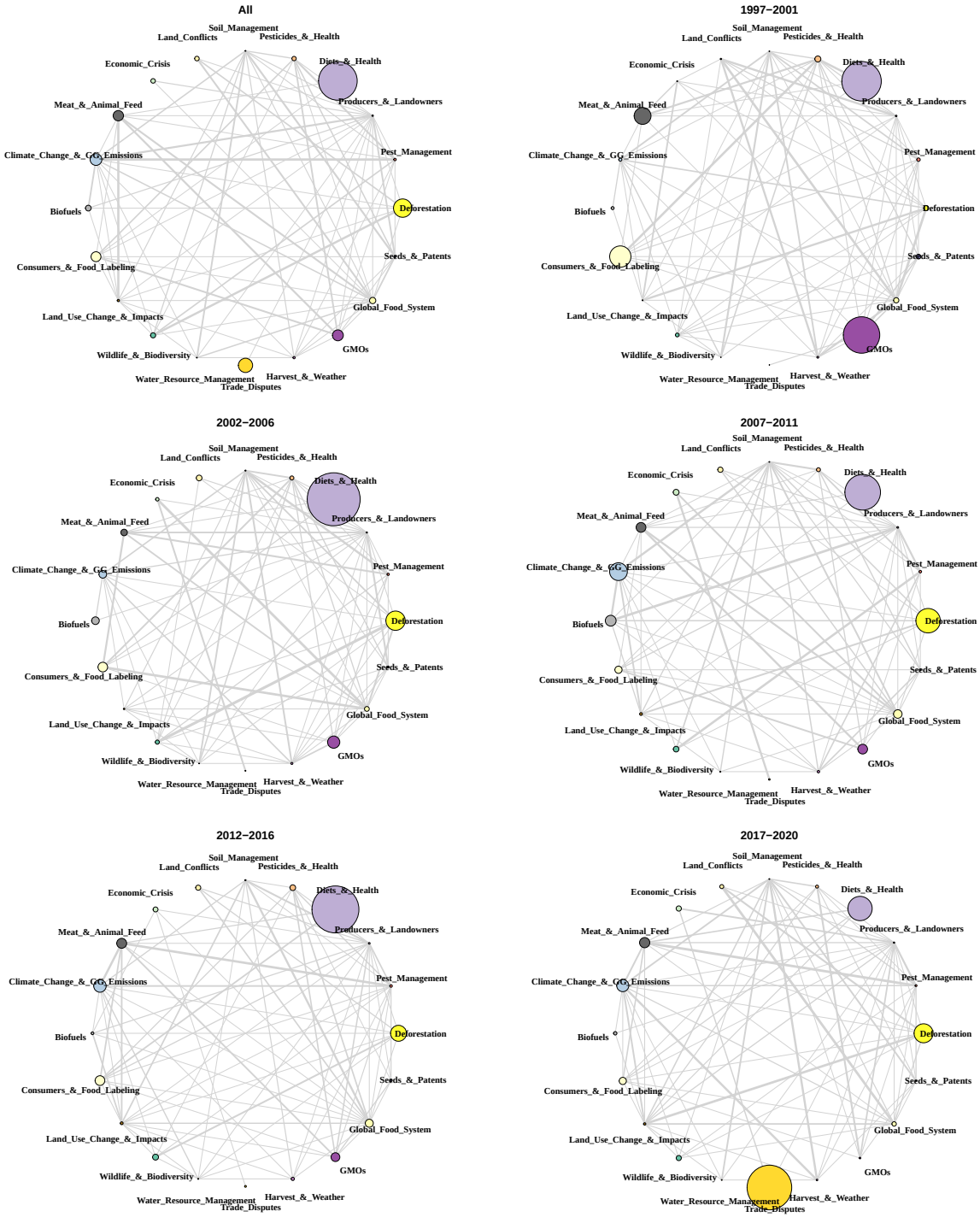


Figure 4.4: Evolution of topic co-occurrence in EU print media. Circle size represents topic prevalence and line width indicates edge weight. Only edges with weights above the mean were included here.

for the period between 2007 and 2011 but remain relevant until 2020. Between 2017 and 2020, Trade Disputes becomes the most prevalent topic.

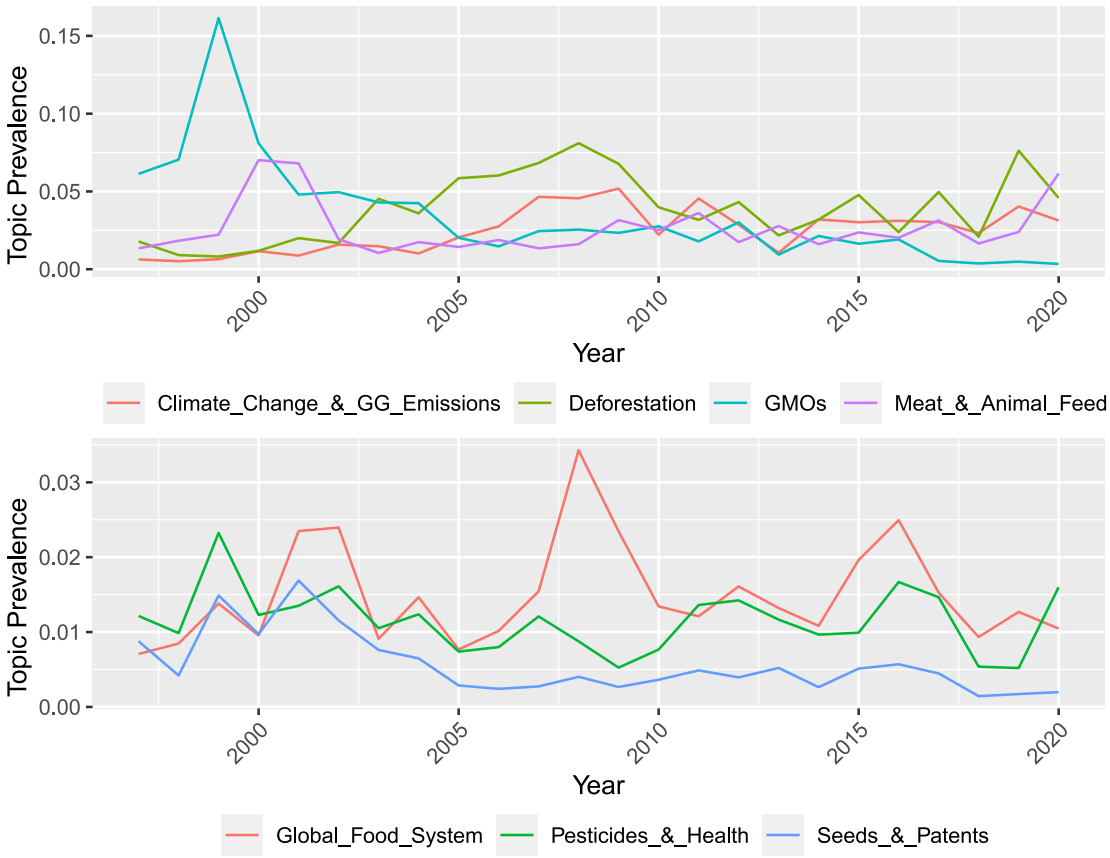


Figure 4.5: Evolution of prevalence for selected topics in EU print media.

4.4.5 A focus on the Amazon and more diverse stakeholders

Regarding the extracted named entities in the EU journalistic field, Figure 4.6 illustrates the evolution of mentioned entities, filtered to include four of the biomes, in which soybean expansion has taken place within the last decades. The graph is organized as a bipartide network to show how the mentions of biomes are linked with topics (using cosine similarities between the prevalence in all documents). The Amazon biome is by far the most mentioned throughout the study period and also shows the strongest associations with most topics, particularly Deforestation. Other associations become progressively relevant since the early 2000s, namely Land Conflicts, Land Use Change & Impacts and Climate Change.

Mentions of the Cerrado and Atlantic forest occur since the early 2000s and in the case of the Gran Chaco since 2007. These biomes are mainly associated with Deforestation, Wildlife & Biodiversity, Land Use Change and Impacts, Land Conflicts (in the case of the Gran Chaco and Cerrado) and Water Resource Management (in the case of the Atlantic Forest). However, both the number of mentions and the degree of association with our topics is less significant than for the Amazon biome throughout our study period.

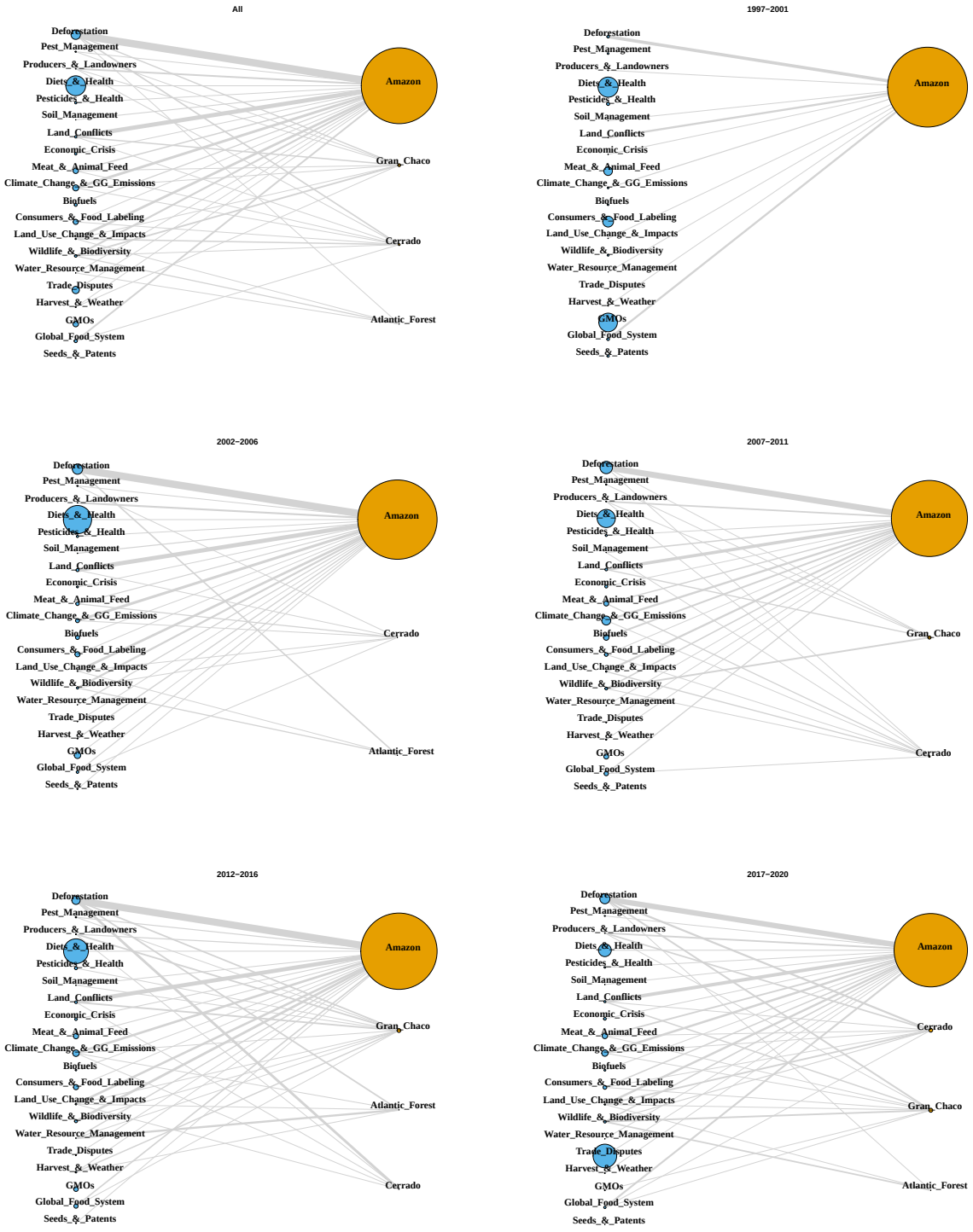


Figure 4.6: Topic-biome bipartide network graphs for EU print media, illustrating the evolution of associations between topics and mentioned biomes over time. Circle sizes indicate relative topic/entity prevalence and lines indicate edge weights. Only edges with weights above the median were included.

For other fields, the picture changes. For instance, in the advocacy field (graph provided in the supplementary material), the Amazon biome is only as dominant as in the EU journalistic field for the time interval 2007-2011. At other times (2017-2020), mentions of the Cerrado are comparably prevalent. Further, for Land Conflicts the association is strongest with the Cerrado biome. In the EU political field only the Amazon biome is referred to at all.

Figure 4.7 illustrates the evolution of entities representing organizations or institutions mentioned in the EU journalistic field and their associations with our 20 topics as a bipartide network graph. For each time interval, the 20 most prevalent entities are selected. In order to enhance readability, only edges within the upper 12.5 % quantile in terms of their weights were plotted. We observe that for the entire study period, the EU is the most prevalent entity mentioned in this category, followed by several companies, NGOs, government institutions and intergovernmental organizations. When looking at the evolution over time, there are three clearly dominating entities in the late 1990s: the EU, the biotech company Monsanto and the NGO Greenpeace. All these show associations with GMOs and Consumers & Food Labeling, two of the dominant topics of that time interval.

We further want to point to the following observations: as the focus on GMOs and Consumers shifts towards Deforestation and Climate Change, the prevalence of entities from the biotech industry (e.g., Monsanto and Novartis) fades and gives way to grain traders (e.g., Cargill), food processing industry (e.g., Unilever), retailers (e.g., Tesco) and food chains (e.g., McDonald's). Further, mentions of NGOs are also mainly associated with Deforestation and Climate Change since the mid-2000s. In the most recent time interval (2017-2020), the association between the topic Deforestation and mentions of the EU is included within the 12.5 % edge weight quantile for the first time, simultaneously with the appearance of the Mercosur trade bloc among the 20 top entities.

4.4.6 Topic prevalence corresponds to key real-life events

When cross-checking the evolution of topic prevalence in EU print media with real-life events, we found strong links between peaks of topic prevalence and certain key events or developments (Figure 8).

Starting with the topic Meat & Animal Feed, the strong increase in prevalence in the years 2000 and 2001 occurs at a time when the EU Commission debated and subsequently decided on a full ban on meat and bone meal (MBM). Feeding MBM to animals had been accompanied by ethical concerns and linked to the outbreaks of Bovine spongiform encephalopathy (BSE) since the late 1980s. The ban was implemented in 2001 and led to an increase in demand for other protein sources in animal feed, such as soybean cake. This interpretation is further confirmed by the strong links between the topic and the entities EU and the European Commission for 1997-2001 (Figure 4.7).

Deforestation shows marked peaks in prevalence between 2005 and 2009, as well as again in 2019. The first peak coincides with broader public concern about high deforestation rates in the Amazon

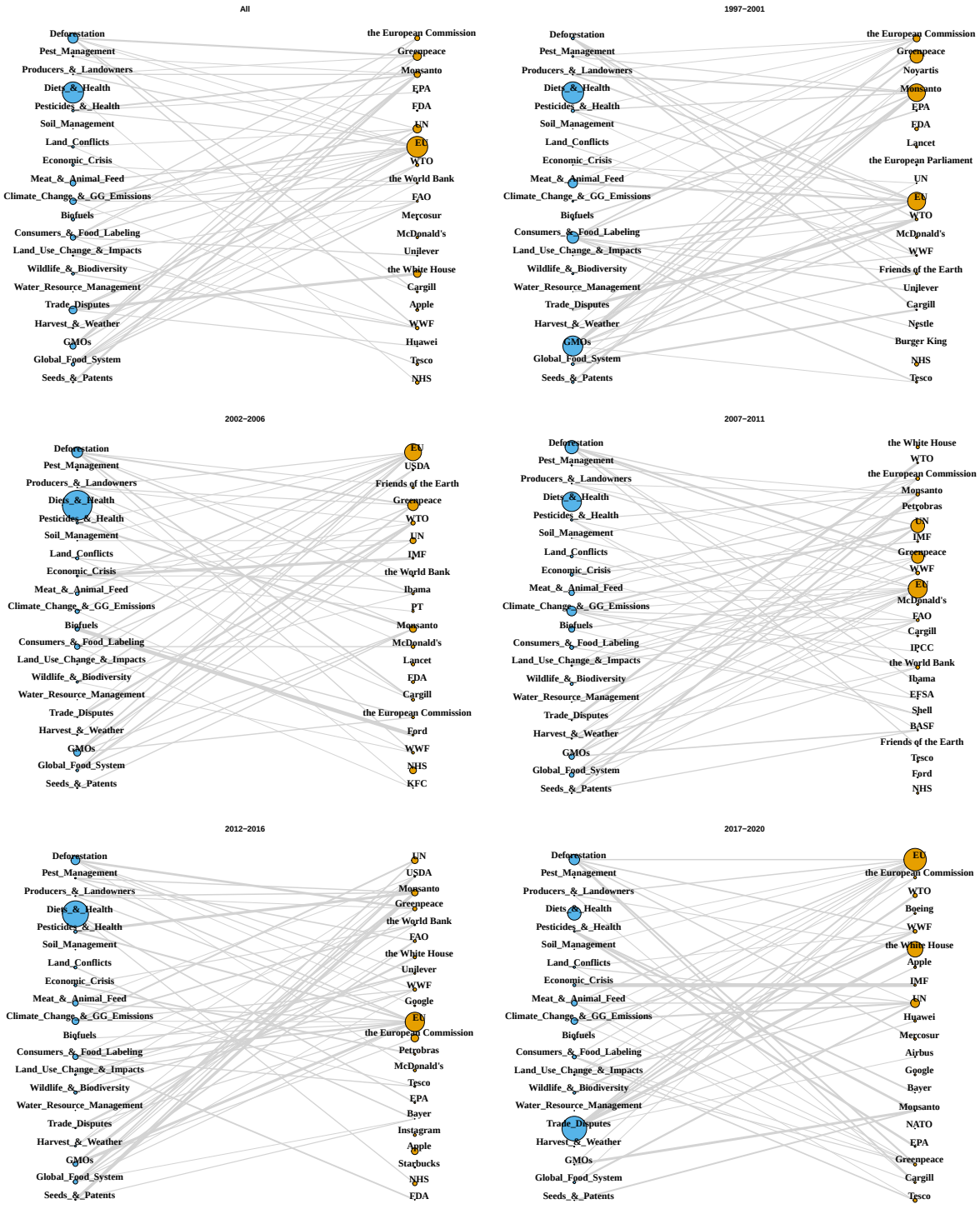


Figure 4.7: Topic-organization bipartide network graphs for EU print media, illustrating the evolution of associations between topics and mentioned organizations over time. Circle sizes indicate relative topic/entity prevalence and lines indicate edge weights. Only edges with weights within the upper 12.5 % quantile were included.

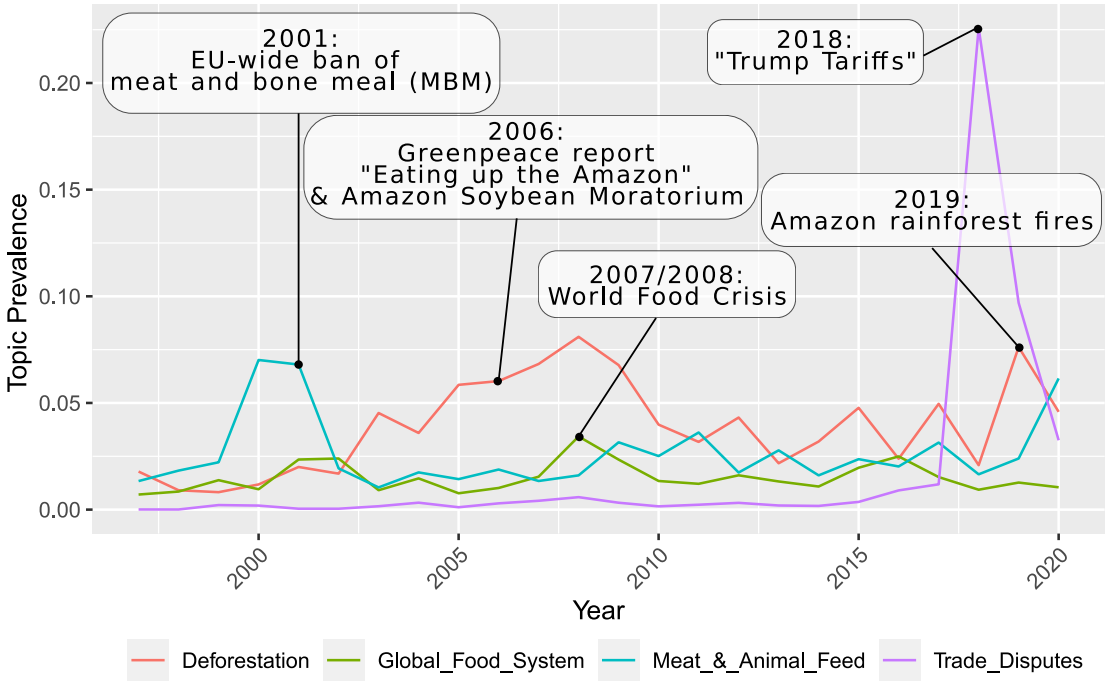


Figure 4.8: Evolution of topic prevalence for selected topics in EU print media with links to key events.

region, leading to the publication of the Greenpeace report "Eating up the Amazon" (2006) and the signing of the Amazon Soy Moratorium (2006) by different stakeholders (see also strong links to Greenpeace in Figure 7). In 2019, broad media coverage followed the fires in the Amazon rainforest.

The topic Global Food System peaks in 2008, at the height of the 2007/2008 food crisis, when food prices skyrocketed worldwide (consider also the strong links to the entities UN and Worldbank). It further shows strong links with the topic Biofuels, which also peaks in that period. Biofuels were often seen as partly responsible for food price hikes at the time.

Lastly, the topic concerning Trade Disputes shows a dramatic peak in 2018, the year in which the Trump administration unilaterally imposed tariffs on different products from China. This was followed by similar tariffs imposed by China on US products, including soybeans (see also the strong links to entities such as the White House, the WTO and companies such as Huawei).

4.4.7 A closer look at media attention toward deforestation

When examining monthly prevalence values for the topic Deforestation for media outlets from the EU and Brazil, as well as transnational news agencies (see supplementary material), we observe that prior to 2003, prevalence levels are consistently higher for Brazilian news media and peaks in prevalence occur quite independently between the three sources. While prevalence remains highest for Brazilian outlets during most of the study period, the levels converge between the different sources and peaks co-occur more frequently.

The outputs from our keyness analysis show that for most years in our study period frequently used terms compared to prior years differ between outlets. However, there are several years with strikingly similar features between sources. In 2003, both Brazilian and EU media outlets appear to report on then newly elected President Lula and Minister of the Environment, Marina Silva. Both sources show peaks for the month of June, when Silva convened an important meeting on deforestation between scientists and civil society. The Brazilian outlets show another peak for the month of July, when Lula issued a presidential decree, laying out policy instruments to combat deforestation. Another common feature is the frequent mentioning of President Jair Bolsonaro in the years 2018 and 2019.

The closest resemblance, however, can be observed for the year 2006, in which key terms include the trader Cargill, the NGO Greenpeace and the fast-food chain Mc Donald's in all sources. Peaks in prevalence are identifiable for the months April, when the Greenpeace report "Eating up the Amazon" was released, and for July, when the Amazon Soy Moratorium came into force. Figure 9 illustrates the co-occurrence networks for the selected months and the entire year 2006 for all three sources. While the Greenpeace report and the moratorium dominate the coverage in EU print media and news agencies for the entire year, in Brazilian print media this is only the case for the months of July and (to some degree) April. Another event that appears to play a major role in the coverage of news agencies that year is the blocking of Cargill's port facility in Santarem by a Greenpeace ship.

4.5 Discussion

Our findings provide indications regarding the evolving debates on soybean expansion and associated impacts within interlinked transnationalizing public spheres, as well as the legitimacy or lack thereof these debates confer to governance interventions at different scales.

The EU print media included in our analysis shows a clear shift from topics directly related to consumer concerns over the safety of GMOs, food labeling and other issues of direct relevance to EU citizens towards more distant or abstract phenomena, such as deforestation in producing countries and climate change. This is accompanied by mentions of a broader set of actors in the production network.

While these topics show a general upward trend, they still seem to be quite event-focused, revealing distinct peaks during times of controversial or disaster-like events. This shift in focus from biosafety of GMOs and consumer health towards deforestation and climate change can also be observed in the documents collected for the advocacy field. However, this field also emphasizes various issues that do not attain the same prominence in European print media, such as those dealing with land conflicts or seeds and intellectual property rights. Further, problems concerning the general structure of the global food system are dominant and central (highly connected to other topics) in the advocacy field, while they never play such a dominant role in the EU journalistic field.

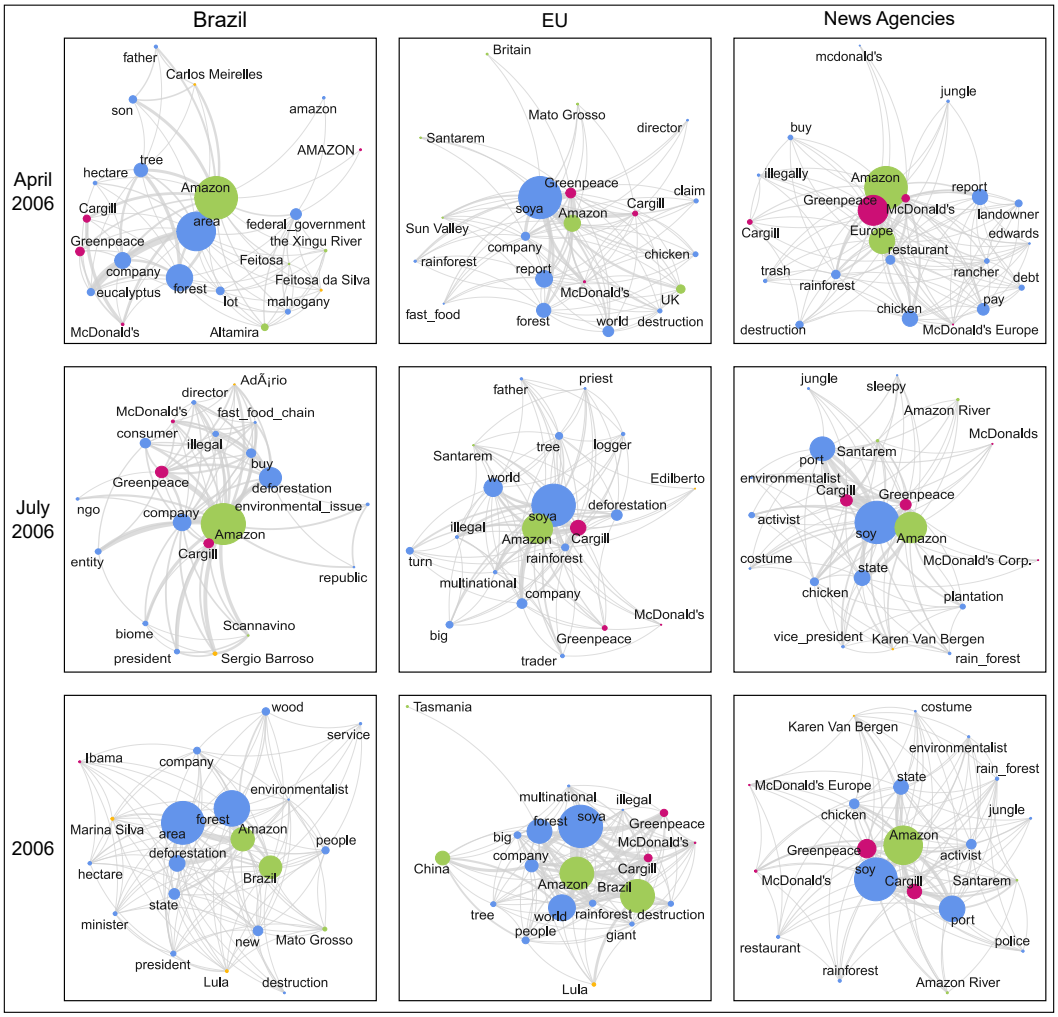


Figure 4.9: Co-Occurrence networks for the topic "Deforestation" and selected regions within journalistic field. Green nodes represent countries or regions, red nodes organizations or companies and yellow nodes named individuals.

There is a clear regional focus on the Amazon biome, particularly concerning topics related to deforestation and climate change in the European journalistic field, which is more pronounced and constant than in the advocacy and academic fields. Brazilian and Argentinian print media put more emphasis on topics dealing with economic impacts and producers' concerns. Brazilian print media pay more attention to land conflicts than their European counterparts, while issues around seeds and intellectual property are a major concern in Argentina, likely due to the yearlong legal disputes over farmers' rights to reproduce GMO seeds and the enforcement of intellectual property rights.

We further observe two simultaneous dynamics over the period 2017-2020: The Mercosur region appears among the most mentioned entities and the association between the EU and the topic "Deforestation" becomes significant for the first time (within the highest 12.5 % edge weights). This suggests increasing attention towards the responsibility of the EU as a major importer of soybeans and other FRCs with the debate around the EU-Mercosur trade agreement.

The event driven nature of environmental journalism as a form of contemporary news reporting has been pointed out before (Hansen 2011; Pezzullo and Cox 2018). This snapshot-like focus on certain issues (e.g. deforestation during the 2019 Amazon rainforest fires) does not provide a broader historical context for audiences (e.g. continuous loss of native vegetation in various biomes since the 1990s). Hansen (2011) also points to the "authority orientation" of news coverage, which will lead to a dominance of scientists' and politicians' key concerns (e.g., the global implications of greenhouse gas emissions from land-use change) over those of directly affected communities (e.g., land conflicts or pesticide-induced intoxication).

Our longitudinal analysis of issues related to soybean expansion confirms findings of other empirical studies. These are often grounded in theories of issue attention cycles (Downs 1972), which aim to describe consecutive stages of attention to issues over time. Researchers have traced media coverage on specific issues, but also the evolution of coverage on entire domains (e.g., the environment) (Hansen 2015b). In this regard, our findings related to the shifting focus over time for the EU journalistic field show close resemblance to Djerf-Pierre's (2013) study of news coverage relating to different environmental issues in Swedish television. This is particularly true for her findings concerning a focus on "the environmental impact of food production (particularly GMOs, 'mad cow disease' and the mistreatment of animals in industrialized meat production) in the late 1990s and early 2000s; and finally, the heavy focus on climate change in the late 2000s" (Djerf-Pierre 2013, p. 501). The peak in attention on climate change around 2006/2007 has also been observed elsewhere and related to the release of the documentary film An Inconvenient Truth (2006) and the findings of the 2007 report issued by the Intergovernmental Panel on Climate Change (IPCC) (Pezzullo and Cox 2018).

With regards to the significance of our findings for public sphere theory, the shift from topics more relevant to individuals' personal life and in their role as consumers (GMOs, health, labeling) towards topics of environmental impacts at distant places (deforestation) or on a global scale (climate change) over the study period, may lead to the conclusion that public spheres become more porous and receptive towards issues from outside their own constituency. They appear to circulate the concerns not only of the citizens of a given polity, but also of those affected by the production networks, whose final products are consumed by those citizens. This could introduce these issues into the centers of decision-making and thereby provide legitimacy to the governance outcomes in the sense of an all-affected or "all-subjected" principle as suggested by Fraser (2009). This could also be understood as a move towards what O'Brien et al. (2009) see as a necessary new form of social contract with a "larger conceptualization of 'we'", an expansion of moral communities, or evidence of what Eakin et al. (2014) call "feeling (empathy) at a distance".

However, while deforestation linked to soybean expansion had already been significant in the Cerrado biome throughout the 1990s (Beuchle et al. 2015), it only becomes a major concern in EU

print media when the agricultural frontier moves further north and high annual deforestation rates in the Amazon biome are linked to soybean expansion in the early 2000s. The strong focus on the Amazon biome and the relatively low prevalence of topics related to issues directly affecting local populations (e.g., land conflicts, pesticide induced health problems and disputes over farmers' rights to reproduce GMO seeds) reflects a fundamental concern with the loss of an emblematic ecosystem and the global threat of climate change rather than with the lives of people on the other side of the value chain. Therefore, in can be argued that EU print media have been more sensitive to the fate and state of ecosystems, rather than the wellbeing and struggles of people managing and living within such distant Nature.

Thus, it is unclear, whether increasing attention towards deforestation really is an outcome of increasing porosity between public spheres. EU news media appear to pay attention to major developments in Brazilian political events (e.g., the stances toward deforestation adopted by the Lula administration or later by Jair Bolsonaro). However, in our study period the journalistic field shows closest resemblance between regions when a major NGO publishes an alarming report, stages a sensational protest, and pushes for a moratorium between private stakeholders. More attention towards deforestation may therefore rather be the result of highly organized campaigning by increasingly powerful conservation NGOs, mainly based in the Global North.

It is important to note that this influence is not only limited to the level of attention an issue receives. Rather, large environmental NGOs also shape the framing of these issues and, following Dauvergne (2016), often tend to pursue an "environmentalism of the rich", emphasizing acts of eco-consumerism and corporate social responsibility. Porosity may then work in the opposite direction: governance becomes a matter of decisions taken by corporate actors, mediated by major NGOs and accountable mainly to final consumers, rather than an outcome of inclusive transnational public deliberation.

This casts a shadow on the promises of deliberative democracy, as the amplification of voices from professional public relations departments and the gatekeeping function of major media outlets do not allow for a level playing field between different stakeholders. Journalism's gatekeeping function may in fact prevent rather than stimulate an open public debate on fundamental asymmetries in the global food system. The increasing reliance on wire services from Western based news agencies, due to the high expense of foreign correspondents, may further aggravate this concern, as these tend to reflect the interests of the Global North (Boyd-Barrett 2000; Hafez 1999; Johnston and Forde 2011; Lewis et al. 2008).

Moreover, the dominance of a single biome in media attention towards soybean expansion may help explain why there has never been a similar effort of private food law to prevent the further loss of native vegetation in the Cerrado as there has been for the Amazon. Evidence for high rates of deforestation related to soybean farming in the Cerrado exists (Rausch et al. 2019) and recently, the

carbon footprint of soybean exports from the Cerrado biome has been calculated to exceed those of other biomes in Brazil, largely due to emissions from land use change (Escobar et al. 2020). Calls by experts for a Cerrado soy moratorium (Soterroni et al. 2019) have been met with great reluctance by the industry.

The negotiations over the EU-Mercosur trade agreement appear to have temporarily pushed the question of the European Union's responsibility for environmental impacts associated with its imports into media discourse. Policy options to address this issue are currently being assessed by the European Commission (Bager et al. 2020; European Parliament 2020) and the European Parliament has recently voted for an Amendment to the EU-Mercosur trade agreement, signaling reluctance to ratify it, mostly over environmental impacts (Boffey 2020). However, the concerns voiced by European politicians primarily seem to echo the focus on Brazil's handling of commodity expansion in the Amazon biome, particularly after the large media attention to the 2019 Amazon rainforest fires.

It remains questionable whether the general increase of attention to abstract or distant impacts of imported agricultural commodities, such as soybeans, will lead to a widespread fundamental debate on the implications of the current global food system for all groups affected by it. The findings of this study point instead to a pattern of recurring focus on individual issues, mainly linked to limited geographical regions and concerns. Also with regards to the political field, the outcomes of recent renegotiations on the EU's agricultural subsidies have been read by critics as mainly a continuation of the present state of large-scale, input-intensive agriculture and animal husbandry, largely dependent on the import of animal feed (Cwienk 2020).

Further, theorists of communication studies have pointed to the individualization of media content consumption in the age of social media and even proposed the end of agenda-setting (McCombs 2005). Bennett and Iyengar (2008) suggest that the fragmentation of audiences leads to selective consumption of information, which reinforces the individual's prior views and concerns. For our findings, this could imply that some of the less prevalent issues may only reach limited audiences, which are largely already informed about these. However, others have pointed to a more complex "inter-media agenda setting process" (Anderson 2014). It therefore remains open how the more interactive, networked configuration between traditional media and individualized content generation will affect the construction of environmental issues in public spheres and what this means in terms of legitimacy and efficacy regarding processes of environmental governance.

4.6 Conclusion

In this contribution we have mobilized a text mining approach to trace the evolution of socio-ecological issues constructed around the expansion of soybean production and trade in the last two decades. Our focus has been on the journalistic field within the EU in relation to other fields and re-

gions. Through this approach we have analyzed the functioning of contemporary, transnationalizing public spheres and their legitimacy and efficacy with regards to environmental governance.

We have shown that in the EU journalistic field, a high prevalence of issues around GMOs, health, and consumer labeling in the late 1990s has given way to more abstract and distant phenomena, such as deforestation in producing regions and climate change since the mid-2000s. This has been accompanied with a broader perspective of different stakeholders, but also with a strong regional focus on the Amazon biome. Less attention has been directed at immediate concerns for local communities, such as land conflicts or disputes over intellectual property rights, which are more prevalent in the advocacy field or the journalistic fields in Brazil and Argentina. These findings are broadly aligned with other empirical studies in the field of environmental communication.

Our findings suggest that there is some porosity between different public spheres and that reporting increasingly considers more distant and abstract impacts. However, the overarching concerns in EU news media seem to relate to the loss of emblematic ecosystems and the prospects of global warming as disaster-like events rather than to the struggles of local communities. This may help explain the relatively narrow focus on current governance mechanisms and the reluctance of corporate actors to expand these to other regions.

We also show that, even as the level of attention toward a given issue, such as deforestation, converges between different sources, the focus of reporting can still differ quite considerably. Major events and the public relations efforts of professionalized actors may temporarily align this focus. However, the themes thereby introduced can dominate reporting in Western media far beyond their immediate aftermath. The asymmetry in different stakeholders' ability to direct attention and construct dominant themes casts doubt on the promises of deliberative democracy in transnationalizing public spheres.

Even as the debate on the Mercosur trade agreement has provided a new spotlight on the European Union as an importing region of animal feed, this limited focus may lead to addressing specific regional outcomes through technical solutions and hinder a more fundamental debate on asymmetries in the global food system. Finally, in the light of the current restructuring of networked and individualized news production and consumption, we propose to include an analysis of social networks and the sharing of and interactions with news content in future studies.

Chapter 5

Re-MEDIAting distant impacts - How Western media make sense of deforestation in different Brazilian biomes

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This chapter presents work published in the following journal article:

Mempel, F. and Bidone, F. (2022). Re-MEDIAting distant impacts - how Western media make sense of deforestation in different Brazilian biomes. *Environmental Sociology*, pages 1–16

Abstract

Brazil plays a central role in Western depictions of and narratives on tropical deforestation. In this contribution, we gather a large text corpus from Western media outlets with articles on deforestation in the Brazilian Amazon and Cerrado biomes. The sources include outlets from Europe, the US, Canada and Australia and span a time period from the late 1980s to 2020. Leveraging several text-mining approaches, such as topic modeling and automated narrative network analysis, we disentangle the way that Western media have tried to make sense of deforestation in the Amazon and the Cerrado biomes. We show that the former has received disproportionately more news coverage, specifically in times of international concern over the Brazilian government's commitment to tackle deforestation. Further, Western media frequently report on the struggles of indigenous populations in the Amazon, often following an essentialist depiction of these communities, while in the case of the Cerrado, traditional populations are hardly mentioned at all. Our findings provide a methodologically innovative and empirically grounded case for the often raised concern over a relative invisibility of the Cerrado biome and its traditional populations, which may help explain observed disparities in governance interventions.

5.1 Introduction

Brazil plays a central role in Western depictions of and narratives on tropical deforestation. It is among the countries with the largest share of remaining native vegetation, but simultaneously has emerged as one of the planet's leading deforesters. Since the 1970s, the country turned from a net food importer to a modern agricultural powerhouse and a leading exporter of products such as soybeans, beef and coffee (Stabile et al. 2020). This has been enabled by policies of targeted settlement in frontier regions, readily available rural credit, large infrastructural projects, dedicated agricultural research and successive commodity booms, most recently triggered by strong demand from East Asia (Oliveira and Schneider 2016). Agricultural expansion has encroached into various biomes, such as the Amazon rainforest and the Cerrado, a tropical Savannah biome with exceptionally high endemic biodiversity, which has already lost more than 50 percent of its native vegetation (Lahsen et al. 2016).

While different commodity booms in the Amazon go back at least to the first rubber boom in the late 19th century and regional economic development has been pushed for by the Brazilian military since the 1930s (Hecht and Cockburn 2011), in the Cerrado this process started later, when targeted government programs inserted the region into the realm of capitalist production in the 1970s. This transformed the image of the Cerrado, which had previously been rendered invisible due to its reputation as barren land without economic value (da Silva and Chaveiro 2010). What appears to remain invisible though, is the cultural and socio-environmental diversity of traditional populations occupying the Cerrado, who have often found themselves in conflict with large development projects and agribusiness (Russo Lopes et al. 2021; Gualdani and Sobrinho 2018; Mazzetto Silva 2009).

Federal legal protection, international agreements and corporate commitments have sought to address environmental impacts associated with the recent commodity booms. This resulted in a significant decline of deforestation rates in the Amazon biome after 2004 (Heilmayr et al. 2020). However, the strong political advocacy of large landowners, corporate agribusiness and the changes of political leadership following the ouster of former president Dilma Rousseff challenge this development. Further, the Cerrado biome has not received the same legal protection, and is not covered by most zero-deforestation commitments, leading to rapid landuse change and conversion of native vegetation (Lahsen et al. 2016; Rausch et al. 2019; Green et al. 2019). Between 2002 and 2011, deforestation rates in the Cerrado were more than twice as high than in the Amazon, putting pressure on an ecosystem, which is vital for the regional hydrological cycle, a biodiversity hotspot, a source of livelihood for local populations and leading to the decimation of large carbon stocks (Strassburg et al. 2017).

The perceived asymmetry in attention towards different biomes is not limited to the Amazon and Cerrado. Recently, scholars introduced the concept of Biome Awareness Disparity (BAD), to describe a general failure to appreciate the significance of diverse biomes in terms of conservation (Silveira et al. 2021). BAD generally appears to favor tropical forests over open biomes, such as grasslands,

savannas, and shrublands, which have been shown to receive significantly less attention compared to the area they occupy (Silveira et al. 2021) and are less often the focus of conservation and restoration practice (Temperton et al. 2019; Qin et al. 2022). Further, even as the expansion of soybean monocultures is associated with larger deforestation risks in the Cerrado, discourse in Western media and political institutions appears to have focused on the Amazon (Mempel and Corbera 2021).

This contribution analyses the asymmetry in attention between these biomes and the construction and framing of the problem of deforestation in Western media outlets. Starting from the assumption that social problems do not manifest themselves directly, but through processes of claims-making between different actors and mediated though different channels (Hannigan 2006; Hansen 2015a), in this contribution we ask:

1. How much coverage has deforestation in the Brazilian Amazon and Cerrado biomes received in Western media outlets at different time periods in the past decades?

2. What drivers, impacts and responses are dominating media narratives on deforestation in these biomes at different time periods?

3. What actors receive most attention and what actions are these commonly associated with in narratives on deforestation in the different biomes?

4. In how far does the amount of coverage and the framing of deforestation in the two biomes correspond to asymmetries in governance initiatives to halt forest loss?

To address these questions, we gathered a text corpus consisting of 9,113 news articles from Western news outlets as well as global news agencies and used a text mining approach to select relevant articles, classify topics, extract named entities and identify relevant actors and the associated actions they are portrayed to perform. The following section locates our research in ongoing debates on global environmental governance and the role of Western media therein. Section 3 details the methods used in our analysis, section 4 presents the findings, section 5 discusses the results and section 6 ends with our conclusions.

5.2 Linking Western media to environmental governance of tropical deforestation

The role of communication and discourse in the realm of environmental issues has interested scholars since the 1970s, not least due to the rapid rise of attention toward a domain, which only began to be fitted with its own vocabulary and themes in the postwar era and emerged as a ground of political contestation with dedicated social movements and advocacy groups (Downs 1972; Hansen 2015a). Here we are interested in the role of Western media in the "politics of signification" (Hall 1982) in the

context of global environmental governance of tropical deforestation. In other words, we start from the assumption that mass media play a role in defining and giving meaning to issues of deforestation both for stakeholders and the wider public and thereby influence the formulation and legitimization of governance interventions.

While the term "global environmental governance" has different connotations and uses (Biermann and Pattberg 2008), these still share a set of defining characteristics, all of which can be observed in the context of commodity-driven tropical deforestation. Like other environmental arenas, over the past decades forest politics has seen experiments with novel forms of interventions characterized by new configurations of actors, including nation states, subnational governments, intergovernmental organizations, international courts, private actors and civil society. Among these interventions are market-based certification programs, such as the Forest Stewardship Council (FSC), commodity-specific multi-stakeholder roundtables (e.g., Round Table on Responsible Soy), corporate zero-deforestation commitments and public-private voluntary declarations (e.g., New York Declaration on Forests). Further, international funding has become increasingly important for conservation efforts, particularly for projects in the Global South (Waldron et al. 2013; Qin et al. 2022). In Brazil this new forest politics can be traced back to the Pilot Program for the Protection of Tropical Forests (PPG7), which was launched during the UN's Earth Summit in Rio de Janeiro, following international pressure in the aftermath of the assassination of Chico Mendez and public growing concern over deforestation in the Amazon (Bidone and Kovacic 2018). The program was largely funded by European countries, resources administered by the World Bank and the projects included efforts from the Brazlian government, as well as NGOs, the United Nations Development Program (UNDP) and donor agencies.

These "post-sovereign" (Pattberg 2007) approaches to forest politics are also envisioned as solutions to increasingly distant and globally entangled drivers of forest loss, strongly influenced by international demand for commodities sourced from deforestation frontiers. However, questions remain concerning the effectiveness and legitimacy of these interventions. For example, even though the relevance of individual corporate actors, who have consolidated significant shares of forest risk commodities in their supply chains, is clear (Folke et al. 2019), it remains disputed what part they can and should play in resolving environmental problems (Dauvergne and Lister 2012; zu Ermgassen et al. 2022). For our purposes the important observation is that these new forms of forest politics involve processes of signification, deliberation and legitimization in public spheres distant from the deforestation frontiers themselves. Given the importance of Western actors in corporate control over forest risk commodity value chains, conservation funding and international environmental advocacy, we will focus on Western media discourse.

In this context, we are interested in when (Mangani 2021) and where (Silveira et al. 2021) deforestation becomes a matter of concern and how it is framed (Ladle et al. 2010; Park and Kleinschmit

2016). By frame, we mean a "schema of interpretation" (Goffman 1974) or "central organizing idea or story line that provides meaning" (Gamson and Modigliani 1987) and communicates "why an issue or decision matters, who or what might be responsible, and which political options or actions should be considered over others" (Nisbet and Newman 2015). Problem framing is value-laden, carries presuppositions or assumptions from particular contexts and can remain silent on some aspects while emphasizing others (Bacchi 2009). Following Snow and Benford (1988) we broadly distinguish three types of frames: diagnostic frames, which identify problems and attribute responsibility; prognostic frames, which suggest solutions and strategies; and motivational frames, which provide the rationale for action by stressing moral considerations or urgency of impacts.

When, where and how deforestation receives media coverage matters rather independent on the specific conceptualization of mass media and their role in the broader socio-political context. Mass media have been characterized as an important arena for rational debate in a form of deliberative democracy (Habermas 1996) or rather as a political actor largely reflecting elite views in a "capitalist information production" (Mosco and Herman 1981). We agree with Kleinschmit (2012) that while it appears that mass media do not fully comply with the functions of democratic deliberation due to inherent constraints, these functions still provide useful normative expectations to evaluate empirical findings against. This is true particularly in the age of post-sovereign politics, where the public arena plays a role in the regulation of transnational corporations (TNCs) and other private actors with large leverage in environmental affairs (Newell 2001).

Finally, news media framing on tropical deforestation does not occur in a historical void. These frames engage with broader evolving discourses on environmental affairs (Herndl and Brown 1996; Dryzek 2013). Further, they are fed by socially accepted narratives and imagery on particular places, for example through the proliferation of travel narratives and fictional literature about the Amazon, which has been linked to its fetishizing as a symbol of wild nature (Vieira 2016).

5.3 Methods

We use a text mining approach to analyze the occurrence and nature of Western media coverage on deforestation in the Brazilian Amazon and Cerrado biomes. The process of data acquisition, data processing and data analysis is illustrated in Figure 5.1.

We sourced news articles from factiva.com (Dow Jones & Company 2020). Two separate searches were performed for the Amazon and Cerrado biomes to gather articles dealing with deforestation in each (see search strings in supplementary material). We included all available news outlets from Europe, the United States, Canada, Australia, and New Zealand, as well as news wires from all available international news agencies. The study period was defined from 1980 to 2020. Only articles in English language were selected. The process of data collection ensured a relatively large number of relevant news articles through the study period and further a broad spectrum of different publication

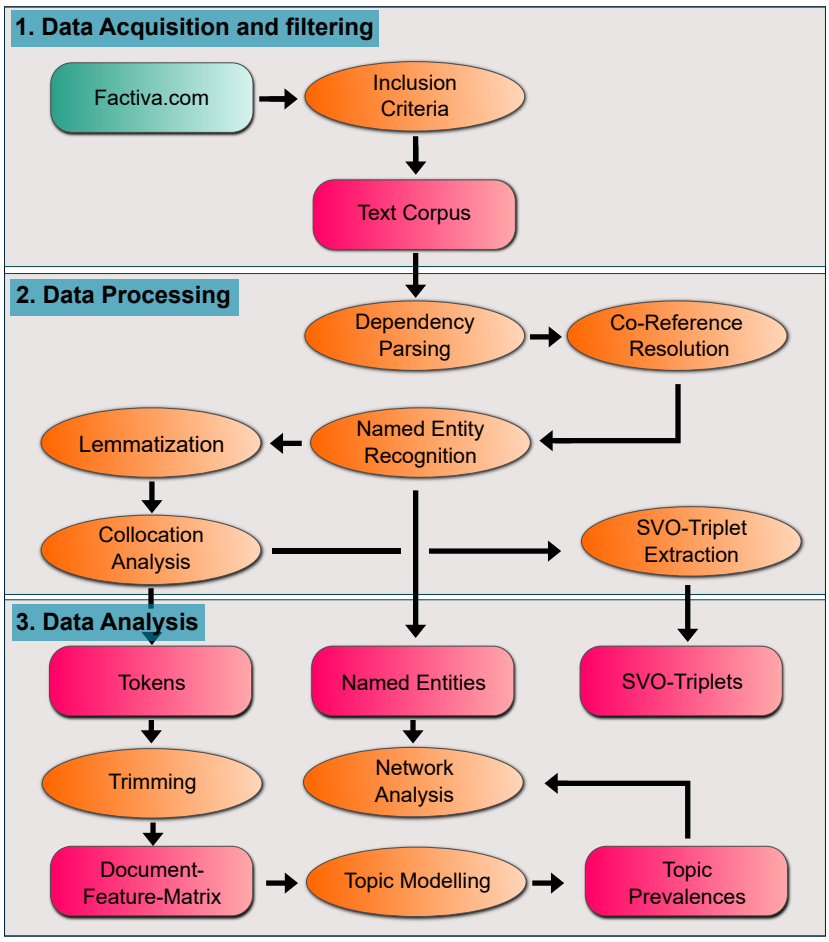

Figure 5.1: Flow diagram of methods used.

types. However, it also means that the composition of news outlets changes over the time period, as not all news sources are available for the entire study period, giving a much more sparse selection especially for the 1980s. To correct for this, when calculating corpus statistics, we calculate prevalence as the number of articles in a given year divided by all articles that are available for all included news outlets on factiva.com for the same year. In total, 485 different news outlets are included in the sample.

To ensure that the selected articles in fact focus on deforestation in the respective biomes, we further defined a set of inclusion criteria. Full documents were only included if the respective biome was mentioned in the headline, the lead paragraph or if the following condition is satisfied:

$$N \geq 1 + \frac{n}{4}$$

, where N denotes the number of mentions and n the total number of paragraphs in the document. For all other documents, only those paragraphs mentioning the respective biome were included.

Included documents were pre-processed with the natural language processing library SpaCy (Honnibal and Johnson 2015) for the Python programming language (Van Rossum and Drake 2009). Texts were parsed to identify grammatical dependency structures and resolved for co-

references. Named entities were identified and collected separately. Compound words were detected using collocation analysis. Tokens (words and compound words) for the topic model were trimmed to include only nouns, verbs, adjectives, and adverbs and to exclude named entities, which were collected separately. We extracted Subject-Verb-Object (SVO) triplets from all documents, loosely following the approach outlined by Sudhahar et al. (2015a,b). This allows to identify key actors and objects as well as their mutual relations (through actions), in order to approach an automated analysis of narrative content (Sudhahar et al. 2015a), thereby going beyond merely identifying topics and themes.

The tokens were converted to a document feature matrix (DFM) using the quanteda text mining library (Benoit et al. 2018) in the statistical programming environment R (R Core Team 2020). A DFM is a statistical representation of a text corpus, indicating the frequency of all occurring terms for each document. Word order is not relevant in this representation. The DFM was supplied to the stm package (Roberts et al. 2019) to compute a structural topic model (STM) (Roberts et al. 2014). Topic models are a statistical framework used to identify topics in a text corpus (Wesslen 2018). They belong to the group of unsupervised machine learning algorithms and do not depend on training datasets, but provide classifications based on patterns identified within the data itself (Grimmer and Stewart 2013). Compared to other topic modeling algorithms, the STM allows for the inclusion of document metadata as covariates. Here we included publication year and the biome (Amazonia or Cerrado) as covariates. After evaluating several tests statistics, we decided on using a model with 40 topics (the model parameter K).

We labeled and aggregated the resulting topics and grouped them into the following categories: *Drivers*, for those related to processes that drive deforestation in the respective biomes, *Processes*, for topics related to other processes accompanying deforestation or otherwise linked to it, *Impacts*, for those related to impacts resulting from deforestation, *Responses*, for those referring to measures or reactions responding to deforestation, and *Other*, for topics not associated with any of these categories. We then compared the topics' prevalence for different time periods and calculated cosine similarities between the vectors indicating the prevalence of each topic within each document. The similarity matrix was then converted into a network representation with node size illustrating topic prevalence and edge width indicating the degree of co-occurrence between topics. The same was done with topics and extracted named entities referring to organizations and institutions.

SVO triplets were filtered to include only those, in which the subject can be identified as a relevant actor (a subject, which is sufficiently defined to represent a social group, profession, economic sector, institution etc.). We selected the 25 most frequently occurring subjects for each biome and study period and plotted each of these subjects with its respective 25 most common SVO structures as network diagrams, in which nodes represent subjects and objects and edges represent verbs. These

semantic graphs illustrate the main actors, objects and actions that constitute the narration contained in the news articles on deforestation in the respective biomes (Sudhahar et al. 2015a).

Finally, a sample for manual coding was selected from the text corpus in order to enhance and validate the automated text analysis with human coding. The sample consists of 222 texts, which were selected to represent the distribution of topics found by the topic model for each time period. We randomly selected 30 articles for each time period and biome in 10,000 iterations. For each time period and biome the iteration which most closely resembled the topic prevalence distribution found by the topic model (cosine similarity) was selected. Due to lack of articles for the Cerrado biome in the earliest time period, the selection falls short of the expected number of articles (240).

The selected articles were manually coded according to three questions, loosely based on the identification of diagnostic and prognostic frames:

1. What actors are portrayed as being responsible for deforestation or for enabling it (diagnostic frames)?
2. What responses and solutions are identified, which are being implemented or should be implemented to address the problems (prognostic frames)?
3. What urgent consequences and problems associated with deforestation are identified (motivational frames)?

Coding was performed in the free application QCAMap (Mayring 2014; Fenzl and Mayring 2017), consecutively exporting all results into the R programming environment for analysis.

5.4 Results

5.4.1 Uneven and fluctuating attention to deforestation

After applying all selection criteria and removing duplicates, the text corpus consists of a total of 8,072 documents of which 7,330 are full news articles and 742 are selected paragraphs. The total number of documents dealing with deforestation in the Amazon biome (7,538 documents) is more than 14 times greater than the number of documents found for the Cerrado biome (534 documents). Further, most texts on the Amazon are full news articles, while most texts on the Cerrado are paragraphs extracted from texts, which may have differing main topics (see Figure 5.2).

When examining the distribution of sourced texts over time (see Figure 5.3) we see several distinct peaks in years, in which deforestation in the selected biomes appears to have attracted more attention, most notably for 2019 in the case of the Amazon biome. Since the availability of the selected outlets in factiva.com changes over time and is generally much lower for years before 2000, we calculated the prevalence of texts dealing with deforestation in the two biomes, by dividing the number of

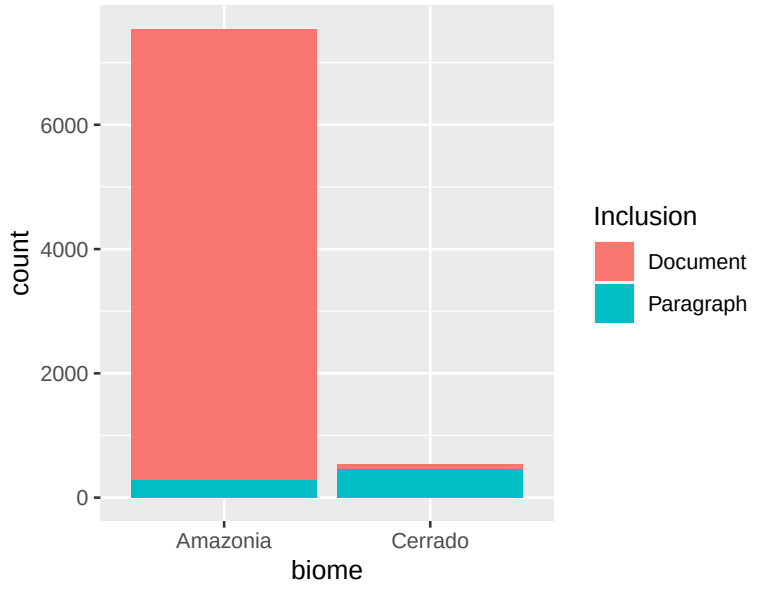

Figure 5.2: Document count by biome and inclusion type.

sourced texts by all articles available from all selected outlets in the same year. Another distinct peak of attention towards deforestation in the Amazon becomes visible for the year 1989.

Figure 5.3: Evolution of document count and prevalence for each biome over the study period.

Further, of the 485 different news outlets included, only 46 (9.5 percent) featured at least one full length article on deforestation in the Cerrado biome in the entire study period, compared to 470 (96.9 percent) for the Amazon biome. When including individual paragraphs, 139 news sources (28.7 percent) mentioned deforestation in the Cerrado, compared to 474 for the Amazon (97.7 percent).

5.4.2 Framing deforestation in the Brazilian Amazon and Cerrado

In the following sections we present our results from the topic model, extracted named entities, SVO-triplets and manual coding to analyze how Western media have framed deforestation for the Amazon and Cerrado biomes. Figure 5.4 illustrates the 8 top terms associated with each of the 40 resulting

topics, their assigned labels as well as the topics' total prevalence within the entire text corpus. As illustrated we aggregated topics into 27 distinct themes in our analysis, each either a unique topic from the model or a combination of several topics. Prevalence values for composite topics are sums. These themes are further classified into the categories *Drivers*, *Processes*, *Impacts*, *Responses* and *Other*.

Figure 5.4: Topics with absolute prevalence and top 8 contributing terms. Categorized as Drivers (green), Impacts (red), Processes (olive), Responses (pink), Other (blue).

Figures 5.5 and 5.6 are network representations of the results from the topic model for the two biomes and all time periods. A given topic's prevalence is indicated by node size. Co-occurrence of two given topics (cosine similarity) is illustrated by edge thickness with only the upper 25 percentile of edges being plotted to enhance readability. Figures 5.7 and 5.8 are the semantic graphs from the extracted SVO-triplets for the two biomes. Each network indicates the 20 actions and objects a given subject is most associated with in the text corpus and the order of subjects reflects their frequency of occurrence. Here, we plotted the 15 most frequently occurring subjects for each biome. More

detailed semantic graphs for each time period, the network graphs from extracted names entities and the results from our manual coding are found in the supplementary materials.

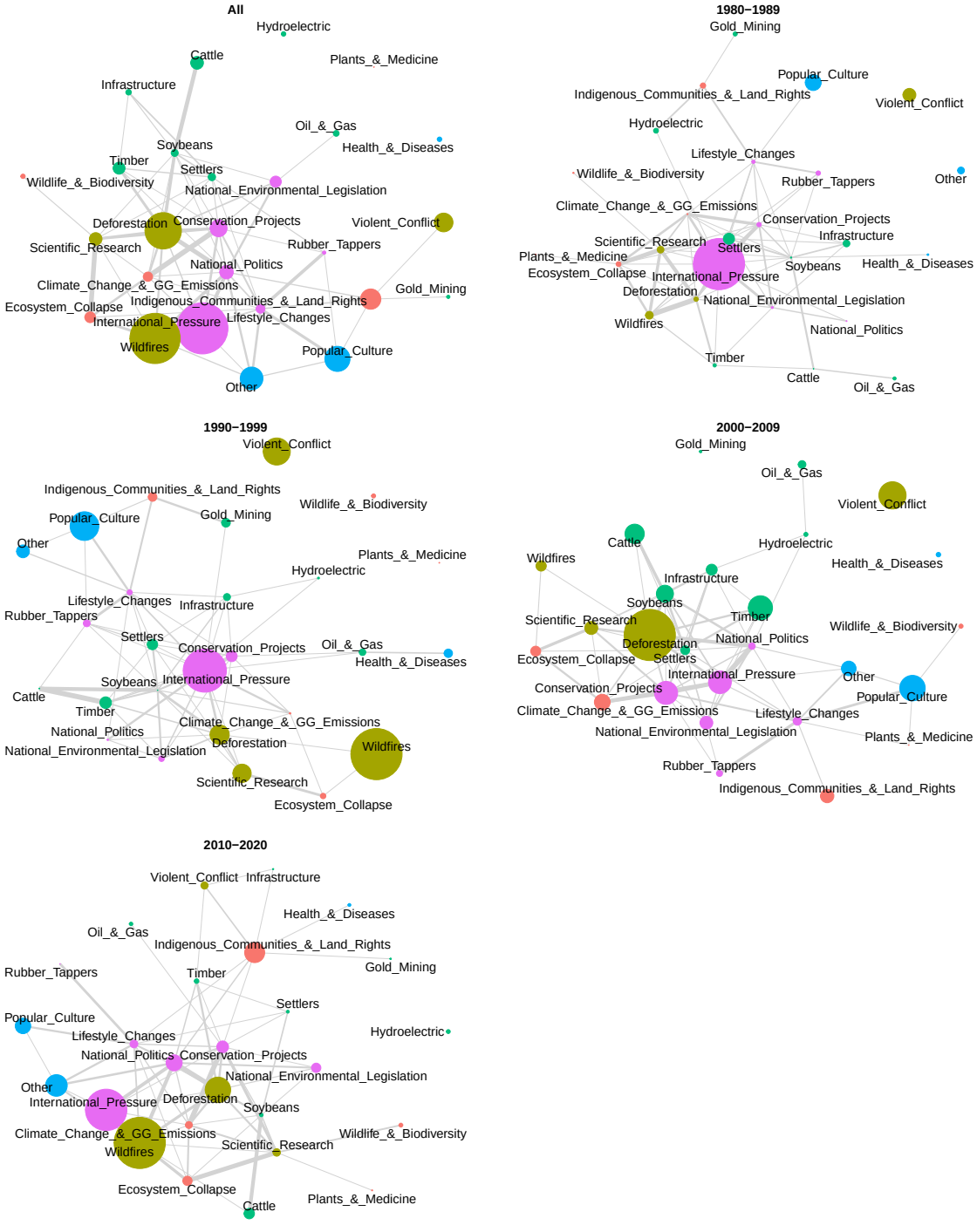

Figure 5.5: Topic co-occurrence networks for articles on the Amazon biome. Node colors are according to topic category. Only the upper 25 percentile of edges is plotted.

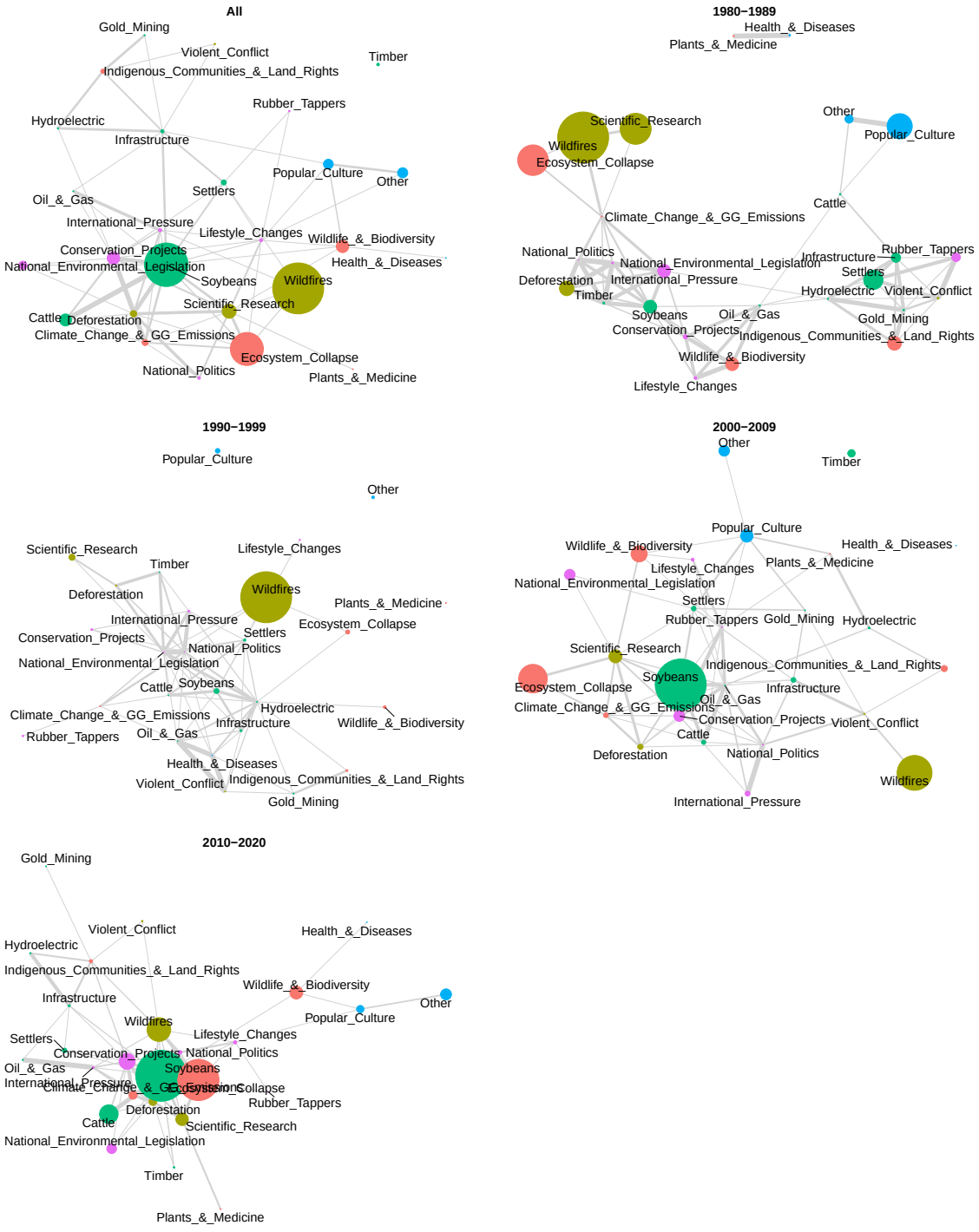

Figure 5.6: Topic co-occurrence networks for articles on the Cerrado biome. Node colors are according to topic category. Only the upper 25 percentile of edges is plotted.

Local conflicts and international pressure: Western media and deforestation in the Amazon

Corresponding to the larger abundance of articles on deforestation in the Amazon biome, we also find more variety and dynamics in occurring themes. As revealed in the topic networks and con-

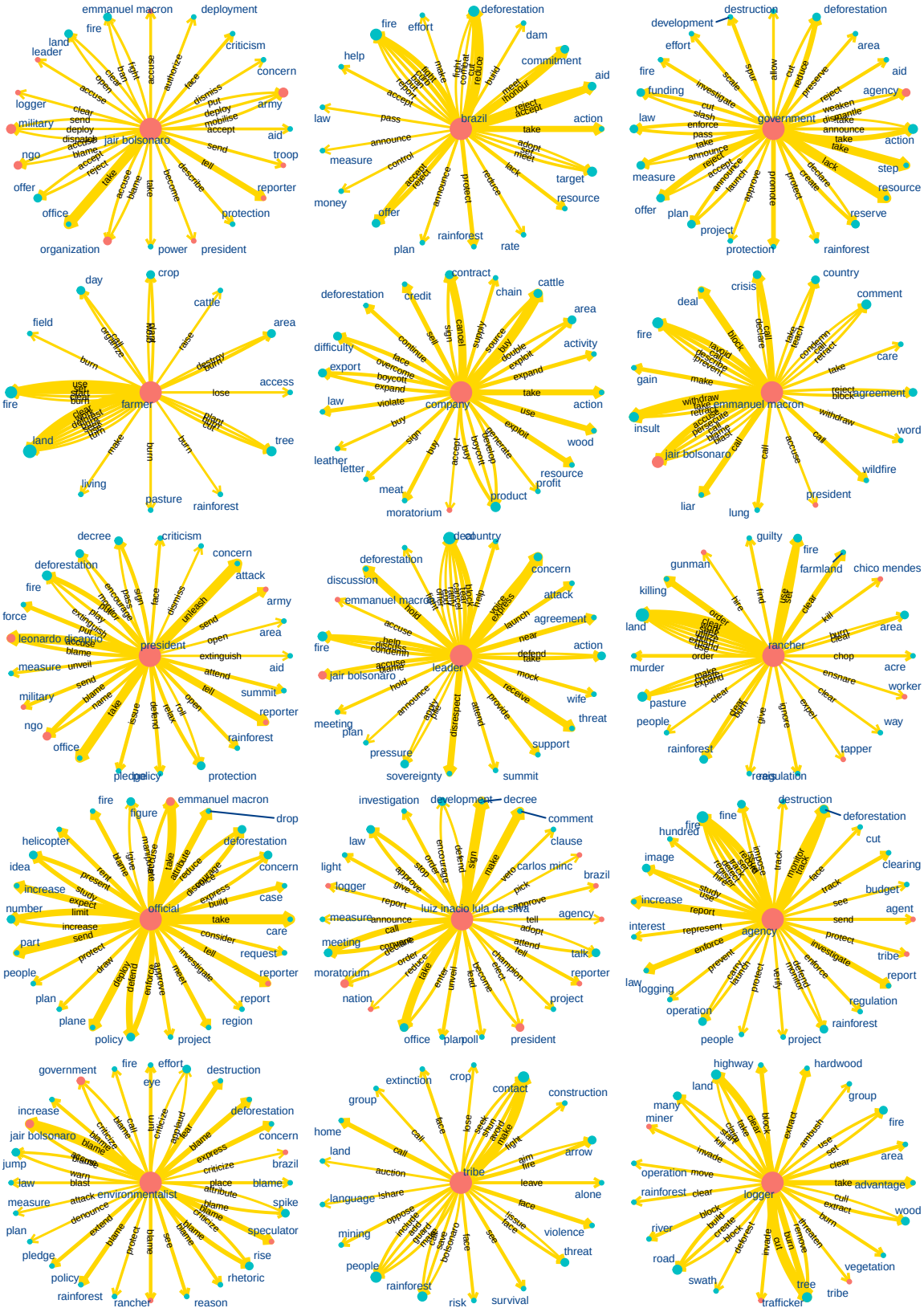

Figure 5.7: SVO-Triplet networks for 10 most frequently occurring actors in articles on the Amazon biome.

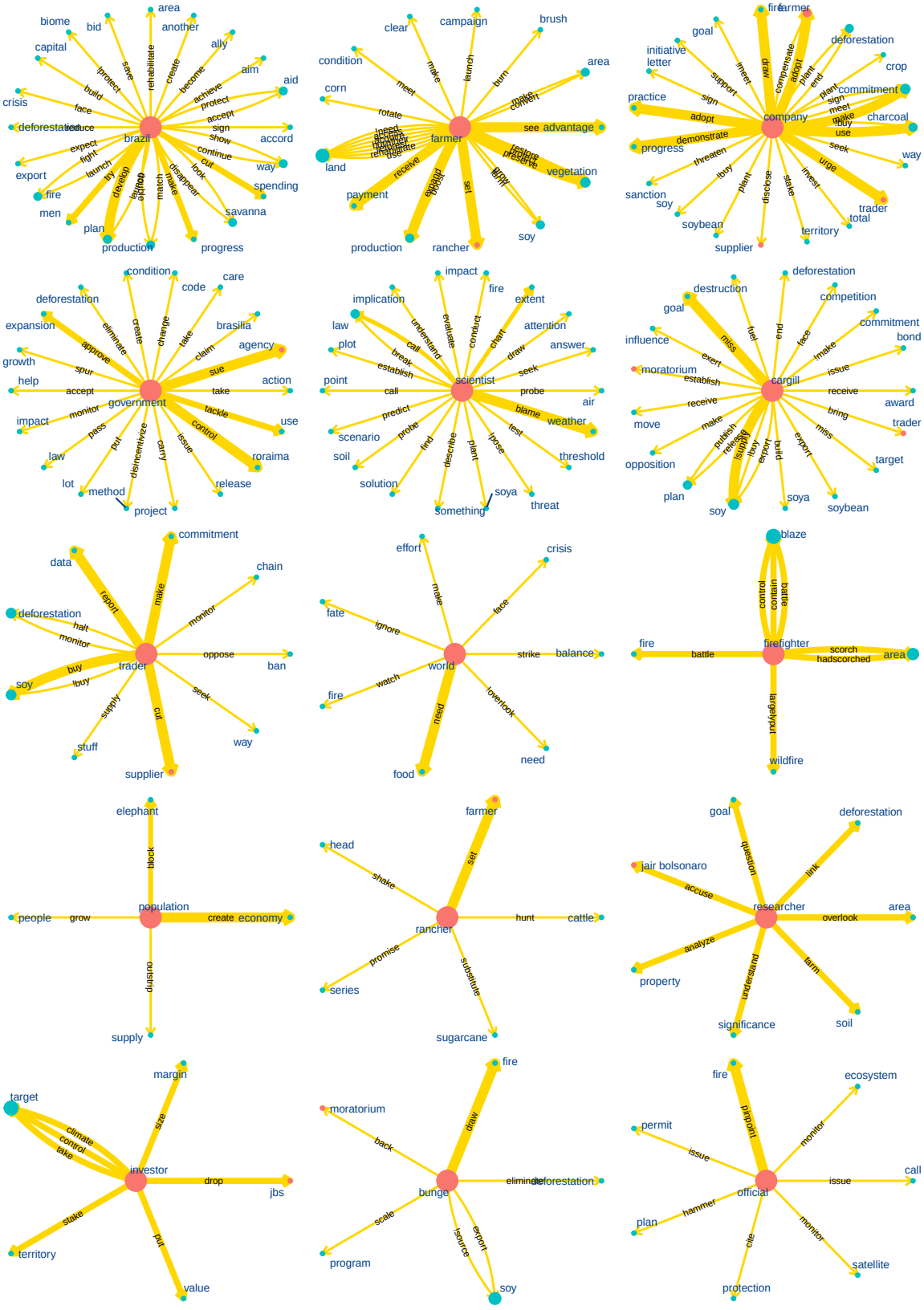

Figure 5.8: SVO-Triplet networks for 10 most frequently occurring actors in articles on the Cerrado biome.

firmed through our manual coding, articles tend to explicitly reference various drivers throughout the study period. These diagnostic frames attribute responsibility to both, national actors, such as the national government, gold miners, cattle ranger or farmers, and to transnational corporations or international demand. The periods with highest media attention (1980s and 2010s) tend to emphasize Brazilian politics and the responsibility of the national government, while the expansion of various commodities (e.g. timber, cattle, soybeans) dominates in the 2000s. Next to wildfires, violent conflicts are mentioned as processes accompanying deforestation. This is confirmed in the semantic networks, which reveal narratives of conflict in which local stakeholders are portrayed in a very contrasting manner. Farmers, ranchers and loggers are often framed as responsible for deforestation and for violent threats towards indigenous communities. In stark contrast to that, indigenous communities are portrayed as environmental defenders, armed with primitive weapons and receiving support from international environmentalists. Companies appear as subjects of phrases that either characterize them as drivers of deforestation, or as signatories of important agreements and good-will actors.

We also observe a high prevalence of topics related to various responses, particularly international pressure and conservation projects. This is confirmed by our manual coding, which identified prognostic frames related to international pressure, international funding and even calls for an internationalization of the Amazon region (in the form of a United Nations controlled global patrimony) occurring in the time periods with highest media attention. National legislation as well as monitoring and enforcement are more dominant in the 2000s. Responses through supply chain management or corporate governance appear more frequently over the past decades. The importance given to international pressure is confirmed by the semantic networks. These are dominated by phrases of international political figures (e.g., Emmanuel Macron) or institutions (NGOs) in rhetorical exchanges with Brazilian politicians (e.g., Jair Bolsonaro).

The selected news articles stress the importance and urgency of several problems associated with deforestation in the Amazon. These motivational frames include references to climate change, biodiversity loss, the collapse of ecosystems and related services, public health issues and the incursion on indigenous lands. All of these appear since the early 1980s, while a number of recent news articles also mention the loss of endemic species and associated consequences for developing new pharmaceuticals. The importance of indigenous communities and human rights is further highlighted by the fact that several named entities relating to organizations in the realm of human rights and indigenous affairs occur frequently and are strongly associated with topics on indigenous groups and land rights. These include FUNAI, a Brazilian governmental agency for indigenous rights and Survival International, a human rights charity organization.

The articles also include significant references to topics around popular culture. These news stories tend to cite travel accounts, documentaries or fictional writing, which combine appreciation

of the biome's biodiversity and culture with depictions of processes and impacts of deforestation, particularly wildfires, biodiversity loss and incursions on indigenous lands.

Wildfires and biodiversity: framing forest loss in the Cerrado

In general, articles on the Cerrado biome are less diverse in terms of prevailing topics. Regarding diagnostic frames, wildfires and soybean expansion are dominant across all time periods. This is confirmed by the results from our manual coding, which indicate that farmers and agribusiness are most often attributed responsibility for deforestation where explicitly identified. The dominance of wildfires in framing the processes behind deforestation in the Cerrado is further highlighted by the semantic networks, which include firefighters and other frequently occurring subjects engaging in monitoring and suppression of fires. However, as for the other categories, articles on the Cerrado, which are often single paragraphs, do not engage as often with question around drivers or responsibility when compared to the Amazon biome. In fact, these paragraphs are often mere footnotes to the entire news article, which often share the same main topic: deforestation in the adjacent tropical forest.

References to responses or solutions are even less prevalent than drivers. National legislation, monitoring (e.g., real time satellite imagery for fires) and enforcement as well as conservation projects dominate. For the 2010s, supply chain management becomes the most important response referenced. The importance of corporate actors in these prognostic frames is highlighted further by the extracted named entities. Most of these correspond to corporate actors, including retailers (e.g., Tesco, Walmart), foodchains (e.g., McDonald's), food processing companies (e.g., Unilever) and investors (e.g., Norges Bank, which manages the Norwegian Government Pension Fund Global).

Mentions of impacts and consequences are mainly restricted to biodiversity loss and ecosystem collapse for most time periods. In the past decade climate change appears as the most significant concern. Indigenous or traditional populations are hardly referenced at all in the selected articles. Accordingly, the semantic networks do not reveal the same framing of deforestation as social conflict. The dominant subjects are mostly stakeholders in commodity chains, researchers, and government institutions. Deforestation appears to be portrayed as a problem objectively raised by researchers, monitored by officials, and addressed to varying levels of success through commitments by private stakeholders.

5.5 Discussion

Western mass media play a role in the networked setting of post-sovereign forest politics. Whether conceptualized as an important forum for deliberation or as political actors performing selective gatekeeping, their reporting reflects, interacts with and has a legitimizing function in the processes of global environmental governance. In the context of commodity-driven tropical deforestation in

Brazil, researchers have pointed to an asymmetry in the efforts to halt the loss of native vegetation in the Cerrado biome when compared to the Amazonian rainforest. These accounts characterize the Cerrado and its traditional populations as a blindspot in conservation funding, corporate commitments or protected areas. Our findings provide empirical evidence that indeed there is a strong difference between the two biomes in terms of how much attention they receive and how deforestation is framed in Western mass media.

Our results indicate that the Amazon biome not only receives significantly more attention, but also that concerns for human rights, particularly linked to indigenous people, are much more dominant, while in the case of the Cerrado references to local populations are sparse. This confirms accounts of the Cerrado being portrayed as empty space (Sauer and Oliveira 2021; da Silva and Chaveiro 2010), a narrative which has also been key in different Brazilian administrations' efforts to turn the region into an agribusiness hotspot since the mid-20th century. The increasing appearance in full-length articles on deforestation in the Cerrado in the past decade, with more direct references to drivers and responses, appears to be due to the recent recognition of the biome's relevance in the context of global climate change and biodiversity loss.

It would be pointless to argue that media should essentially cover deforestation in the two biomes identically. After all, they do represent separate entities, bio-physically and socioeconomically. However, our findings corroborate and, to certain extent, help to explain that the Cerrado, as other open biomes, receives less attention in conservation efforts than tropical forests, as suggested by Silveira et al. (2021). Asymmetries in media attention and framing may also be linked to what Qin et al. (2022) find to be a "major bias towards rainforests" in funding from international donors for conservation-related projects in South America. The authors also find that the expressed objectives of this funding towards the Amazon biome are more often related to development and human rights, while those for the Cerrado mostly center around conservation and ecosystem services. Further, in the Cerrado protected areas cover significantly less surface area, obligations under the Brazilian Forest Code are weaker and major corporate commitments, such as the Soy Moratorium do not apply (Strassburg et al. 2017).

As previously argued, media discourse does not emerge from a historical void. Rather, Western media's representations and discourses are built upon constructs of reality drawn from historical processes (Dryzek 2013). This includes the particular place the Amazon basin holds in Western imaginaries, or, in the words of Susanna Hecht and Alexander Cockburn: "What imbues the case of the Amazon with such passion is the symbolic content of the dreams it ignites" (Hecht and Cockburn 2011, p.1). Particularly since the 1980s (the beginning of our study period), following the release of imagery from Space Shuttle Colombia, which revealed clearly visible patterns of deforestation in the Amazon basin, the fate of Amazonia, which had thus far been seen as a remote, pristine wilderness, started to raise widespread concern and anxiety among Western publics (Miller 2007).

This global concern with deforestation in Amazonia has gone hand in hand with rather binary and essentialist characterizations of different actors. Indeed, current framings on the Amazon region hold historical roots to seminal, colonial Eurocentric imagery, which began influencing the modern perception about the region. Such fables were readily adopted by Western colonizers, intellectuals, and later politicians of Amazonian nations, as a response to their "inability or even lack of interest to come to terms with the complexity of Amazonian life" (Vieira 2016, p. 123). Our findings show that media coverage on deforestation in the Amazon biome often references travel accounts, documentaries and literature. This highlights the importance of what Hendle and Brown (1996) refer to as "poetic discourse", narratives that assign an intrinsic emotional or spiritual value to nature and which can be tapped into by media frames, perhaps making these stories more attractive and newsworthy for media organizations.

A typical frame in this context is that of the ecological noble savage, depicting indigenous communities as primitive forest dwellers, mainly concerned with protecting pristine nature from economic development and occupation by cattle ranchers, gold miners or farmers, armed with bows and arrows (Murphy 2017). This has made these communities natural allies for Western environmental NGOs and celebrity advocates, who have championed a myth of indigenous people as authentic, natural conservationist within a discourse characterized by a strong dichotomy between economic development and nature conservation, often referred to as Green Radicalism (Dryzek 2013; Murphy 2017). Media accounts tap into these depictions to construct relatively simplistic "injustice frames" (Gamson et al. 1982), which amplify the victimization of indigenous groups. These frames have allowed indigenous communities to strategically insert their own concerns into wider public discourse and gain visibility on the global political stage. However, this narrow framing has also at times restricted their messages to those parts in line with the agenda of international environmentalists and its implicit image of indigenous populations (Murphy 2017).

Despite widespread global attention to deforestation in the Amazon biome, distinct peaks in coverage are visible, indicating rather event-focused coverage. These occur particularly at times, when the Brazilian national government is attributed with responsibility for deforestation, as during the administrations of José Sarney (1985 - 1990) and Jair Bolsonaro (2018 – present). In these periods international pressure, foreign financial aid and at times even calls for an internationalization of the region feature prominent among the responses mentioned. Disputes between international political figures are also referred to commonly. Less coverage is attracted by periods of relative progress in legislative measures to tackle deforestation (e.g., during the Lula administration, particularly with Marina Silva as Minister of the Environment).

Such pressure has proved at times to be effective and shown to drive Brazilian environmental governance steps further towards an agenda of sustainable development (Bidone and Kovacic 2018), as through the Pilot Program for the Protection of Tropical Forests (PPG7) in the 1990s. It aimed at

protection and sustainable use of the Amazon Forest and the Mata Atlântica, with improvements in the quality of life of local populations and was established after a certain international clamor from developed nations to assist in Brazil's troubles in dealing with Amazonian deforestation. This indicates that attention towards and framing of deforestation in Brazil across western media influences or at least reflects new approaches to governance interventions.

With increasing attention towards commodity expansion as a driver for deforestation, topics around consumer responsibility and corporate supply chain management become more dominant. This trend is in line with a turn towards a more pragmatic approach towards sustainability in environmental discourses or what Dryzek (2013) refers to as the "Ecological Modernization" discourse. Particularly news articles on deforestation in the Cerrado seem to be dominated by this framing, which highlights the tackling of problems by involving corporate stakeholders, intensifying land-use to release pressure on forest and by increasing monitoring efforts for wildfires. Local communities and their struggles are hardly referred to at all in articles on deforestation in the Cerrado biome.

The inherent technocratic character of ecological modernism perhaps influences this lack of mention towards specific groups of stakeholders, which are marginalized subjects from the process of capitalist expansion in Latin American commodity frontiers. The focus on wildfires and associated monitoring and enforcement measures in the Cerrado may in some cases even frame traditional smallholders, who rely on fires for soil management, rather as part of the problem than as victims of expulsion and marginalization (Eloy et al. 2016). The invisibility of local communities other than indigenous groups is also reflected in the fact that hardly any of the news articles distinguishes between smallholders and large agribusiness, commonly using the ambiguous term "farmer" to refer to both groups and thereby erasing stark differences in ways of producing and living as well as associated economic returns and environmental impacts.

In sum, our findings show that asymmetries in efforts to halt forest loss between the two biomes are reflected in stark differences how much attention these have received and how processes of deforestation are framed in Western media. In the case of the Amazon, widespread media coverage, particularly in the 1980s and 2010s, references to poetic discourse in the form of popular depictions of pristine nature, and the use of injustice frames associated with the plight of indigenous groups may have contributed to increased public awareness, international pressure and new governance interventions. However, these frames also proliferate essentialist depictions of local actors, particularly indigenous groups, and may thereby narrow their role in natural resource management to that of protecting native vegetation against any form of local development. Deforestation in the Cerrado biome has largely been met by silence in Western media, mirroring its depiction as empty, barren land prior to agribusiness development. It appears to gain more attention in the past decade through the acknowledgment of its role for biodiversity and climate change. The issue of deforestation here is framed mainly along lines of ecological modernization and corporate governance, which does not

leave much room for those traditional populations, who have been marginalized by agribusiness expansion.

5.6 Conclusions

In this contribution we have leveraged a text-mining approach combined with qualitative content analysis to analyze the news coverage deforestation in the Amazon and Cerrado biomes has received in Western media. We have shown that the Amazon biome has received disproportionately more attention, particularly in times of international concern about the Brazilian government's commitment to tackle the issue of deforestation. While Western media frequently report on the struggles of indigenous populations in Amazonia, these narratives mostly follow a rather essentialist depiction of these communities in conflict with other local actors. In the case of the Cerrado, traditional populations are hardly mentioned at all.

Our findings provide an empirically grounded case for the often raised concern over a relative invisibility of the Cerrado biome and its traditional populations when it comes to environmental problems, particularly when compared to the Amazon biome. We highlight that mass mediated public discourse plays a role in the context of disparities in governance interventions. Our findings thereby underline and help explain recent findings on Biome Awareness Disparity, which appears to favor tropical forests over open biomes, and asymmetries in international conservation funding both in terms of geographical preferences and states objectives.

Governance initiatives aiming at reducing deforestation have to be carefully scrutinized in terms of the emphasis they put on specific regions and stakeholders. This is particularly the case when corporate governance initiatives or conservation donors respond to public pressure in Western countries, as a result of increased media attention to deforestation and associated impacts occurring in regions of the Global South.

Chapter 6

General Conclusions

6.1 Contributions

The emergence of the global soybean complex is a fascinating story, which has provoked controversies and received attention from scholars across many fields. This dissertation has analyzed how the current function of soybeans in terms of their embeddedness in various provisioning systems has emerged through specific accumulation strategies in the context of large-scale external developments and constraints. It explored the different emerging socio-technical practices that promise to transform the soybean complex towards sustainable patterns. Further, it laid out how the framing of associated socio-ecological problems has differed over time, between various public arenas and stakeholders as well as according to the biome in question. Thereby, this dissertation made a number of contributions, which I will address now by referring to the research questions stated in the introductory chapter.

The first question concerned the lessons from historical processes and legacies shaping the global soybean complex with respect to current approaches to solving socio-ecological problems and research in land system science addressing these. Chapter 2 demonstrated that soybeans have been funneled into different provisioning systems according to specific accumulation strategies and socio-ecological fixes in the context of external developments and technological innovations. The current function of soybeans, dominated by the use of soybean cake in provisioning systems for meat, is a legacy from the post-war era, which assembled surplus grains, oilseeds and animal bodies in a way to allow for continued accumulation. The consolidated network of large corporations, which controls the productive nodes build around this socio-metabolic pathway, will likely resist major transformations. This is particularly true for those practices, which involve rethinking provisioning through functional substitution and new social arrangements.

These findings challenge conventional approaches in land system science, which often trace the impacts of a given demand signal. We propose that more emphasis should rather be placed on how land is put into production according to accumulations strategies and how this shapes provisioning systems. Our findings also demonstrate that focusing on corporate governance mechanisms may lock in current forms of provisioning and thereby prevent transformational change. The role of

government interventions has been essential for regime-shifts in the global soybean complex before, and may have to play an important role again.

Chapter 3 represented a methodological contribution and provided a model that may help address research questions related to the socio-metabolic pathways of individual chemical constituents of food and biomass products. The nutrient-specific multi-regional input-output tables introduced here can help to trace the faith of calories, protein and fat within soybeans or other commodities separately through global socio-metabolic circuits. By applying this chemically explicit lens, we can understand in nuance the dynamics and impacts associated with flexcrops, which are sourced according to the quality and versatility of their chemical components.

Chapters 4 and 5 dealt with research questions concerning the politics of signification in processes of deliberations on governing the global soybean complex and associated socio-ecological impacts. Chapter 4 showed how issues of concern differ quite substantially between regional public spheres and different stakeholders, as well as over time. While news media in importing countries increasingly covered issues relating to soybean production rather than only focusing on final consumers, these issues are mostly limited to those impacts clearly or directly relevant for national audiences. Socio-ecological problems and conflicts, which local communities and producers have to navigate, were much less prevalent.

Chapter 5 explored how the same type of issue (deforestation) can receive very different levels of attention in Western media discourse and be framed in distinct ways depending on where it occurs and what popular imaginary is associated with a given place. This relates to the perceived importance of conserving a given biome but also to the prominence and characterization of traditional local communities and their livelihood. The results showed how Western media disproportionately focused attention on the Amazon biome when compared to the Cerrado. Further, media frames involved many, often rather stereotypical references to indigenous communities in the Amazon, while the Cerrado was often portrayed as devoid of local populations. These findings correspond to observed disparities in the protection status, conservation funding and governance strategies between these biomes.

Given the significant level of influence of Western corporate actors, government bodies and non-governmental organizations in the realm of environmental politics, these findings suggest that researchers should pay attention to whose interests are reflected or ignored in deliberative processes across public spheres. Spillover effects may also result from the shifting of impacts towards regions not in the spotlight of public discourse. Further, governance interventions may address more prominently featured issues while aggravating others, which are not of direct concern to influential actors or Western publics.

Returning to the overarching narrative of this dissertation, how do these findings help us to untangle processes of land use change in the age of reflexive modernity? As outlined in the introductory

chapter, the emergence of a global agenda around sustainability and scientific fields analyzing socio-ecological impacts associated with productive activities are examples of modernity turning on itself. The increasing influence of post-sovereign environmental governance arrangements further signal a shift from Westphalian institutions and values characteristic of earlier modernization projects. Land system science in particular has developed tools to trace the ever more globally entangled relations between land use, consumption and impacts.

This dissertation suggested that current conceptualizations in land system science are reflective, in a sense that they iteratively explore new layers of potential spillover effects, much as in playing a game of Whac-A-Mole. Sticking to this image, I have argued that a truly self-confronting look at modernity would require not only to improve one's skills with the mallet, but to learn how to manipulate the arcade machine. In other words, instead of beginning an analysis from a demand signal, we need to understand how specific strategies to accumulation have organized production in a way that shaped current land use practices and entangled them with provisioning systems and modes of consumption in the first place. Further, while in post-sovereign environmental politics public pressure can create incentives for corporate actors and government bodies to tackle socio-ecological impacts, deliberative processes can create loopholes by emphasizing certain impacts, regions or interests while neglecting others.

6.2 Limitations

The findings presented in this dissertation also come with a set of limitations. Firstly, analyzing land use change and associated economic processes as socially and historically embedded often relies on rather thick contextual descriptions. Untangling processes and drivers in this way cannot always be subjected to the toolkit of statistical hypothesis testing and causal inference which quantitatively oriented scientist are used to. This may also be problematic for a science which aims to provide clear-cut results to inform specific decision-making processes. However, I believe that these approaches are valuable precisely to point out the limitations of studies which describe causality in terms of universally valid, ahistorical processes devoid of larger contexts.

The general limitations inherent in text-mining approaches were already discussed in chapter 4. It is worth repeating here, that algorithms based on statistical or linguistic models of language can enhance reproducibility but come with their own set of biases. Chapter 5 therefore relied on both, manual coding and unsupervised classification. Undoubtedly, models and algorithms will improve with time, but I would like to stress that some level of nuanced meaning will likely always be lost through these approaches. Therefore, careful reading and manual coding of the text corpora used in these chapters could have revealed more layers and nuance to framing devices.

Finally, due to the COVID-19 pandemic, all fieldwork for this dissertation was canceled. Particularly the analysis of deliberative processes would have significantly benefited from direct engagement

with stakeholders and affected communities. It is likely that this would have revealed many additional processes relevant for the politics of signification shaping governance interventions in the realm of the global soybean complex.

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Appendix A

Supplementary Material for chapter 4

A.1 Additional details on methods

Search strings, filtering and duplicate removal

Table A.1 lists the search strings and filtering criteria we used for different sources.

Type	Source	Search String	Filters
News Articles	Factiva	soy* (en) / soja* (de) / soia (it) / soja (es/pt/fr)	Global/World Issues Or Health Or Natural Environment Or Politics/International Relations Or Society/Community
News Articles (News Agencies)	Factiva	soy* and (rst=dpaen or rst=afpr or rst=wefe or rst=sfpressa) or (atleast3 soy* and soy*/F10/ and wc>500 and rst=trtw) or (atleast3 soy* and wc>500 and rst=aprs)	Global/World Issues Or Health Or Natural Environment Or Politics/International Relations Or Society/Community
News Articles	Lexis Nexis	soja (es)	Environment and Natural Resources
Press Releases	Official Websites	soy* (en) / soja* (de) / soia (it) / soja (es/pt/fr)	-
Political Speeches	EU Speeches Corpus	soy*	-
Journal article abstracts	Scopus	(TITLE-ABS-KEY(soy)) OR (TITLE-ABS-KEY(soya)) OR (TITLE-ABS-KEY(soybean))	Environmental science Or Earth and Planetary Science Or Social science

Table A.1: Search strings and filtering criteria for various sources.

The search functions and filtering options provided by the interfaces of the databases and websites used for sourcing our documents differed. To make sure that the final filtering criteria remained constant, we filtered the corpus to include only texts, which included the terms ”soy” or ”soya” or ”soybean*”. Further, some news articles may appear several times due to duplicate listings in the databases. In order to remove duplicates, we computed cosine similarities between the term-

frequency vector representations of all texts and kept only one document for groups of texts with similarity values of 1.

Corpus composition

Table A.2 provides details for the composition of our text corpus. While the political and advocacy fields constitute the smallest numbers of documents (258 and 475, respectively), they tend to be longer (more tokens per document). Unsurprisingly, the academic abstracts tend to be shorter texts and also have shorter sentences (tokens per sentence).

Field	Documents	Tokens	Average Tokens per Document	Sentences	Average Sentences per Document	Average Tokens per Sentence
AcademicField	8331	2245878	270	84957	10	26
AdvocacyField	475	1153325	2428	39152	82	29
BusinessField	1645	1358898	826	43726	27	31
JournalisticField	21831	21670857	993	967905	44	22
PoliticalField	258	457147	1772	13586	53	34
Total	32540	26886105	826	1149326	35	23

Table A.2: Composition of text corpus by field.

Compound tokens

To include relevant compound tokens from multi-word expressions (e.g., "climate_change") we performed a collocation analysis of both the original texts and the tokens after pre-processing. Only those collocations which occurred in both analyses and which had z-statistics of 50 or greater were considered. The z-statistic provides an estimate on whether a given collocation occurs as a result of a multi-word expression or simply by chance. It is based on measuring the standard deviations between observed and expected frequencies of individual nodes and their collocates. Please refer to the documentation of the textstat_collocations() function in the quanteda R package (Benoit et al. 2018) for further details. While we only included bigrams in our initial collocation analysis, the compound function tokens_compound() from the quanteda package renders longer multi-word expressions when bigrams overlap, when the argument JOIN is true. Table A.3 lists the most frequent compound tokens resulting from our collocation analysis both for bigrams and longer compound expressions.

Named entities

The list of extracted entities was further cleaned to correct wrong classifications and remove items, which were wrongly detected as entities. Where entities referring to the same biome or the same organization had several different expressions (e.g., abbreviations) these were renamed to the primary

rank	feature	frequency	docfreq	feature	frequency	docfreq
1	trade˙war	5056	1645	kitchen˙open˙until	1332	54
2	climate˙change	4300	1830	free˙cash˙flow	832	90
3	long˙term	3473	2326	free˙trade˙agreement	507	295
4	soybean˙oil	3250	1856	gross˙domestic˙product	350	306
5	palm˙oil	2872	1005	extra˙virgin˙olive˙oil	335	137
6	vice˙president	2586	1498	mad˙cow˙disease	332	153
7	soybean˙crop	2088	1560	improve˙farm˙productivity	330	325
8	high˙level	1925	1519	intellectual˙property˙protection	292	271
9	greenhouse˙gas	1902	1045	chief˙executive˙officer	265	208
10	fatty˙acid	1751	849	reduce˙greenhouse˙gas	239	207
11	breast˙cancer	1694	449	executive˙vice˙president	236	185
12	short˙term	1689	1121	currently˙available˙information	229	226
13	land˙use	1645	856	soil˙organic˙carbon	192	132
14	vegetable˙oil	1620	842	hormone˙replacement˙therapy	186	140
15	animal˙feed	1605	1081	income˙tax˙provision	177	55
16	soy˙sauce	1564	829	fast˙food˙chain	167	106
17	soya˙bean	1527	937	poor˙buying˙support	166	95
18	raw˙material	1521	1086	senior˙vice˙president	165	118
19	soybean˙production	1504	1158	net˙long˙position	159	107
20	large˙scale	1501	1010	essential˙amino˙acid	145	112

Table A.3: The 20 most frequent compound tokens from our collocation analysis. Bigrams are listed on the left and n-grams on the right.

expression for that entity. For the organizations, the list of detected entities was manually cleaned to only include organizations, companies, and institutions in a broad sense.

A.2 Additional results

Test statistics for determining K

Figure A.1 presents test statistics for topic model setups using the same input DFM with different numbers of topics (K). The held-out likelihood evaluates the performance of different models in completing documents for which a fraction of the words has been held out by using the document-level latent variables. It can thereby by considered a measure of the predictive capacity of the model. Residual dispersion evaluates the model fit based on multinominal likelihood, which implies that a dispersion higher than 1 indicates an optimal K that is larger than the one specified in the model. Semantic coherence indicates whether the words which are most probable for a given topic frequently co-occur within documents. The lower bound is an estimate of the lower bound of the marginal likelihood used for model convergence. While most of the test statistics (apart from semantic coher-

ence) indicate optimal values for K higher than the number of topics specified, manual interpretation found overclustering for values of K higher than 80, splitting coherent topics into several versions of the same.

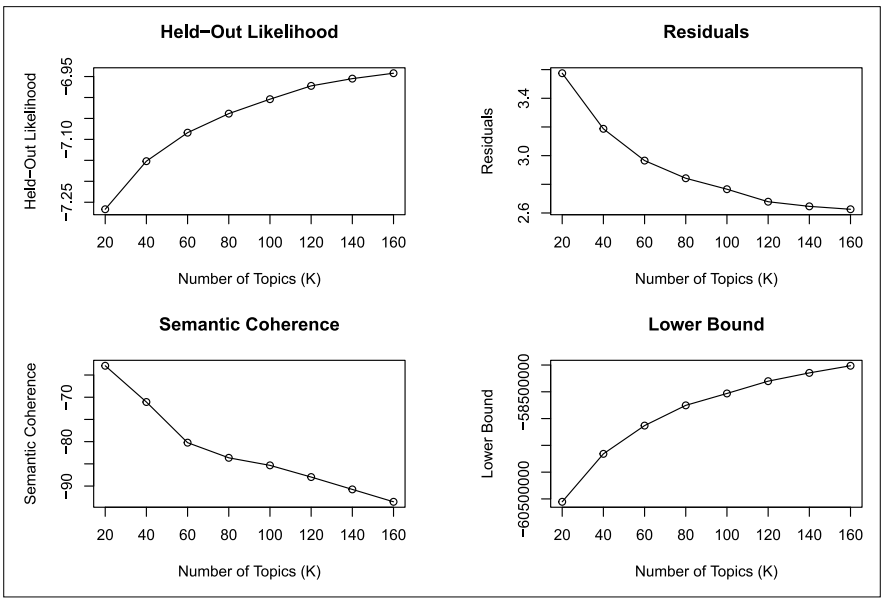

Figure A.1: Test statistics for topic models with topic number (K) between 20 and 160 in steps of 20.

Further, Figure A.2 illustrates the relationship between semantic coherence and exclusivity (indicating in how far words are exclusive to single topics). We can observe that the gains in exclusivity level off relative to decreasing semantic coherence for topic numbers above 80.

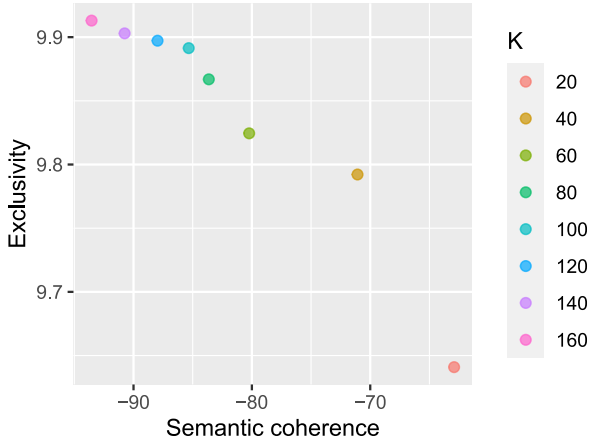

Figure A.2: Test statistics exclusivity and semantic coherence for topic models with topic number (K) between 20 and 160 in steps of 20.

We further calculated semantic coherence by topic and field as illustrated in Figure A.3 (for all 80 topics) and Figure A.4 (only for the selected topics in our analysis). Semantic coherence varies by field and is particularly lower for the academic field. However, this effect is not as pronounced when considering only the selected topics. In the latter case, the academic field has values comparable to the

business field and political field. However, the advocacy field and journalistic field show the highest values in both cases.

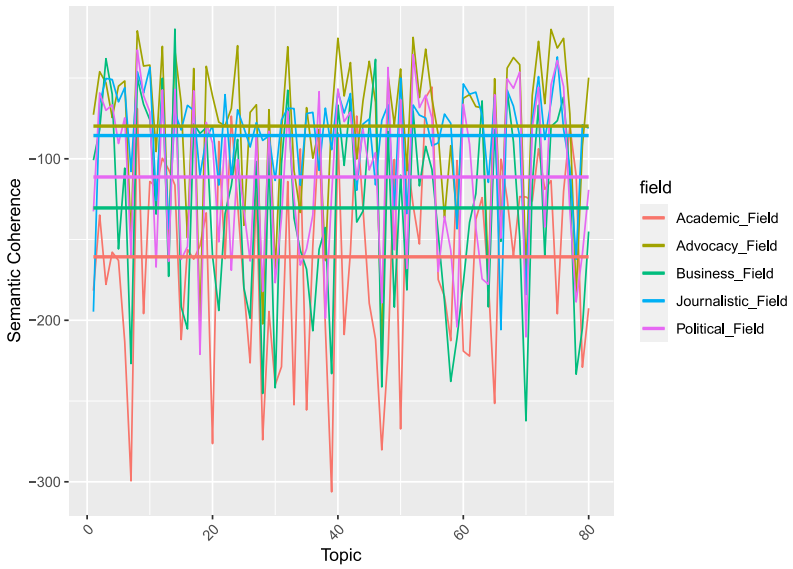

Figure A.3: Semantic coherence by topic and field for all topics. Thick y-intercepts are field-wide averages across all topics.

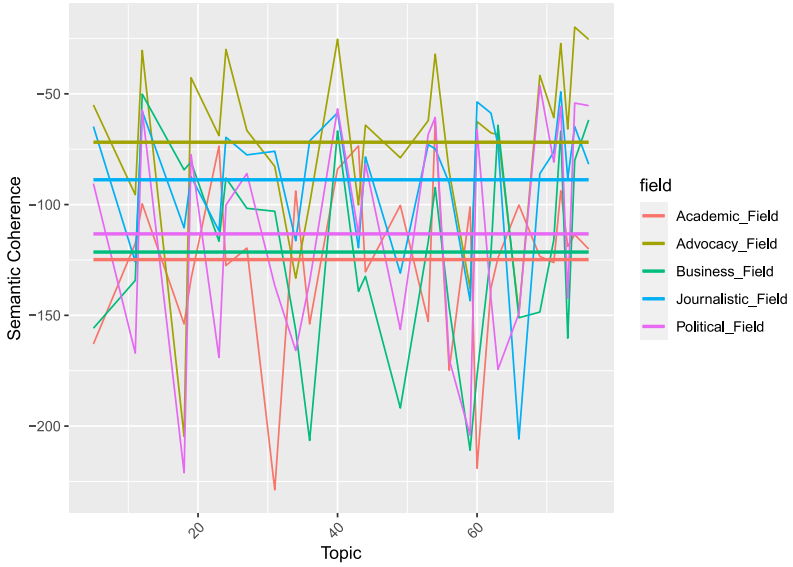

Figure A.4: Semantic coherence by topic and field for selected topics. Thick y-intercepts are field-wide averages across the selected topics.

Topic model validation

Figure A.5 presents the results from hierarchical clustering. Selected and grouped topics are highlighted by colors.

For the supervised element in our model validation we followed Chang et al. (2009b) and designed word-intrusion and topic-intrusion tests for one percent of our corpus material. These tests

evaluate whether the probability distributions of words over topics and topics over documents as inferred by the model relate to how a human coder interprets words as topics and documents as mixtures of topics. Word intrusion refers to inserting so called "intruder" words (top terms from other topics) into the top terms associated with a given topic. It is then evaluated whether a human coder correctly detects these intruders. Similarly, in the topic intrusion test, the coder must identify an intruder topic for every document sampled. The tests were designed using the oolong library in R (Chan and Sältzer 2020). Both tests were carried out independently by two coders.

All results are presented in Table A.4. Note that the Krippendorff's alpha value (0.129) gives a low estimate for inter-coder reliability. This implies that the two coders did not coincide in terms of for which questions they disagreed with the model. However, since the model includes many rather specialized topics and a number of topics, which overlap in meaning, we assume that this is rather due to varying levels of familiarity with different fields and an element of chance when selecting between similar topics.

Statistic	Value
kripp.alpha	0.1290
rater.1.precision	0.9500
rater.2.precision	0.8250
mean.precision	0.8875
rater.precision.p.value	0.0000
mean.TLO	-0.5220
TLO.p.value	0.0000

Table A.4: Test statistics from word-intrusion and topic-intrusion tests.

The topic log odds mean value is rather difficult to interpret by itself. It's upper bound is 0, which would indicate perfect correspondence between the rater's choice and the true intruder topics. In the findings presented by Chang et al. (2009b), the highest scoring model has a mean log odds of around 1, which suggests that our model performed rather well in the topic-intrusion tests.

Topic model output and topic selection

Figure A.6 illustrates the output of our topic model and our selection and aggregation of relevant topics.

Closeness-Centrality values for EU journalistic Field

Tables A.5 and A.6 provide measures of closeness-centrality for all selected topics in the EU journalistic field for different time periods.

Rank	All Years	value	1997	value	2002	value
1	Producers'&'Landowners	0.31	Producers'&'Landowners	0.27	Producers'&'Landowners	0.32
2	Land'Use'Change'&'Impacts	0.34	GMOs	0.29	Climate'Change'&'GG'Emissions	0.37
3	Climate'Change'&'GG'Emissions	0.34	Climate'Change'&'GG'Emissions	0.31	Global'Food'System	0.38
4	Global'Food'System	0.37	Pesticides'&'Health	0.33	Harvest'&'Weather	0.39
5	Harvest'&'Weather	0.43	Pest'Management	0.34	Pesticides'&'Health	0.43
6	Soil'Management	0.44	Global'Food'System	0.37	Land'Use'Change'&'Impacts	0.43
7	Consumers'&'Food'Labeling	0.45	Consumers'&'Food'Labeling	0.38	GMOs	0.43
8	GMOs	0.47	Deforestation	0.38	Deforestation	0.44
9	Deforestation	0.47	Land'Use'Change'&'Impacts	0.39	Consumers'&'Food'Labeling	0.47
10	Pesticides'&'Health	0.47	Wildlife'&'Biodiversity	0.40	Seeds'&'Patents	0.48
11	Meat'&'Animal'Feed	0.49	Harvest'&'Weather	0.41	Soil'Management	0.49
12	Pest'Management	0.49	Soil'Management	0.42	Wildlife'&'Biodiversity	0.50
13	Seeds'&'Patents	0.56	Seeds'&'Patents	0.43	Pest'Management	0.51
14	Water'Resource'Management	0.58	Land'Conflicts	0.46	Water'Resource'Management	0.56
15	Wildlife'&'Biodiversity	0.59	Water'Resource'Management	0.49	Meat'&'Animal'Feed	0.58
16	Biofuels	0.70	Meat'&'Animal'Feed	0.50	Land'Conflicts	0.77
17	Diets'&'Health	0.83	Economic'Crisis	0.57	Diets'&'Health	0.80
18	Land'Conflicts	0.87	Diets'&'Health	0.69	Biofuels	0.96
19	Economic'Crisis	1.10	Biofuels	0.76	Economic'Crisis	1.02
20	Trade'Disputes	2.25	Trade'Disputes	1.12	Trade'Disputes	1.47

Table A.5: Closeness-Centrality measures for different topics and time periods in EU journalistic field.

Rank	2007	value	2012	value	2017	value
1	Producers'&'Landowners	0.28	Land'Use'Change'&'Impacts	0.31	Land'Use'Change'&'Impacts	0.29
2	Climate'Change'&'GG'Emissions	0.28	Producers'&'Landowners	0.32	Climate'Change'&'GG'Emissions	0.30
3	Land'Use'Change'&'Impacts	0.30	Global'Food'System	0.34	Producers'&'Landowners	0.31
4	Soil'Management	0.31	Climate'Change'&'GG'Emissions	0.37	Soil'Management	0.35
5	Global'Food'System	0.32	Soil'Management	0.46	Global'Food'System	0.37
6	Harvest'&'Weather	0.35	GMOs	0.47	Meat'&'Animal'Feed	0.38
7	Consumers'&'Food'Labeling	0.38	Pest'Management	0.47	Consumers'&'Food'Labeling	0.42
8	Pesticides'&'Health	0.41	Consumers'&'Food'Labeling	0.47	Harvest'&'Weather	0.44
9	Seeds'&'Patents	0.41	Harvest'&'Weather	0.47	Deforestation	0.45
10	Deforestation	0.41	Water'Resource'Management	0.47	Pesticides'&'Health	0.51
11	Biofuels	0.43	Pesticides'&'Health	0.48	Pest'Management	0.52
12	Meat'&'Animal'Feed	0.43	Meat'&'Animal'Feed	0.48	Wildlife'&'Biodiversity	0.57
13	GMOs	0.44	Deforestation	0.49	Water'Resource'Management	0.59
14	Pest'Management	0.45	Biofuels	0.54	GMOs	0.60
15	Water'Resource'Management	0.57	Wildlife'&'Biodiversity	0.60	Seeds'&'Patents	0.61
16	Wildlife'&'Biodiversity	0.61	Seeds'&'Patents	0.63	Biofuels	0.68
17	Economic'Crisis	0.78	Economic'Crisis	0.88	Diets'&'Health	0.69
18	Land'Conflicts	0.78	Land'Conflicts	0.88	Land'Conflicts	0.92
19	Diets'&'Health	0.81	Diets'&'Health	0.92	Trade'Disputes	1.30
20	Trade'Disputes	1.13	Trade'Disputes	1.24	Economic'Crisis	1.39

Table A.6: Closeness-Centrality measures for different topics and time periods in EU journalistic field.

Topic co-occurrence networks for different fields

Figures A.7 - A.9 illustrate topic co-occurrence networks for different fields. Figures A.11 - A.14 illustrate topic co-occurrence networks for different regions within the journalistic field.

Topic-biome bipartide graphs for different fields

Figures A.15 - A.18 illustrate topic-bome co-occurence bipartide networks for different fields. Figures A.19 - A.22 illustrate topic-bome co-occurence bipartide networks for different regions within the journalistic field.

Topic-organization bipartide graphs for different fields

Figures A.23 - A.26 illustrate topic-organization co-occurence bipartide networks for different regions within the journalistic field.

Monthly prevalence and Keyness for ”Deforestation”

Figure A.27 illustrates the results from our keyness analysis for the topic ”Deforestation”, comparing each year to all prior years for the EU journalistic field, Brazilian journalistic field and transnational news agencies. Key terms are plotted over monthly prevalence values.

A.3 Access to source code

Access to the entire source code for data processing and analysis as a markdown html file is provided HERE.

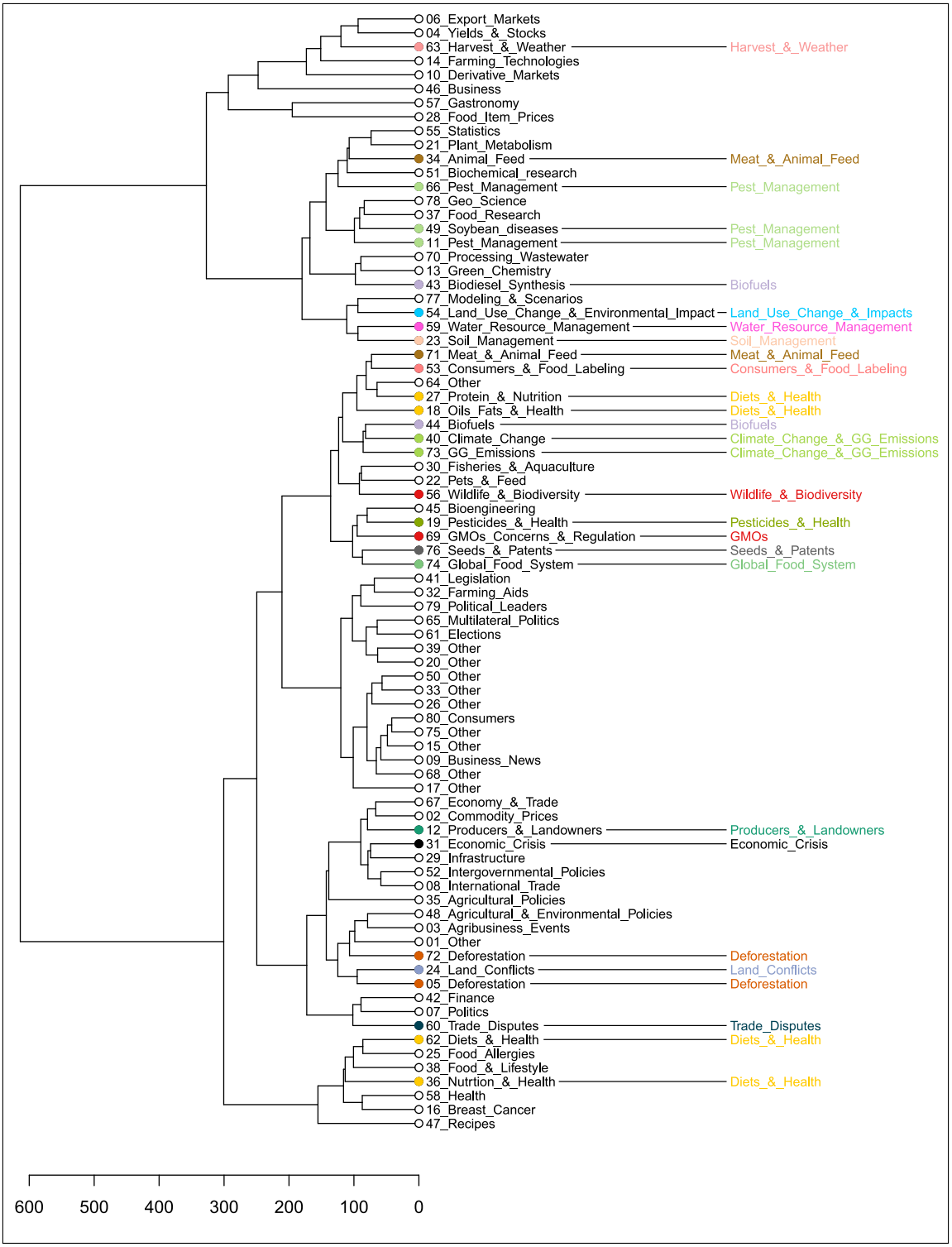

Figure A.5: Dendrogram illustrating results from hierarchical clustering based on Euclidean distance between topic word-vectors. Colored nodes represent topics selected and grouped.

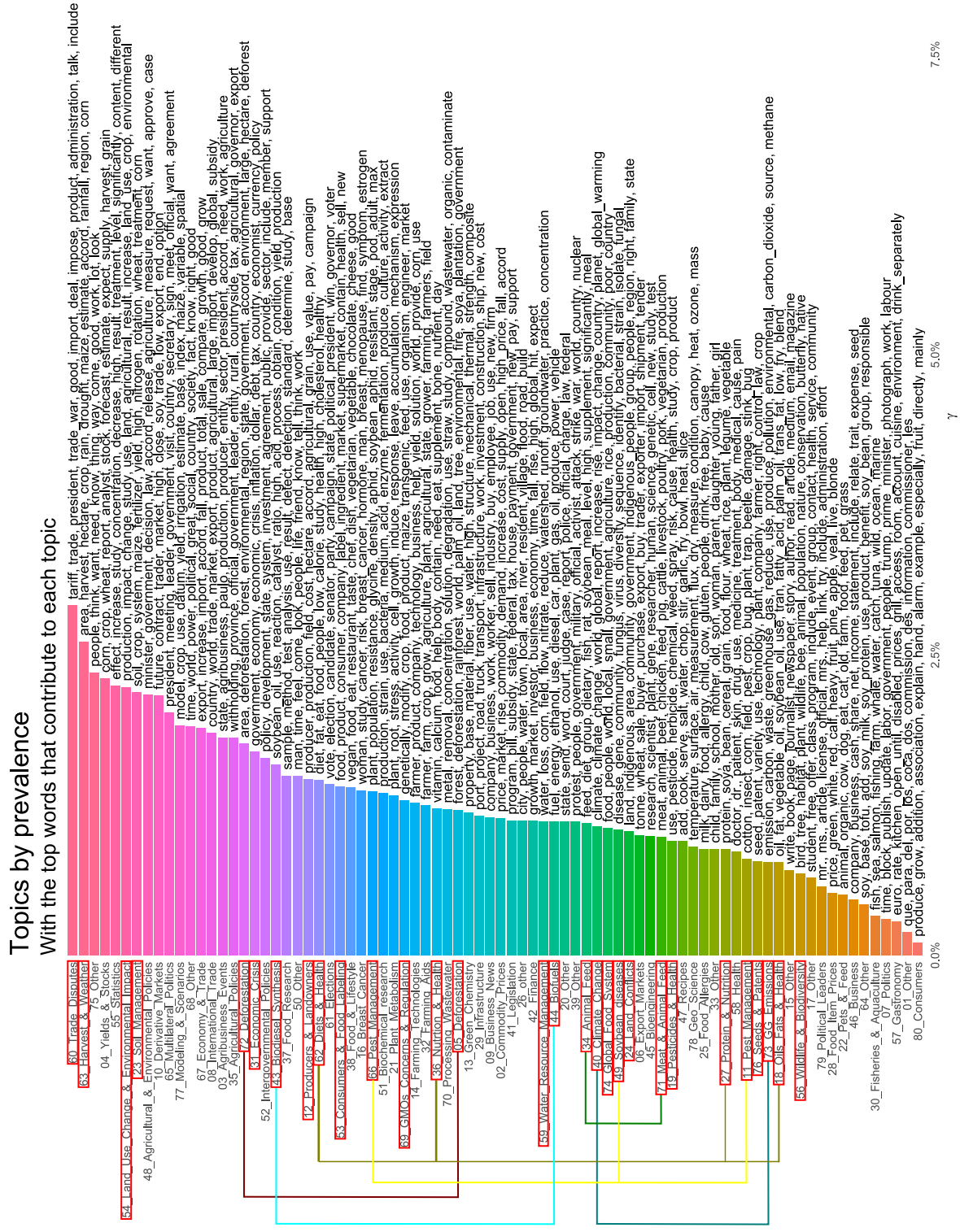

Figure A.6: Topic by prevalence with top contributing terms. Aggregate topics are connected by lines of the same color.

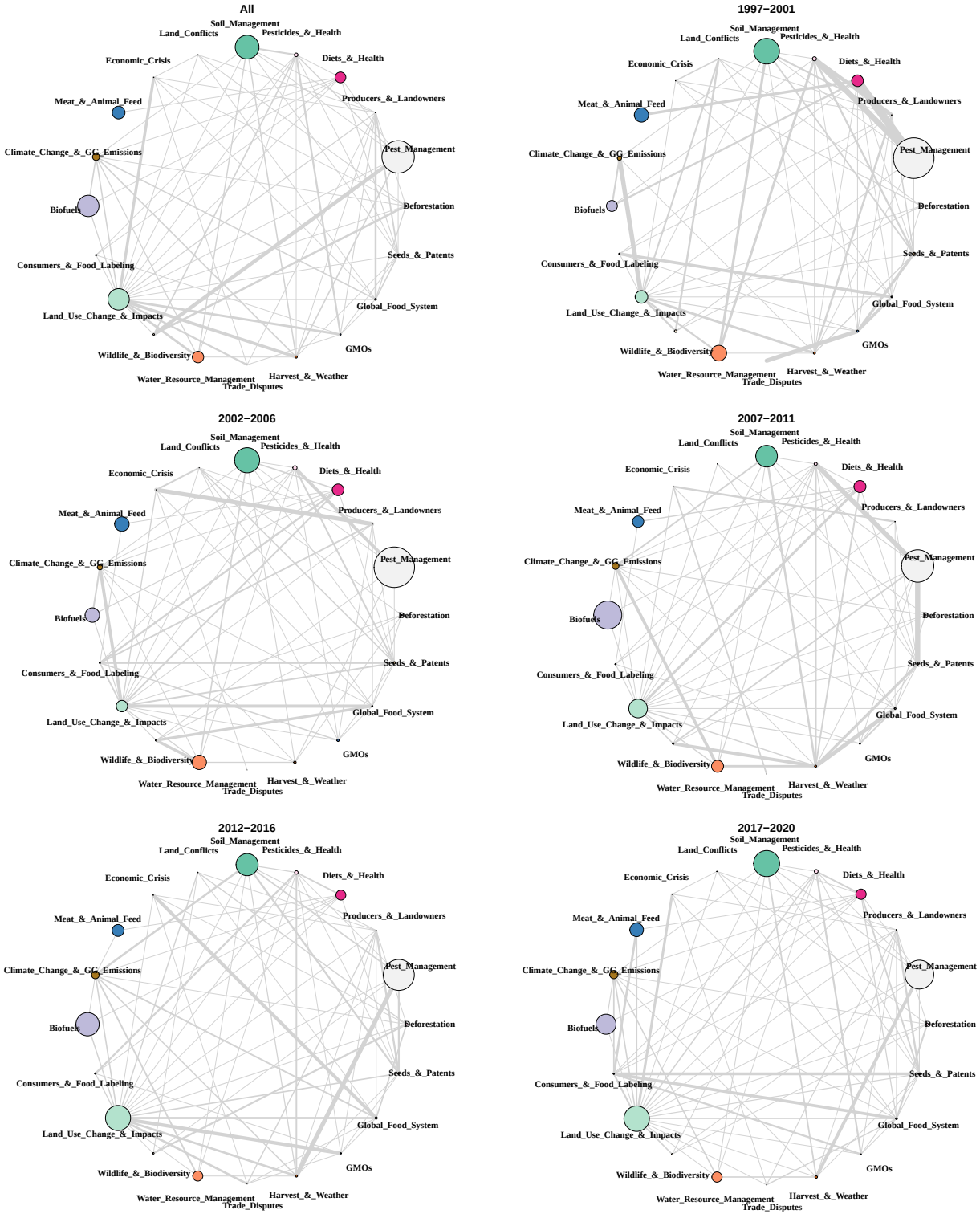

Figure A.7: Evolution of topic co-occurrence for academic field.

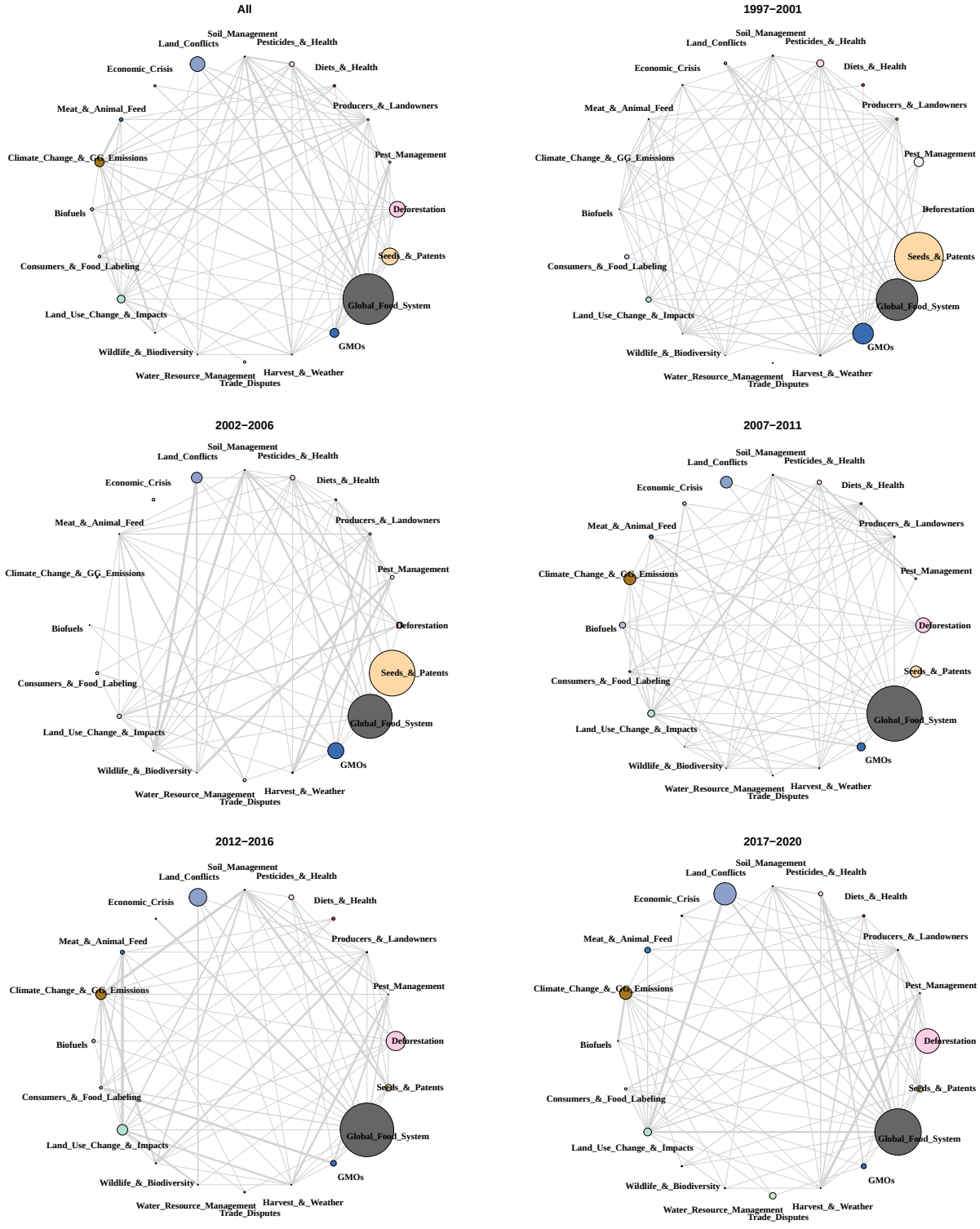

Figure A.8: Evolution of topic co-occurrence for advocacy field.

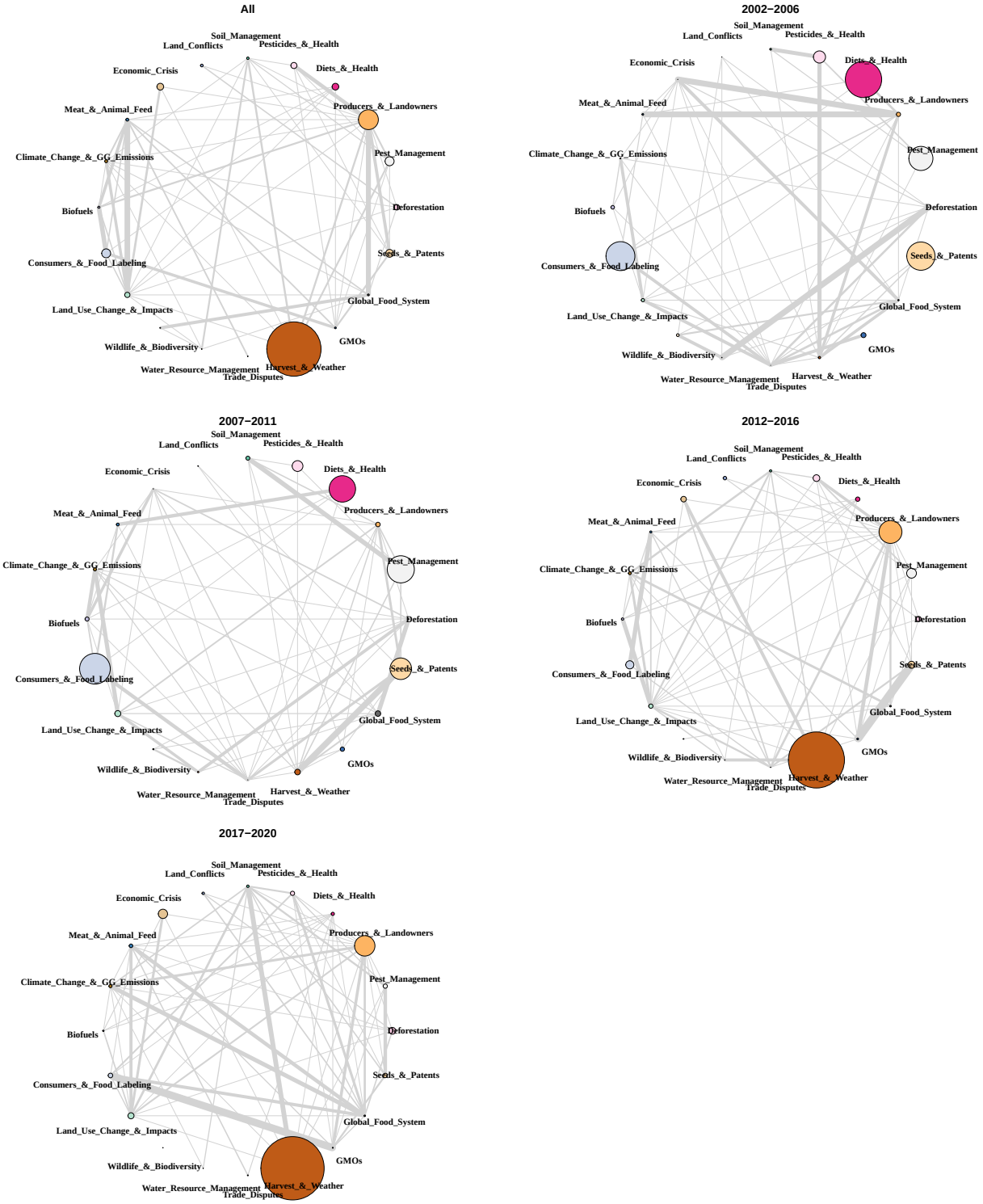

Figure A.9: Evolution of topic co-occurrence for business field.

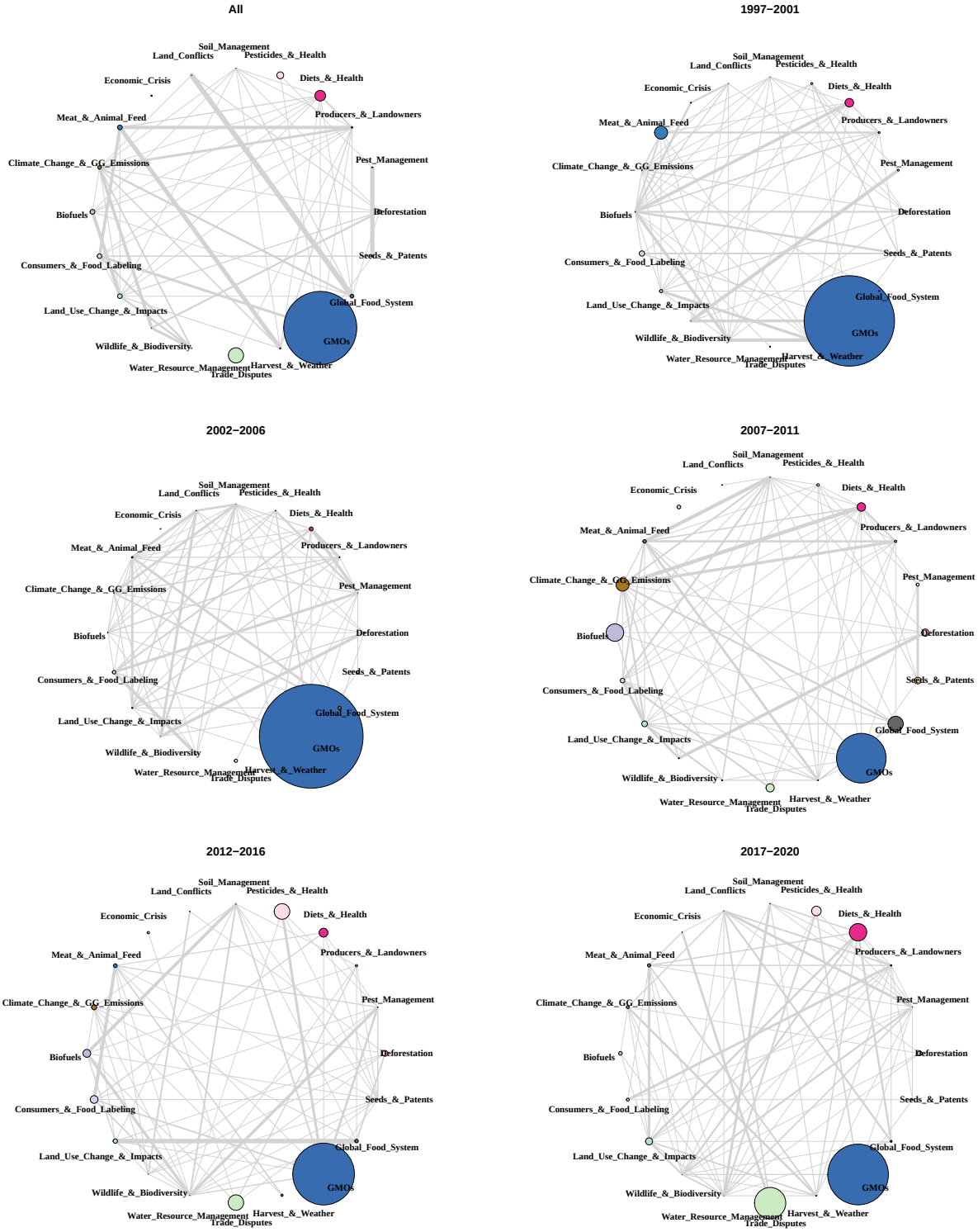

Figure A.10: Evolution of topic co-occurrence for political field.

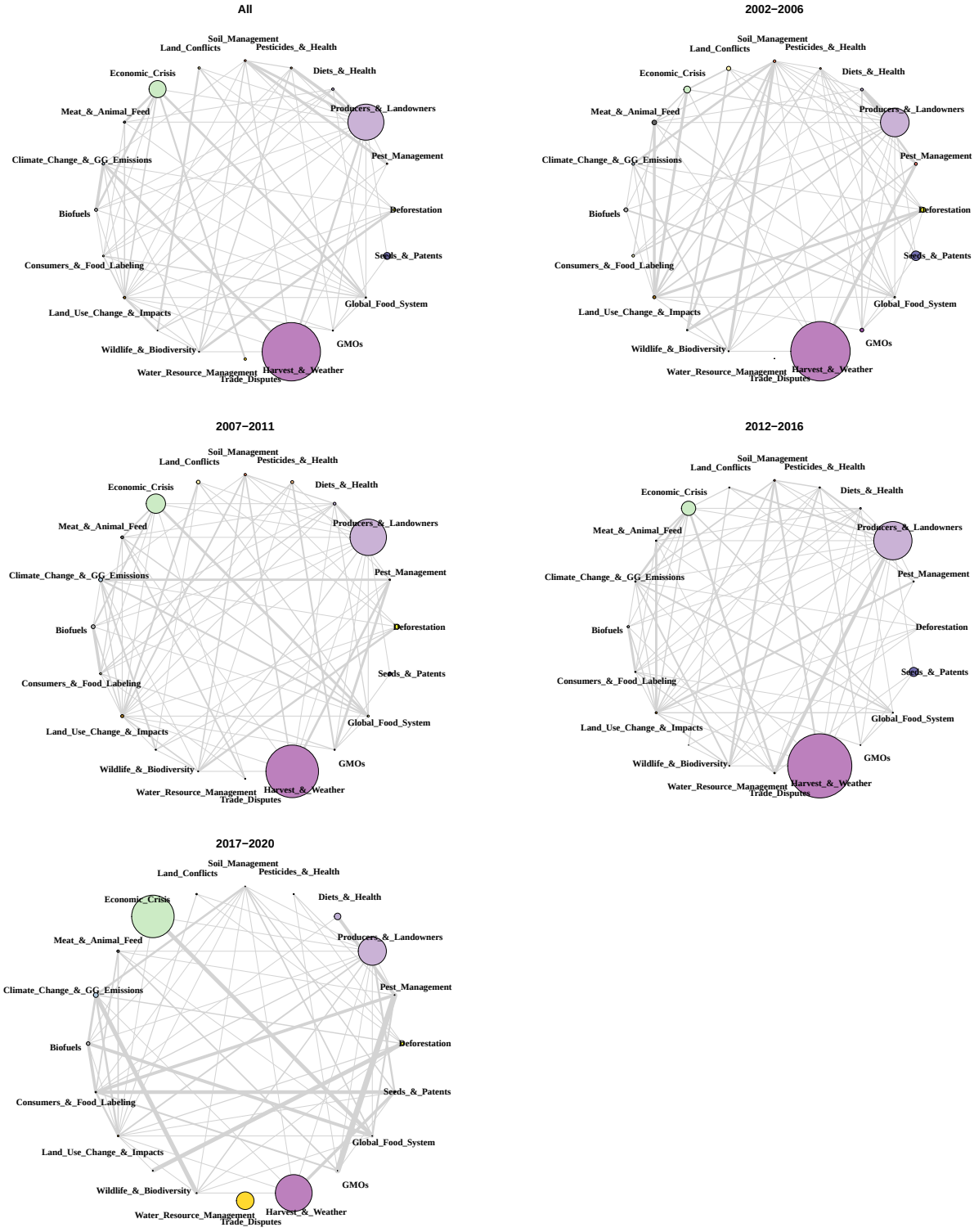

Figure A.11: Evolution of topic co-occurrence for print media from Argentina.

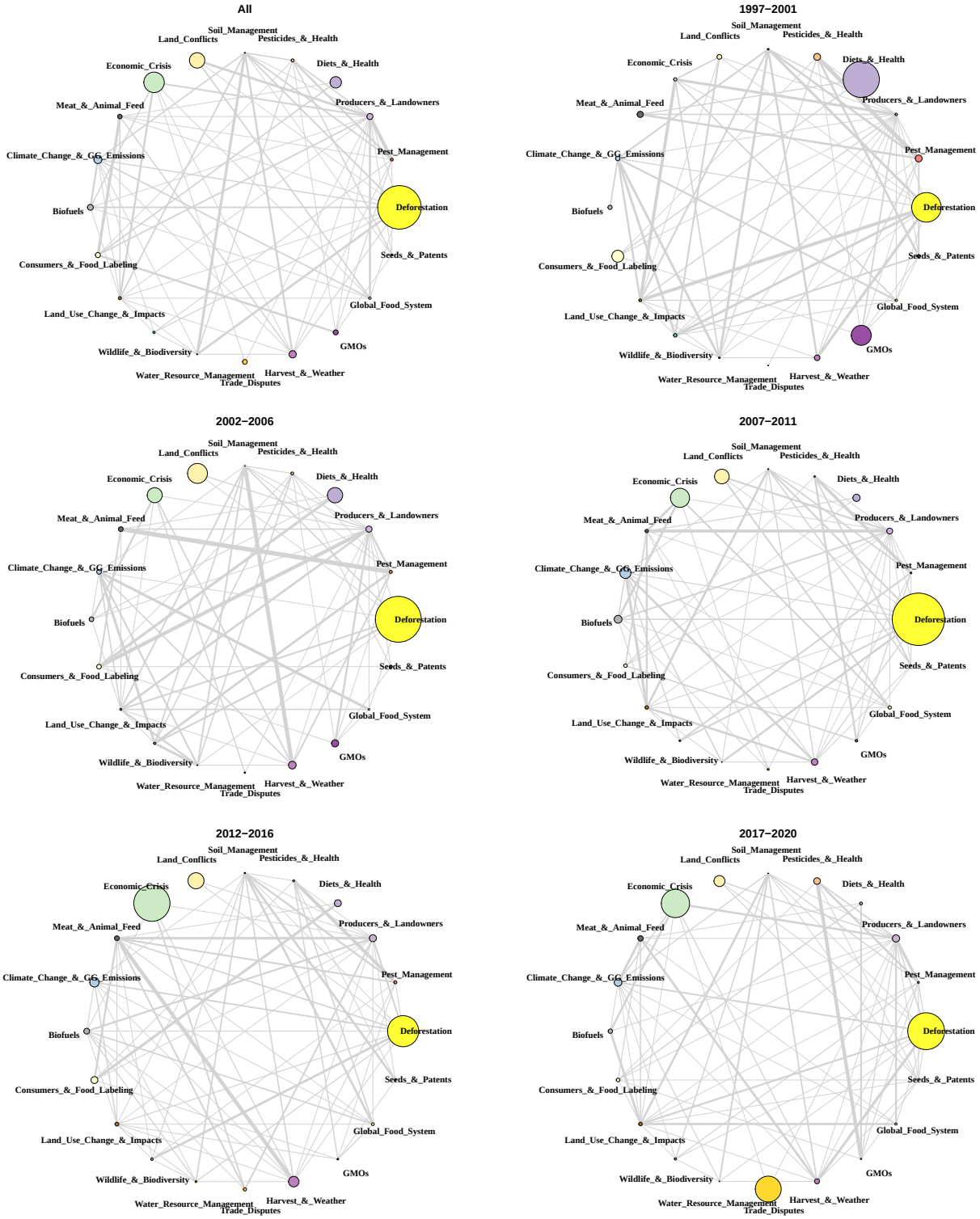

Figure A.12: Evolution of topic co-occurrence for print media from Brazil.

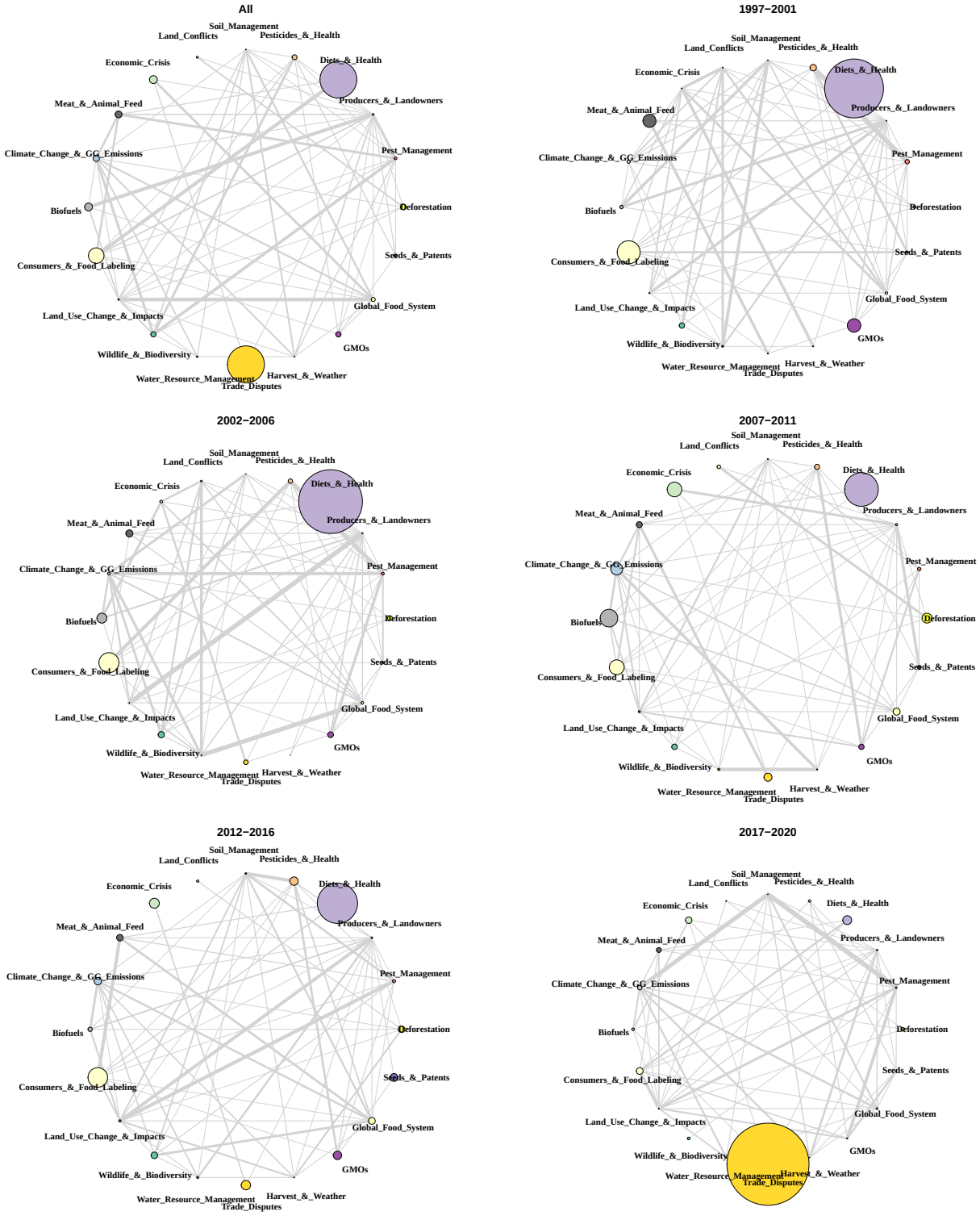

Figure A.13: Evolution of topic co-occurrence for print media from the US.

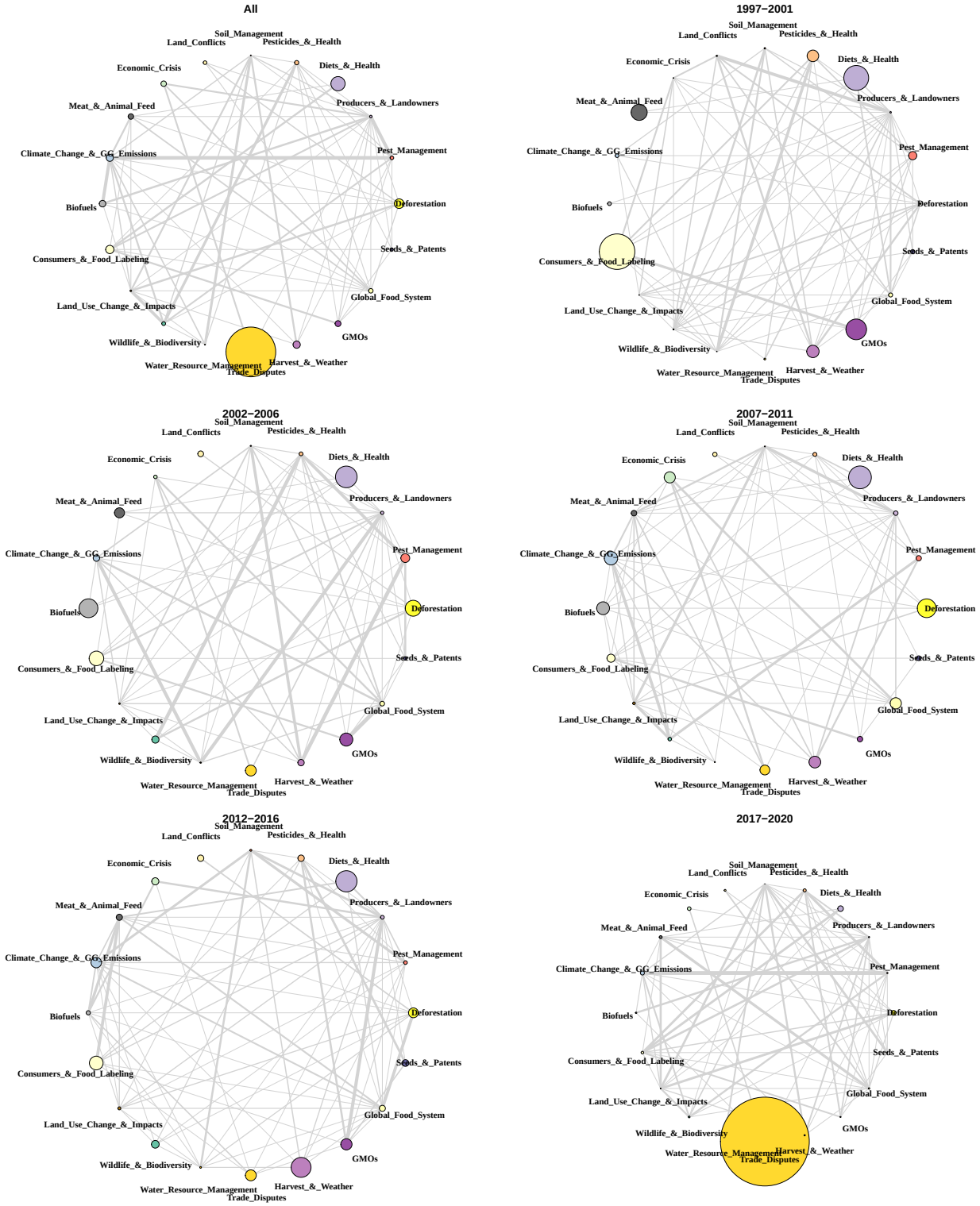

Figure A.14: Evolution of topic co-occurrence for transnational news agencies.

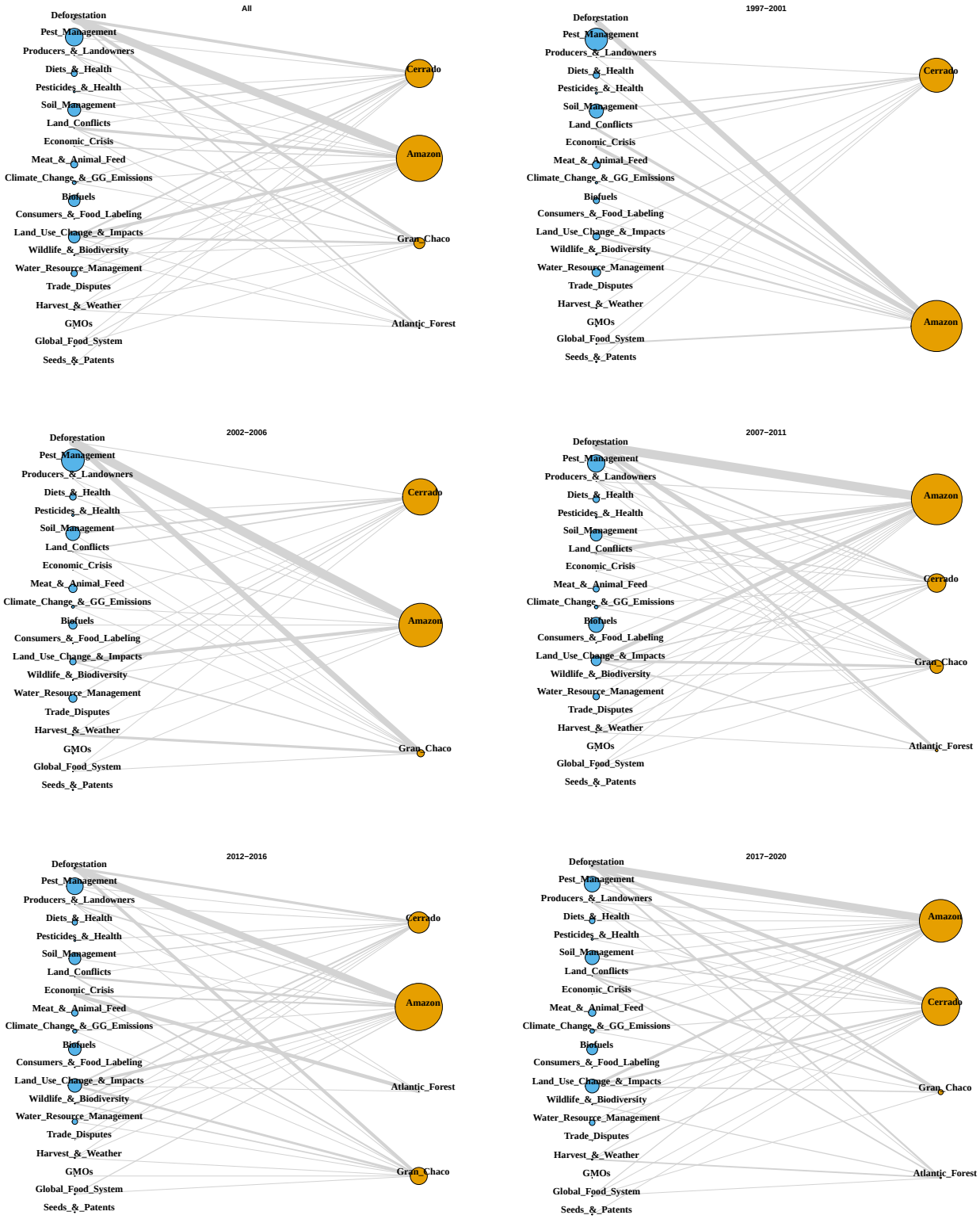

Figure A.15: Topic-biome bipartide network graph for acdemic field.

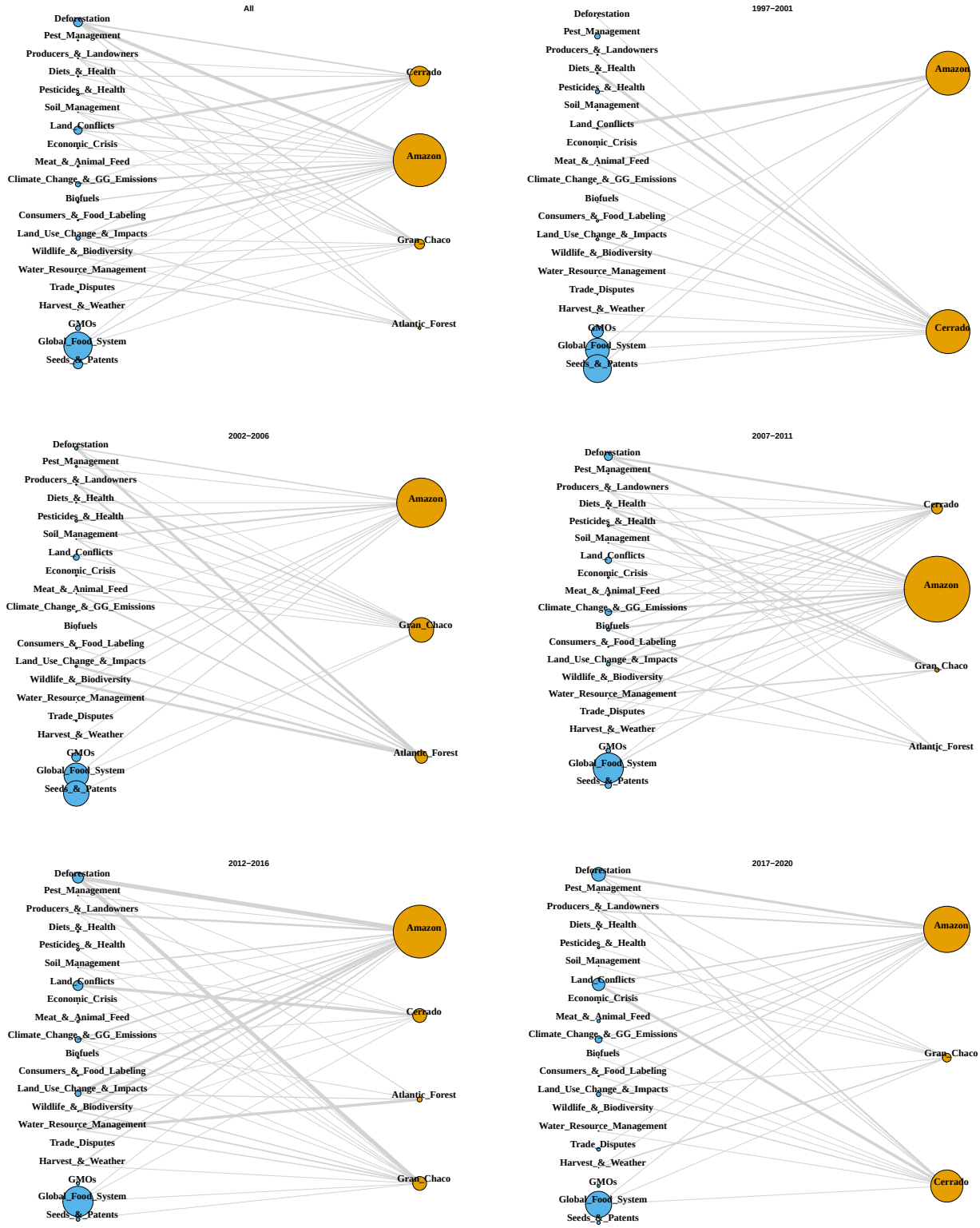

Figure A.16: Topic-biome bipartide network graph for advocacy field.

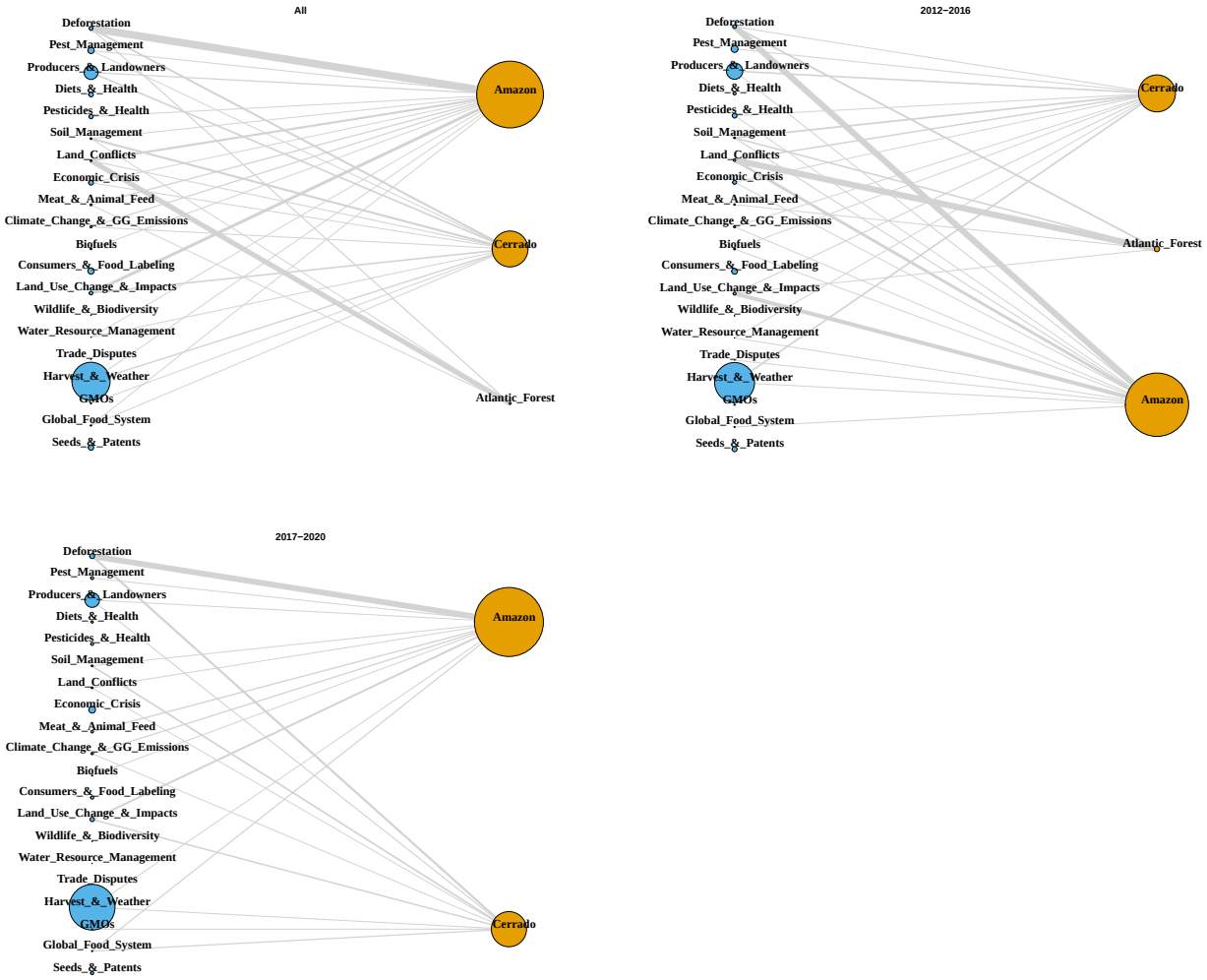

Figure A.17: Topic-biome bipartide network graph for business field.

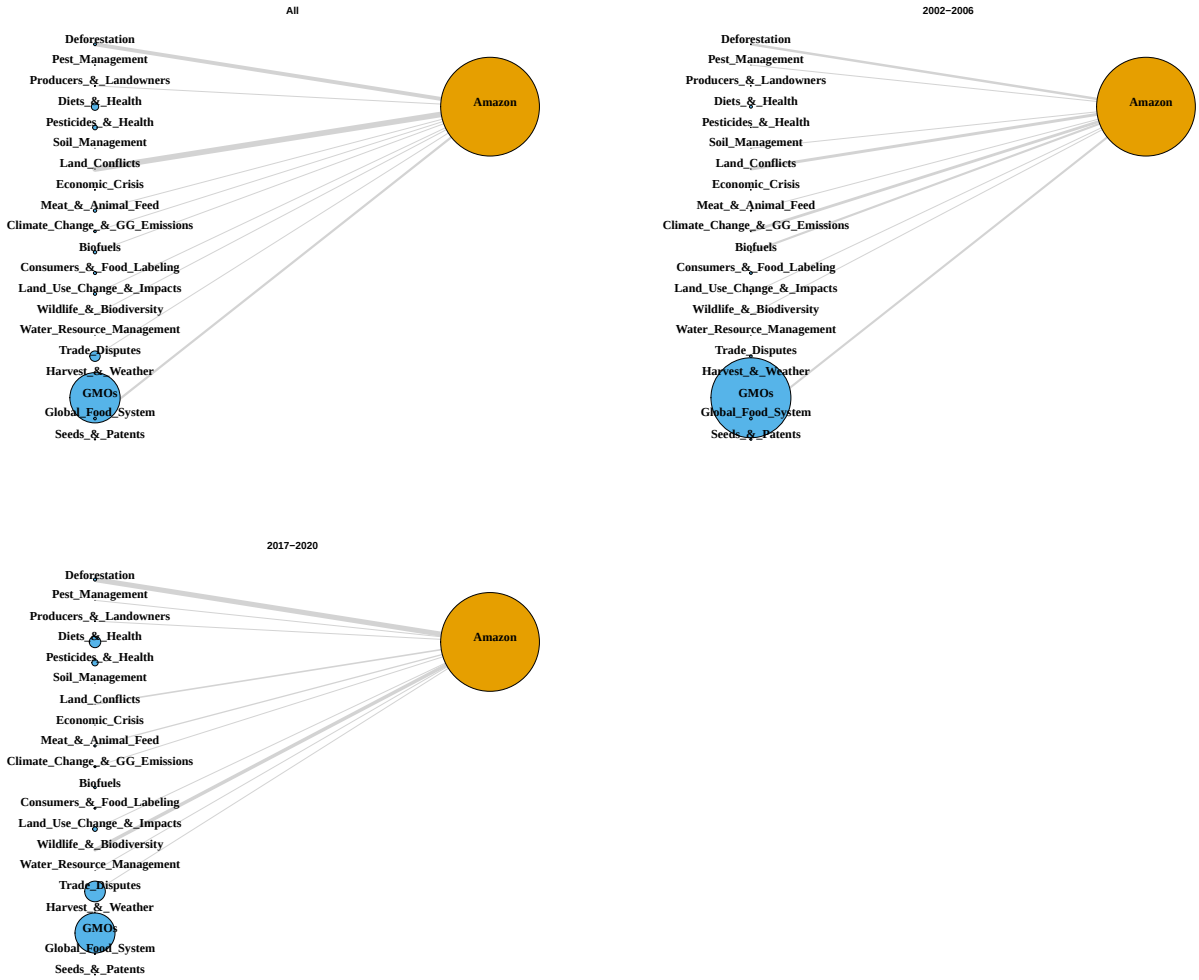

Figure A.18: Topic-biome bipartide network graph for political field.

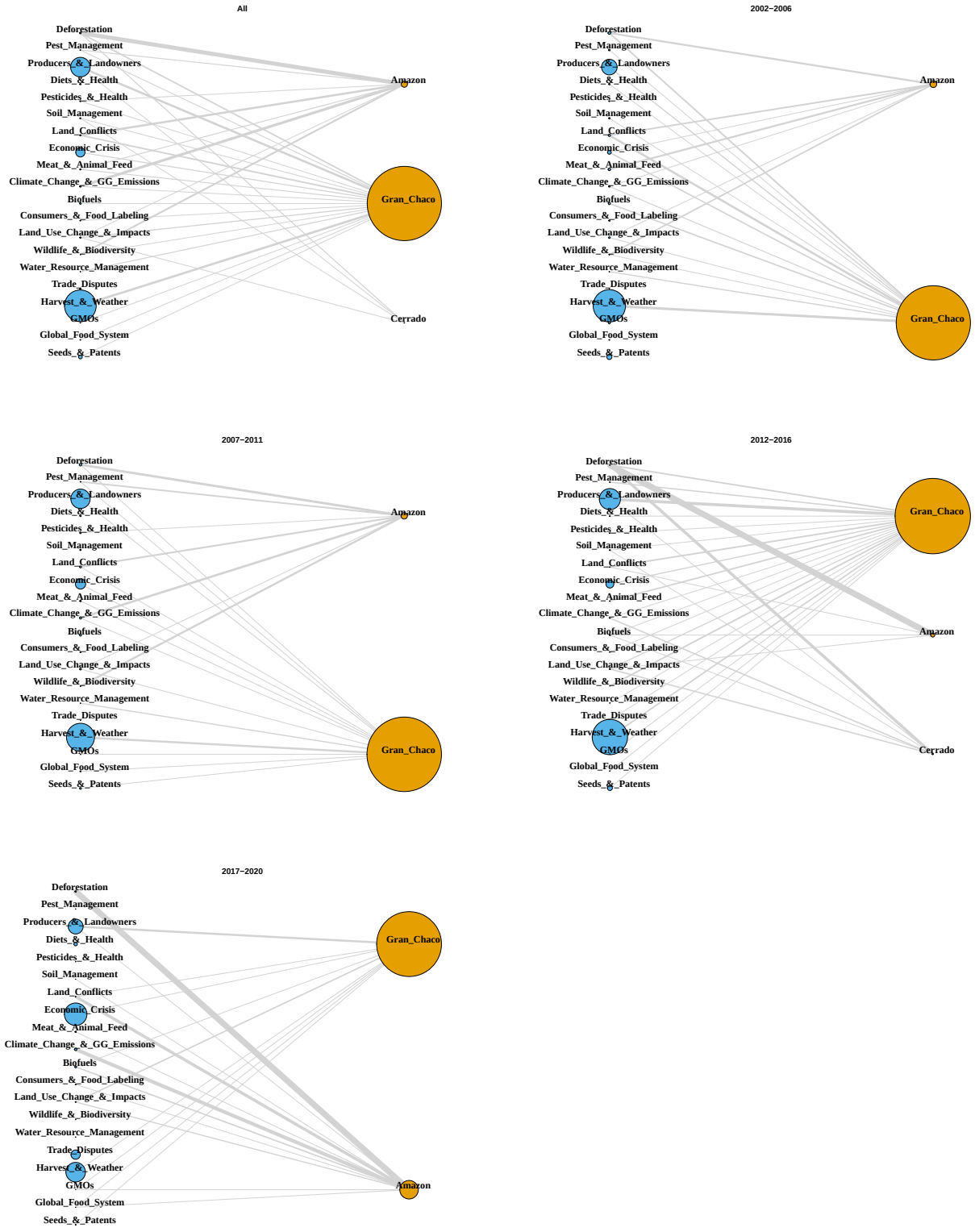

Figure A.19: Topic-biome bipartide network graph for print media from Argentina.

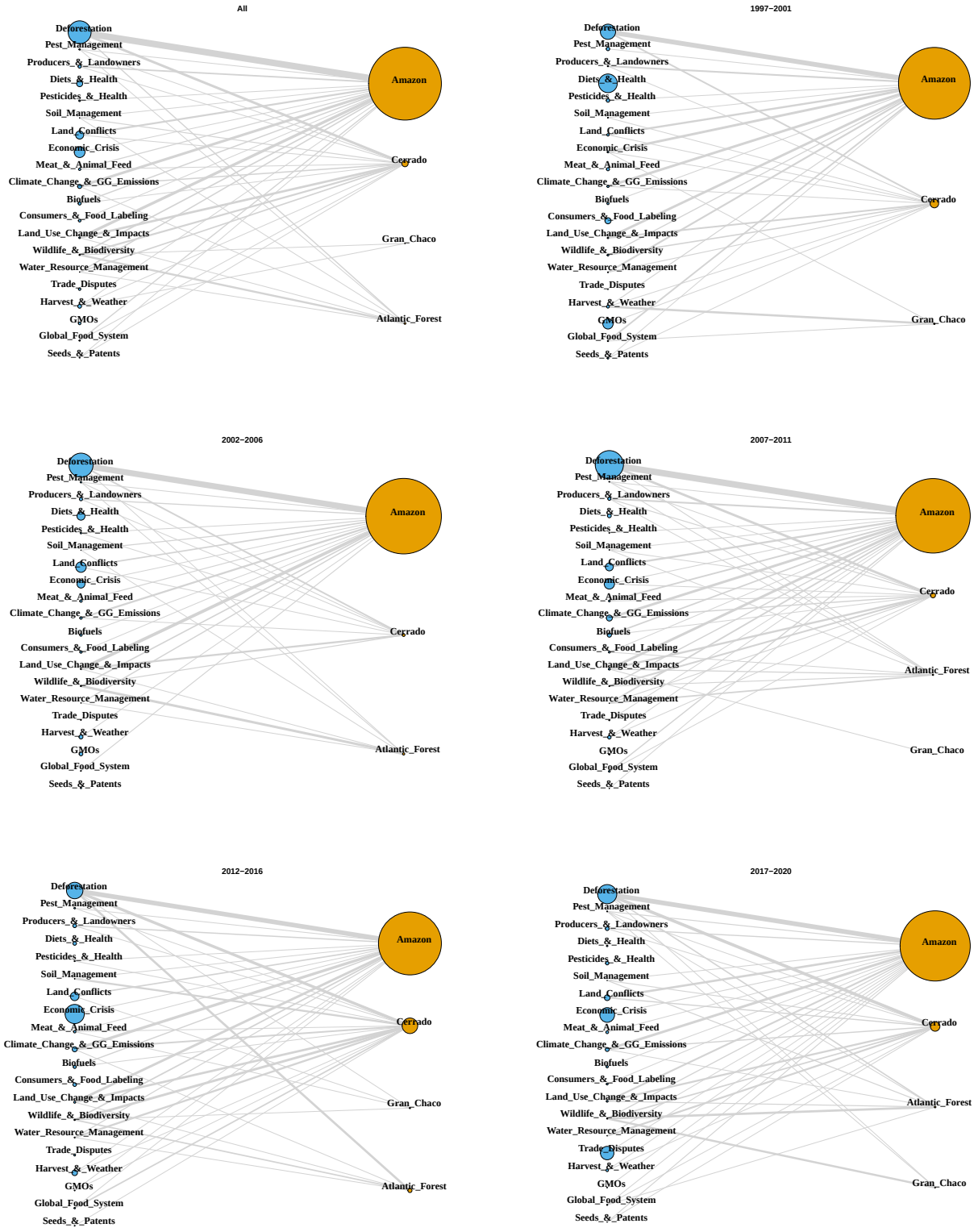

Figure A.20: Topic-biome bipartite network graph for print media from Brazil.

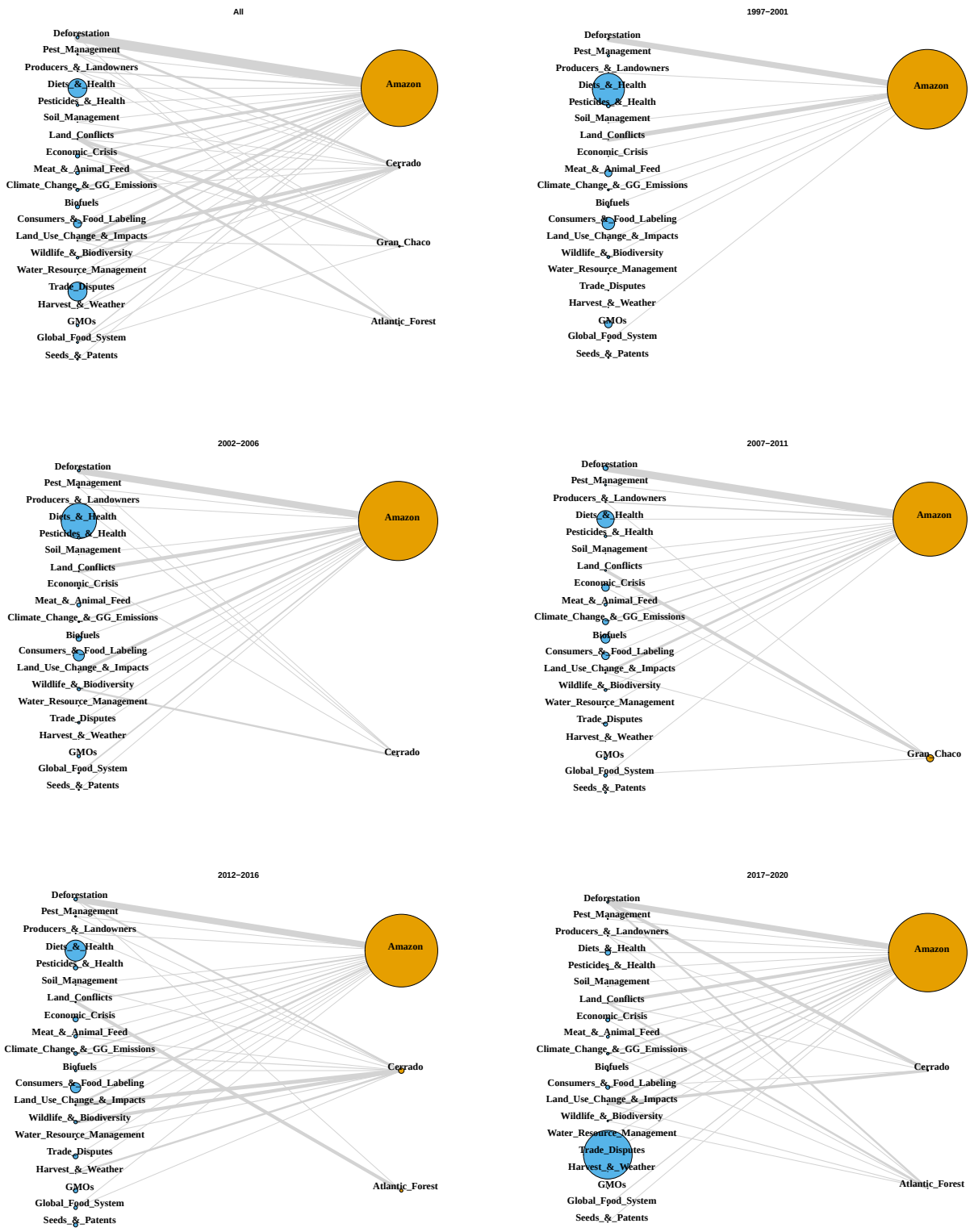

Figure A.21: Topic-biome bipartide network graph for print media from the US.

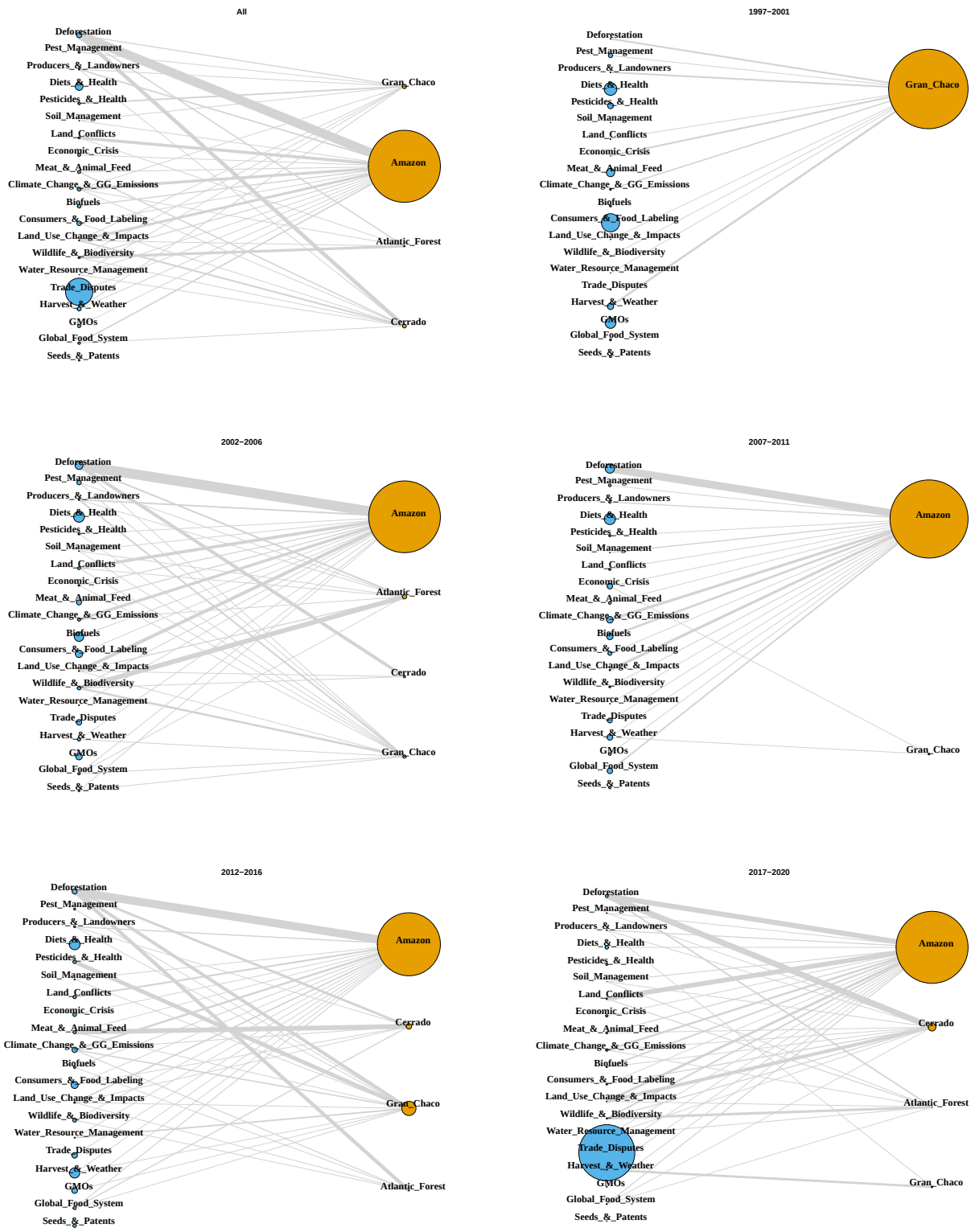

Figure A.22: Topic-biome bipartide network graph for transnational news agencies.

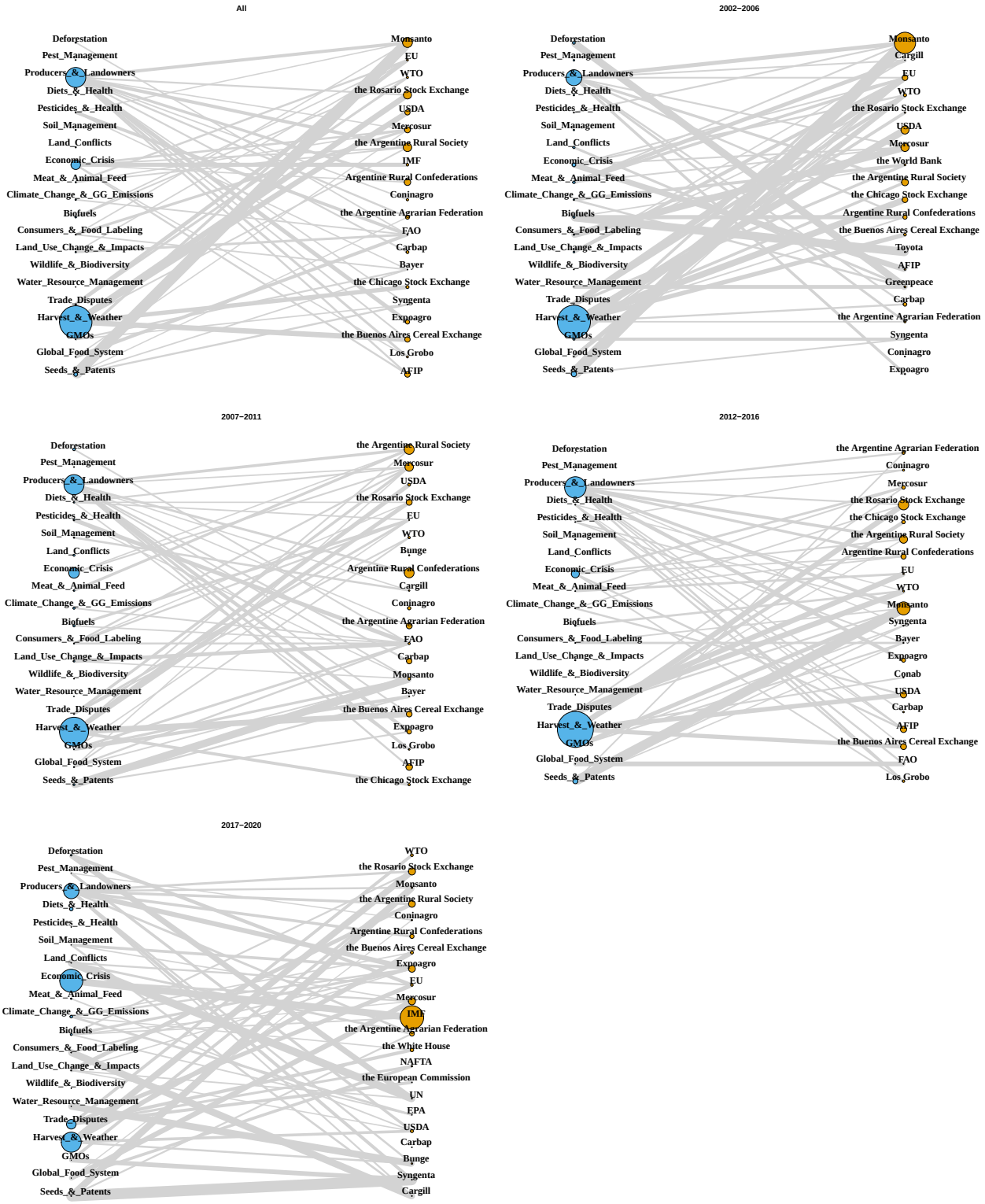

Figure A.23: Topic-organization bipartide network graph for print media from Argentina.

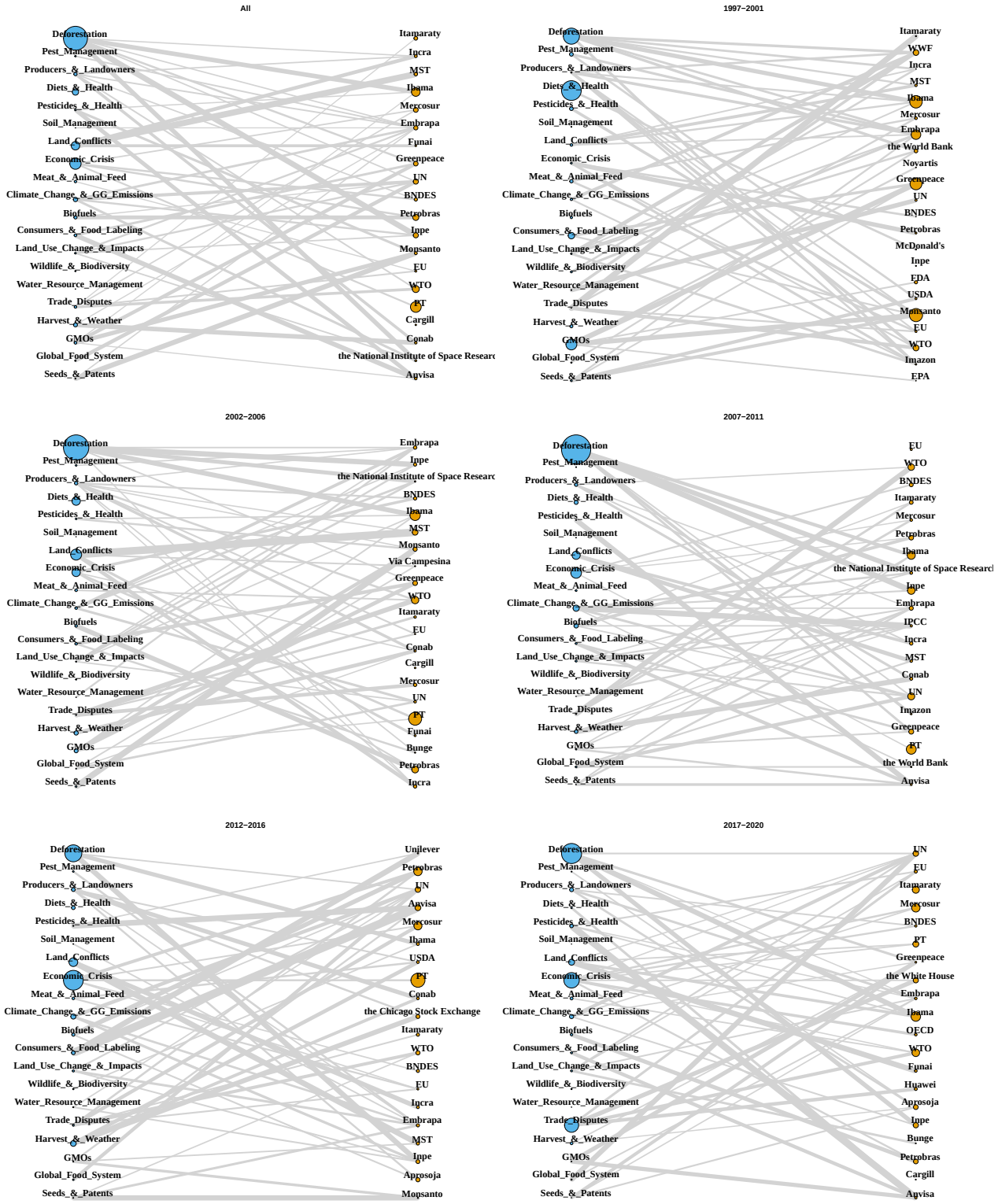

Figure A.24: Topic-organization bipartide network graph for print media from Brazil.

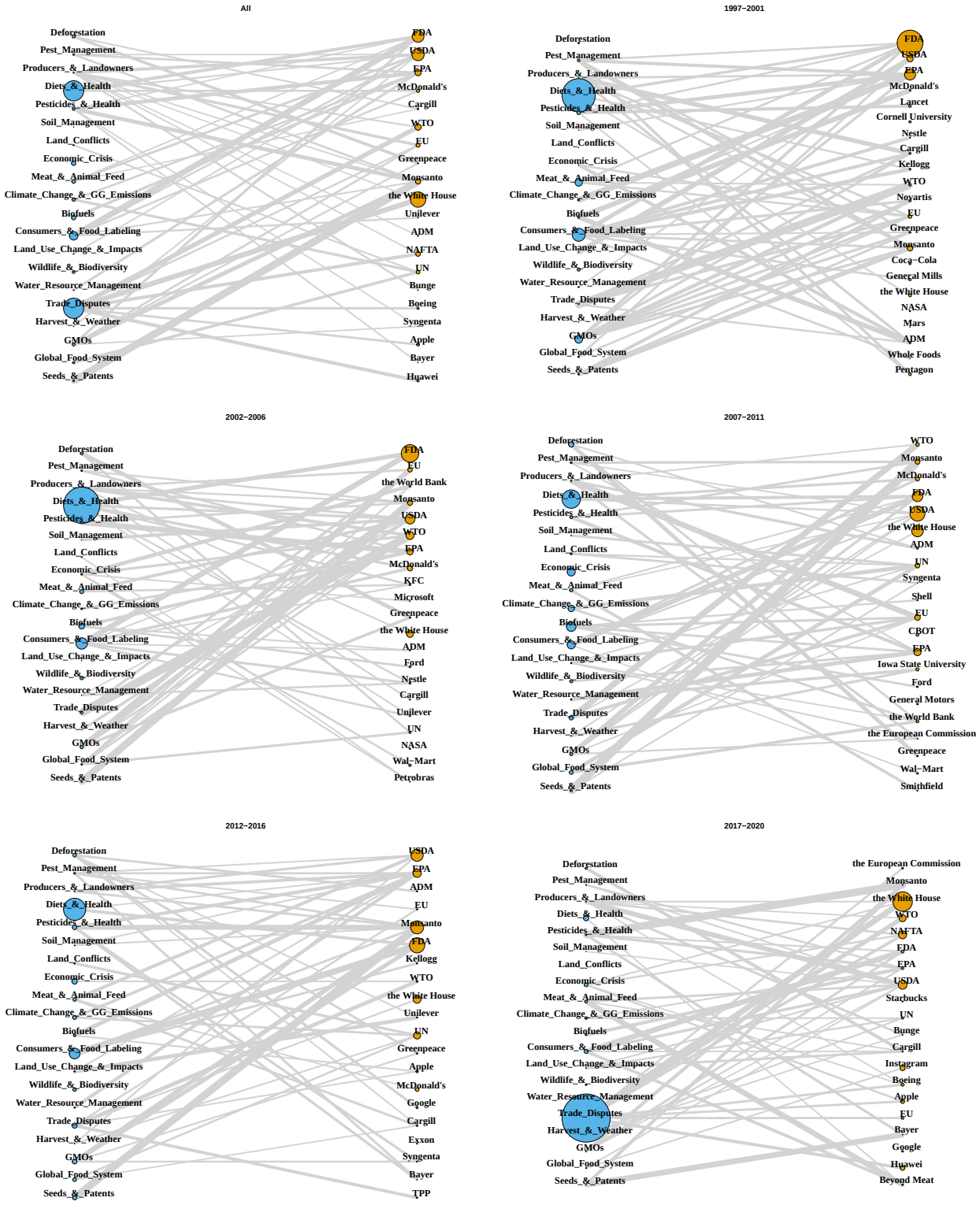

Figure A.25: Topic-organization bipartide network graph for print media from the US.

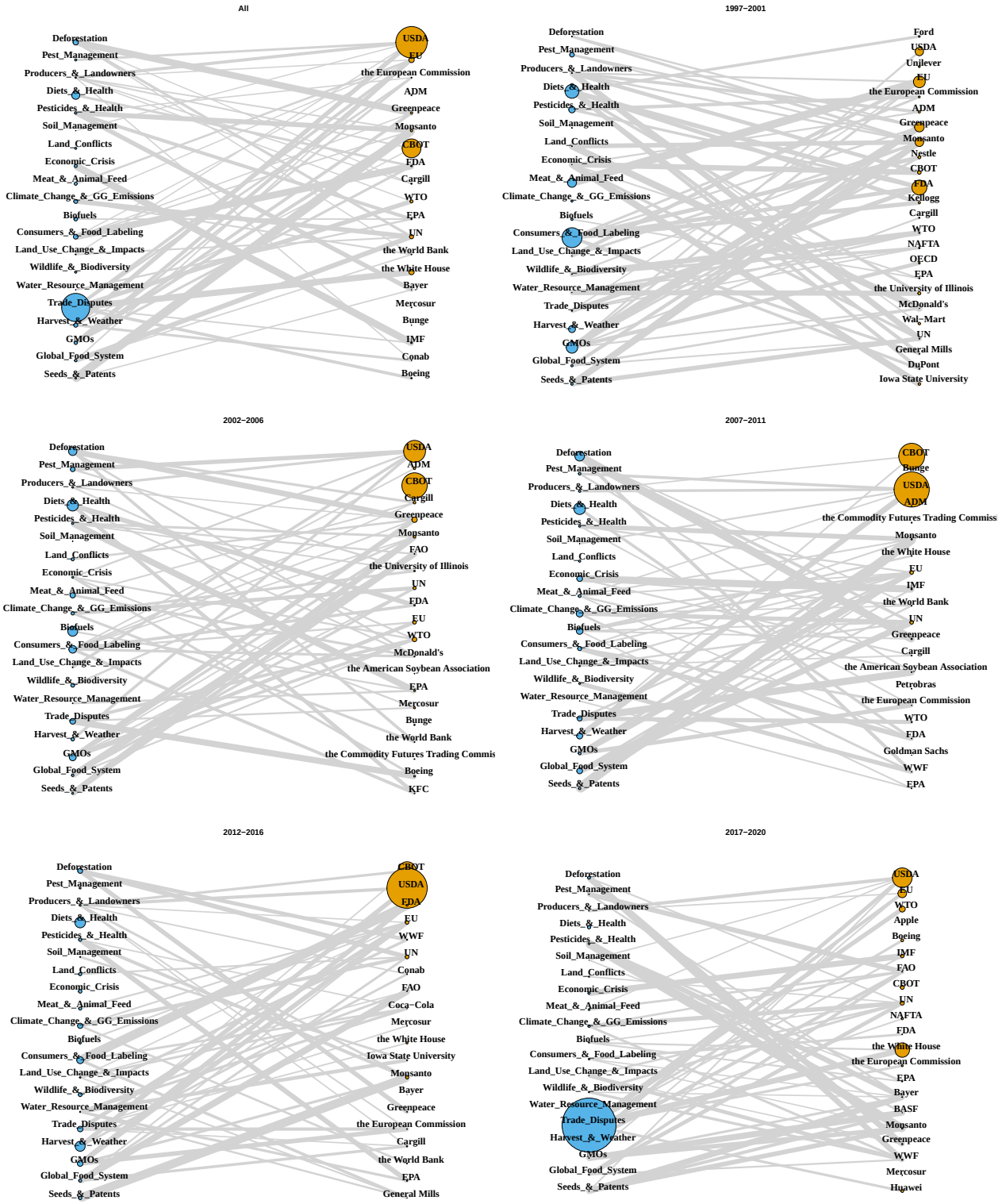

Figure A.26: Topic-organization bipartide network graph for transnational news agencies.

Figure A.27: Monthly topic prevalence and yearly keyness for three different sources.

Appendix B

Supplementary Material for chapter 5

B.1 Additional details on methods

Search strings, filtering and duplicate removal

Table B.1 lists the search strings we used for the respective biomes.

Biome	Source	Search String
Amazonia	Factiva	(amazon*) and (rainforest or basin or biome or forest) and (deforest* or destruction) and Brazil*
Cerrado	Factiva	(cerrado or savanna) and (biome or forest* or ecosystem*) and (deforest* or destruction) and Brazil*

Table B.1: Search strings and filtering criteria for various sources.

Compound tokens

To include relevant compound tokens from multi-word expressions (e.g., "climate_change") we performed a collocation analysis of both the original texts and the tokens after pre-processing. Only those collocations which occurred in both analyses and which had z-statistics of 50 or greater were considered. The z-statistic provides an estimate on whether a given collocation occurs as a result of a multi-word expression or simply by chance. It is based on measuring the standard deviations between observed and expected frequencies of individual nodes and their collocates. Please refer to the documentation of the textstat_collocations() function in the quanteda R package (Benoit et al. 2018) for further details. While we only included bigrams in our initial collocation analysis, the compound function tokens_compound() from the quanteda package renders longer multi-word expressions when bigrams overlap, when the argument JOIN is true.

Named entities

The list of extracted entities was further cleaned to correct wrong classifications and remove items, which were wrongly detected as entities. Where entities referring to the same organization had several different expressions (e.g., abbreviations) these were renamed to the primary expression for that entity. For the organizations, the list of detected entities was manually cleaned to only include organizations, companies, and institutions in a broad sense.

B.2 Additional results

Test statistics for determining K

Figure B.1 presents test statistics for topic model setups using the same input DFM with different numbers of topics (K). The held-out likelihood evaluates the performance of different models in completing documents for which a fraction of the words has been held out by using the document-level latent variables. It can thereby by considered a measure of the predictive capacity of the model. Residual dispersion evaluates the model fit based on multinominal likelihood, which implies that a dispersion higher than 1 indicates an optimal K that is larger than the one specified in the model. Semantic coherence indicates whether the words which are most probable for a given topic frequently co-occur within documents. The lower bound is an estimate of the lower bound of the marginal likelihood used for model convergence. While most of the test statistics (apart from semantic coherence) indicate optimal values for K higher than 40, gains level off and manual interpretation found overclustering for values of K higher than 40, splitting coherent topics into several versions of the same.

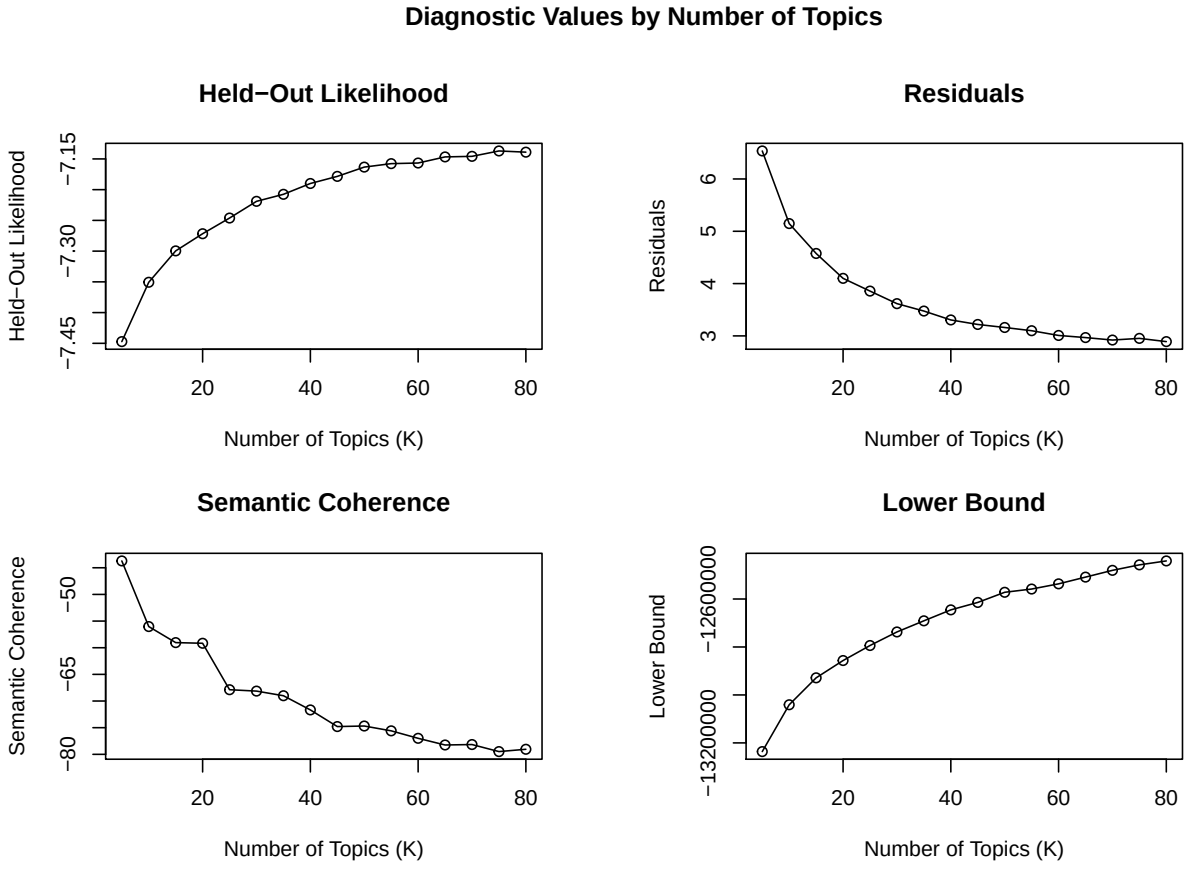

Figure B.1: Test statistics for topic models with topic number (K) between 20 and 160 in steps of 20.

Further, Figure B.2 illustrates the relationship between semantic coherence and exclusivity (indicating in how far words are exclusive to single topics). We can observe that the gains in exclusivity level off relative to decreasing semantic coherence for topic numbers above 40.

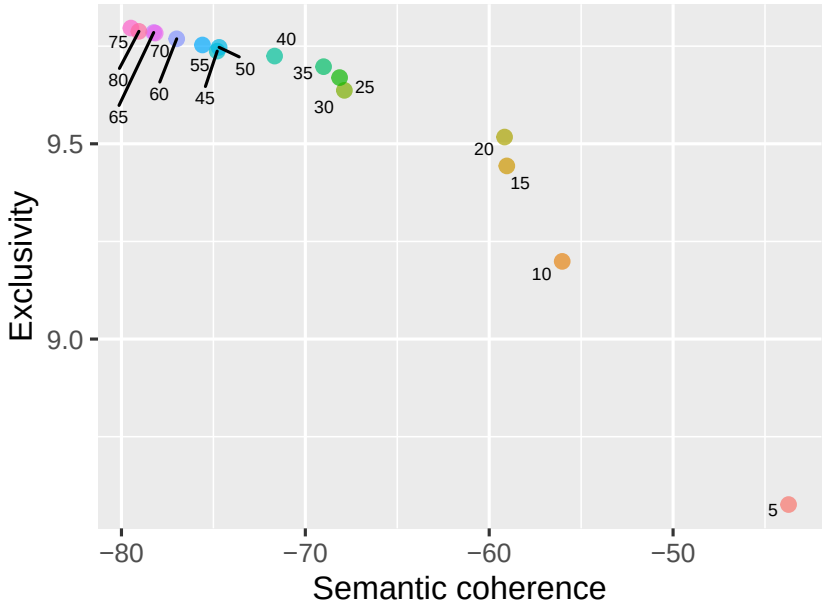

Figure B.2: Test statistics exclusivity and semantic coherence for topic models with topic number (K) between 20 and 160 in steps of 20.

Topic model validation

Figure B.3 presents the results from hierarchical clustering. Selected and grouped topics are coded by colors, indicating classification according to drivers, impacts, responses and others. Related topics tend to cluster at nearby nodes.

Co-occurrence between topics and named entities

Figure B.4 and Figure B.5 illustrate the co-occurrence between the 20 most frequent named entities referring to organizations and institutions and the 27 topics for each biome.

Manual coding

Figure B.6, Figure B.7 and Figure B.8 illustrate the results from the manually coded documents.

SVO triplet networks for different time periods

Figures B.9 - B.16 illustrate the most common SVO triplets for the 15 most frequently mentioned actors in articles on deforestation in the Amazon and Cerrado biomes for all time periods. Edge thickness represents the frequency of a given SVO triplet and red nodes indicate subjects or objects relating to identified actors.

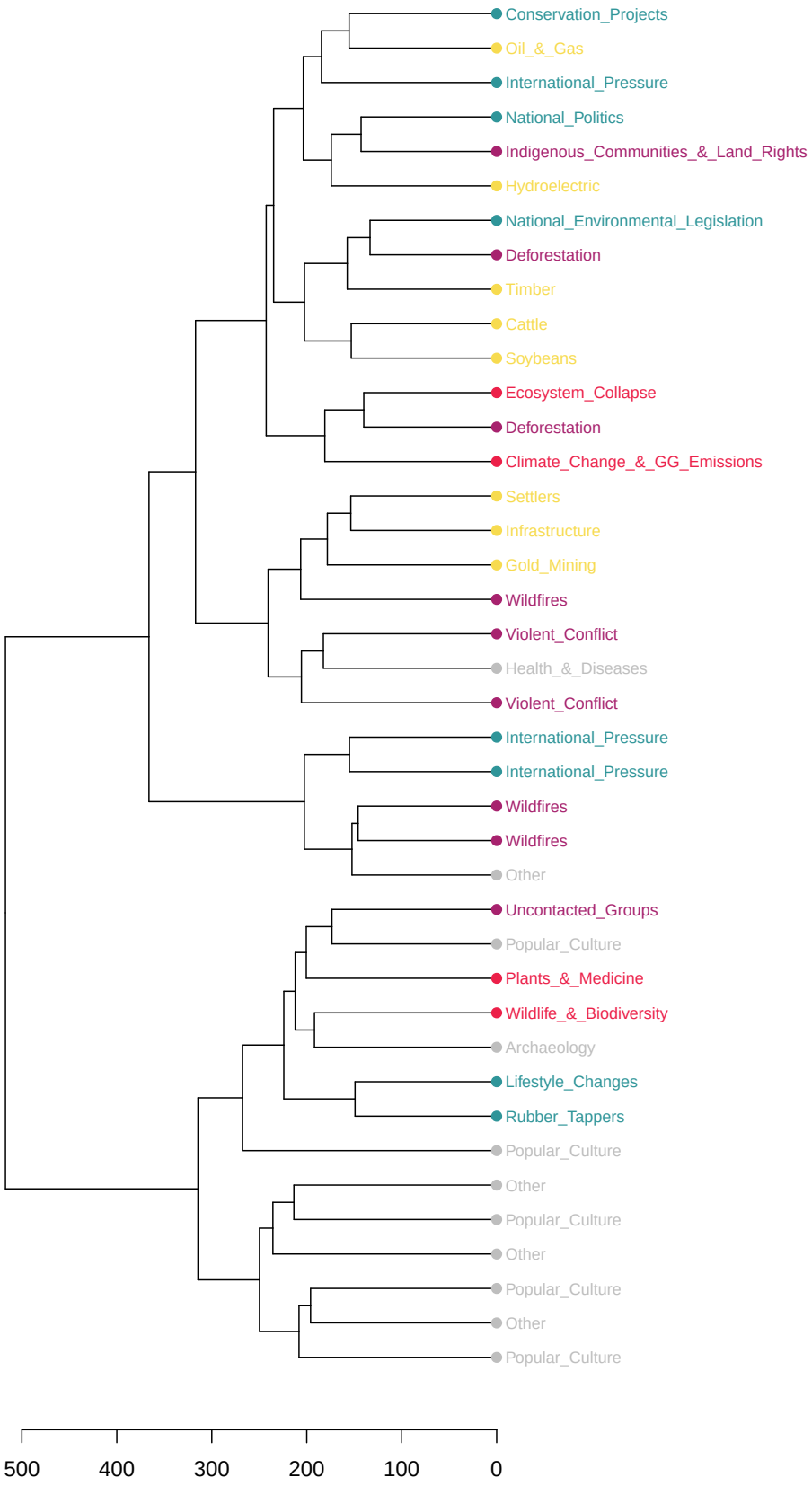

Figure B.3: Dendrogram illustrating results from hierarchical clustering based on Euclidean distance between topic word-vectors. Colored nodes represent topic classification.

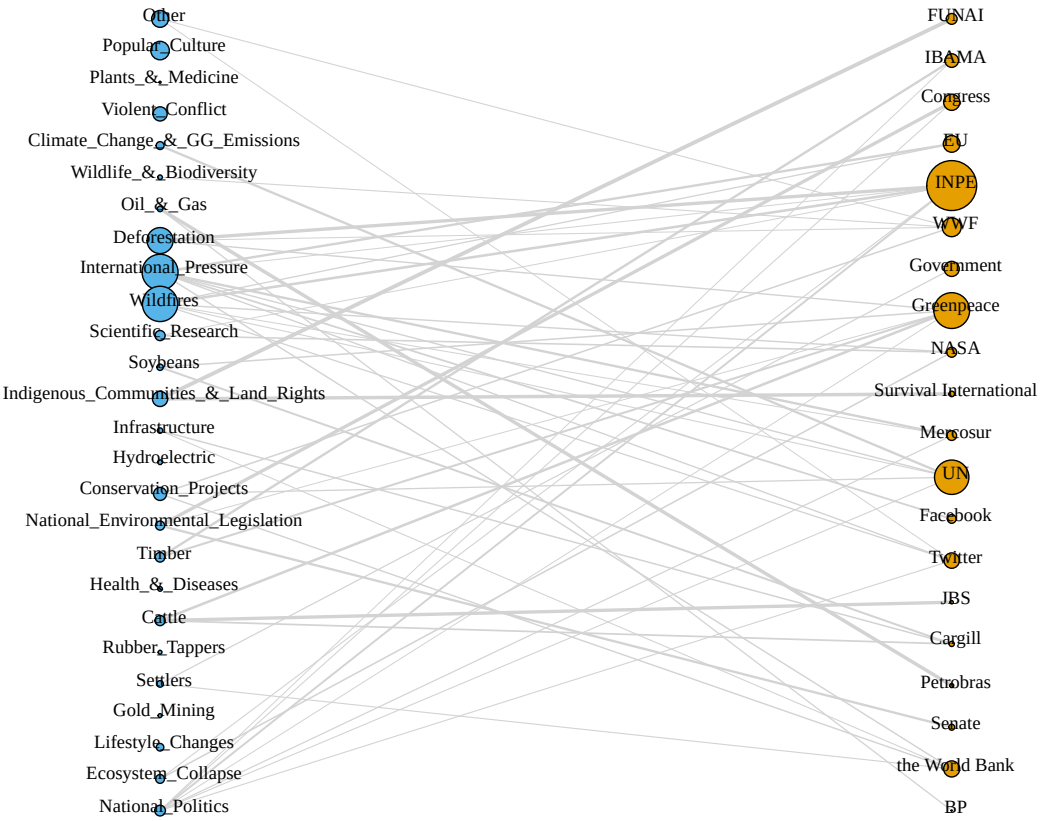

Figure B.4: Bipartite network graph for articles on the Amazon biome indicating co-occurrence between topics and named entities referring to organizations. Node size indicates prevalence of topics and entities. Edge width indicates the level of co-occurrence. Only the top 10% edge weights were plotted.

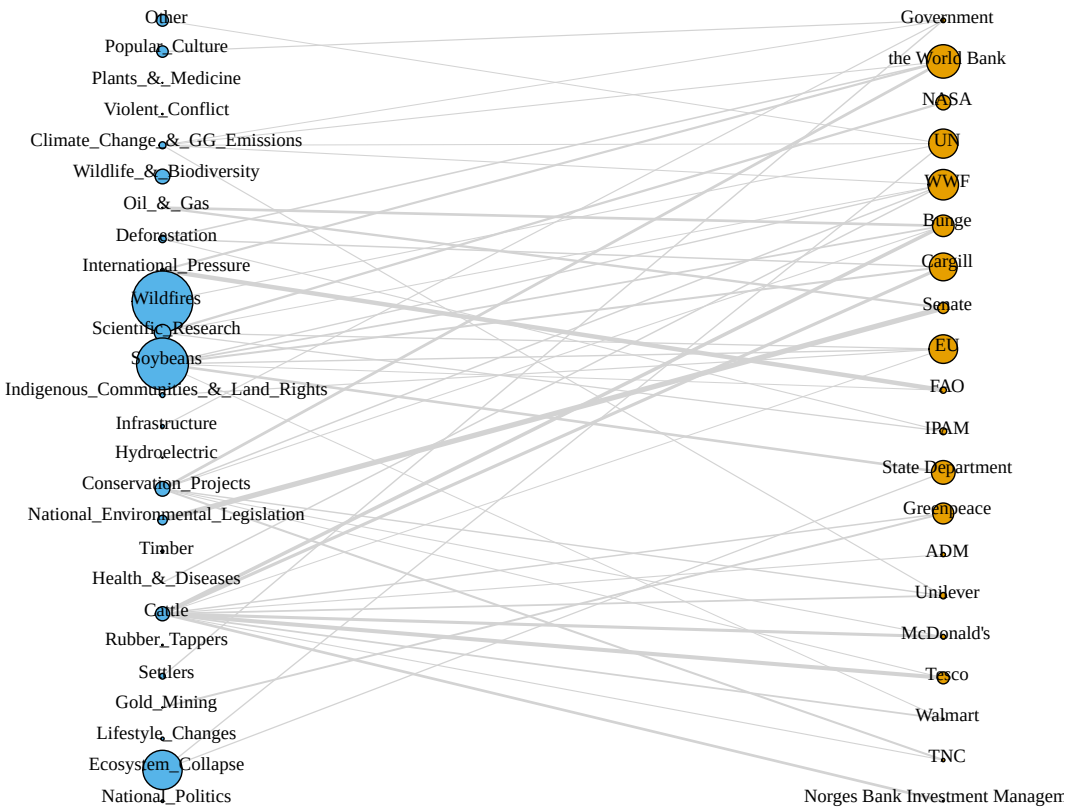

Figure B.5: Bipartite network graph for articles on the Cerrado biome indicating co-occurrence between topics and named entities referring to organizations. Node size indicates prevalence of topics and entities. Edge width indicates the level of co-occurrence. Only the top 10% edge weights were plotted.

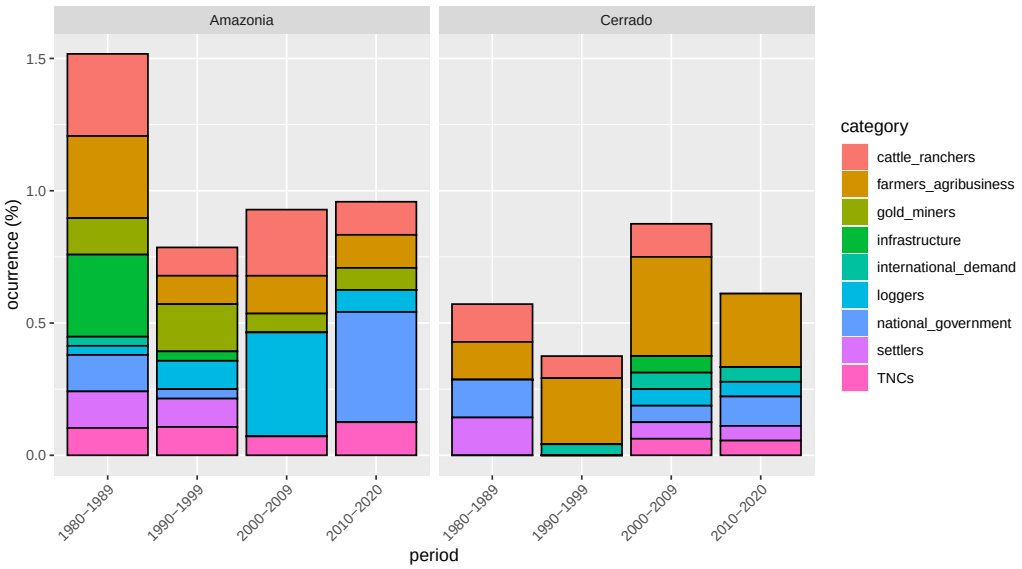

Figure B.6: Results for the manually coded question: What actors are portrayed as being responsible for deforestation? (diagnostic frames).

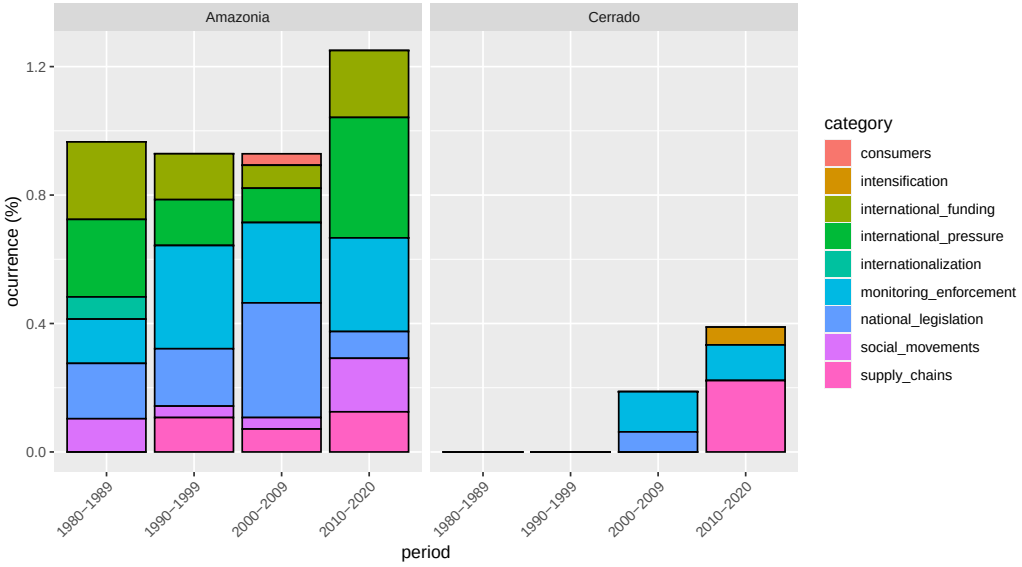

Figure B.7: Results for the manually coded question: What solutions or responses are identified? (prognostic frames)

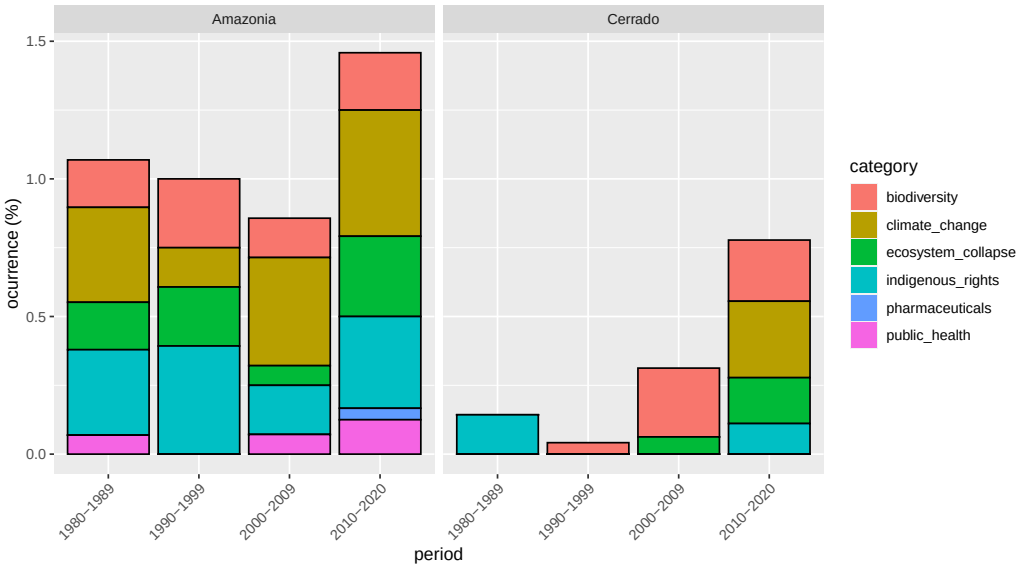

Figure B.8: Results for the manually coded question: What urgent consequences and problems associated with deforestation are identified? (motivational frames)

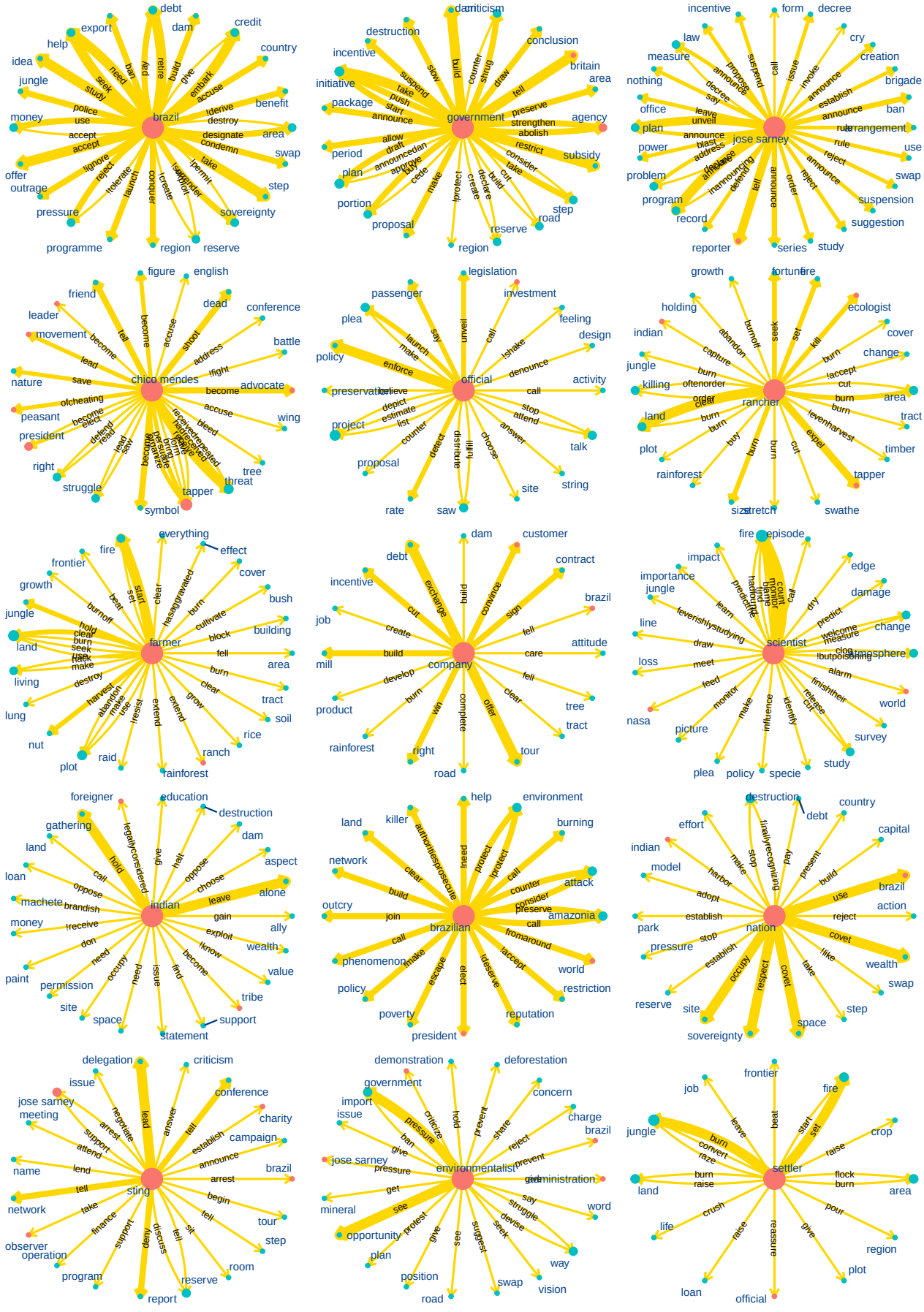

Figure B.9: SVO triplets for Amazonia (1980 - 1989).

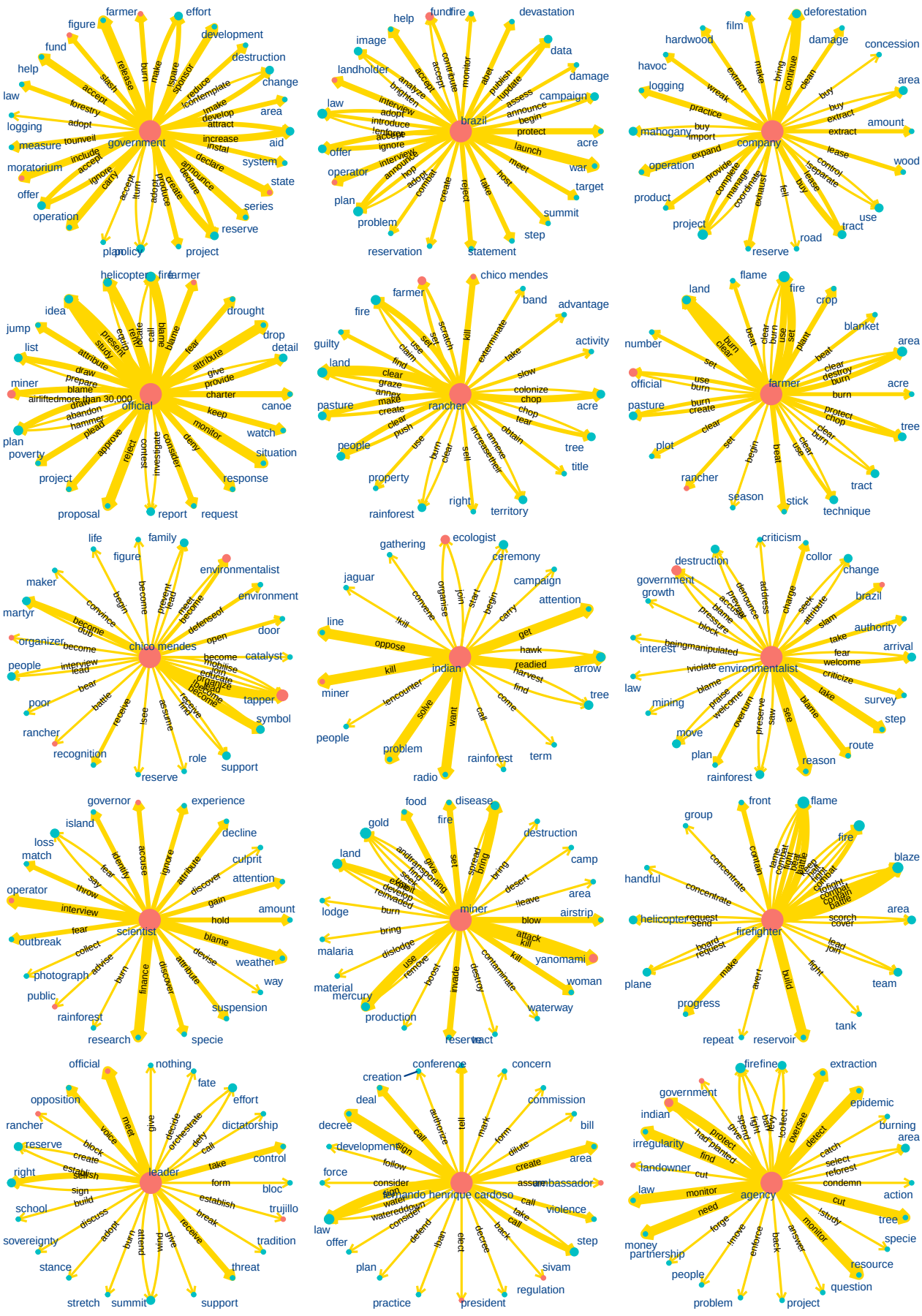

Figure B.10: SVO triplets for Amazonia (1990 - 1999).

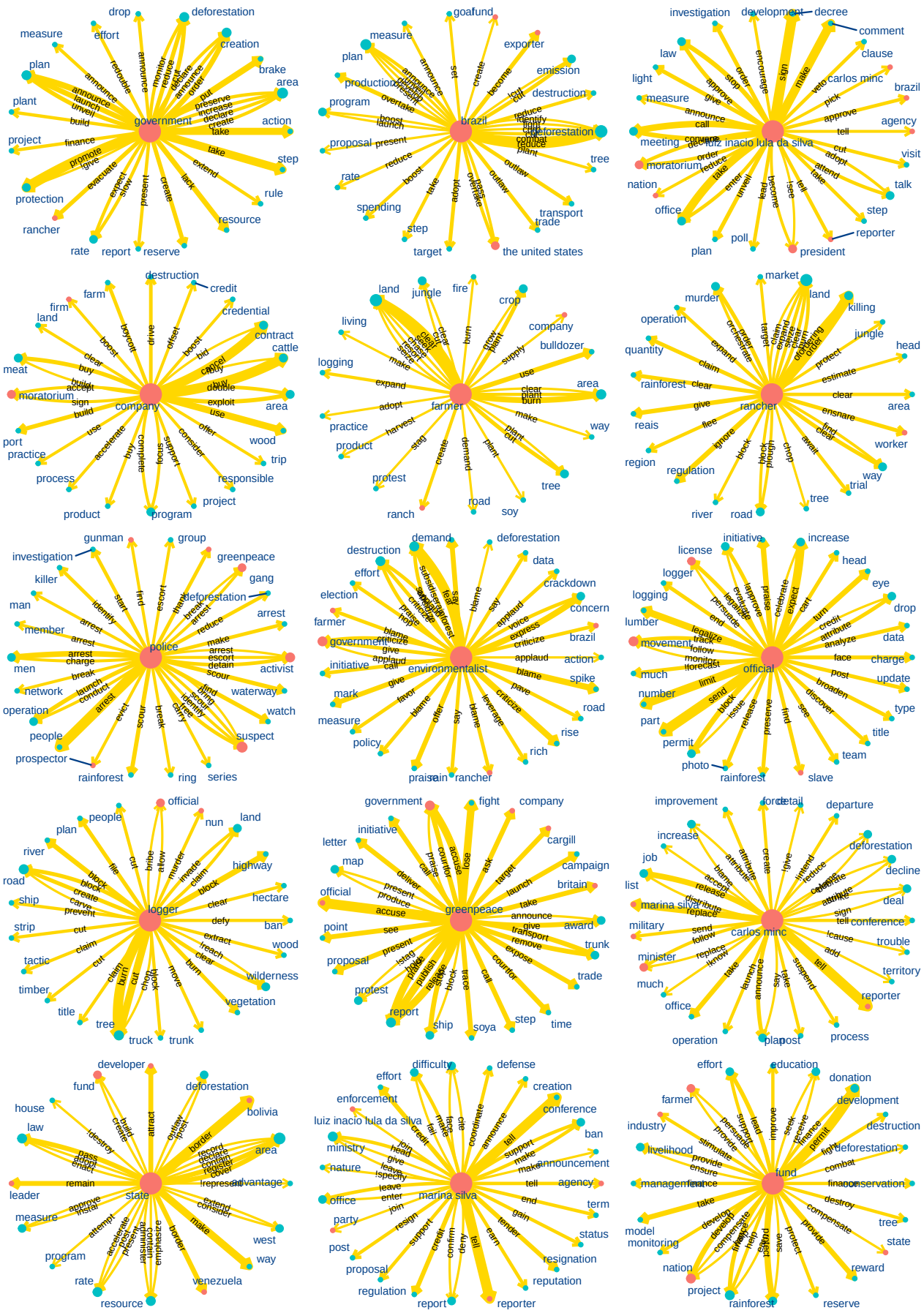

Figure B.11: SVO triplets for Amazonia (2000 - 2009).

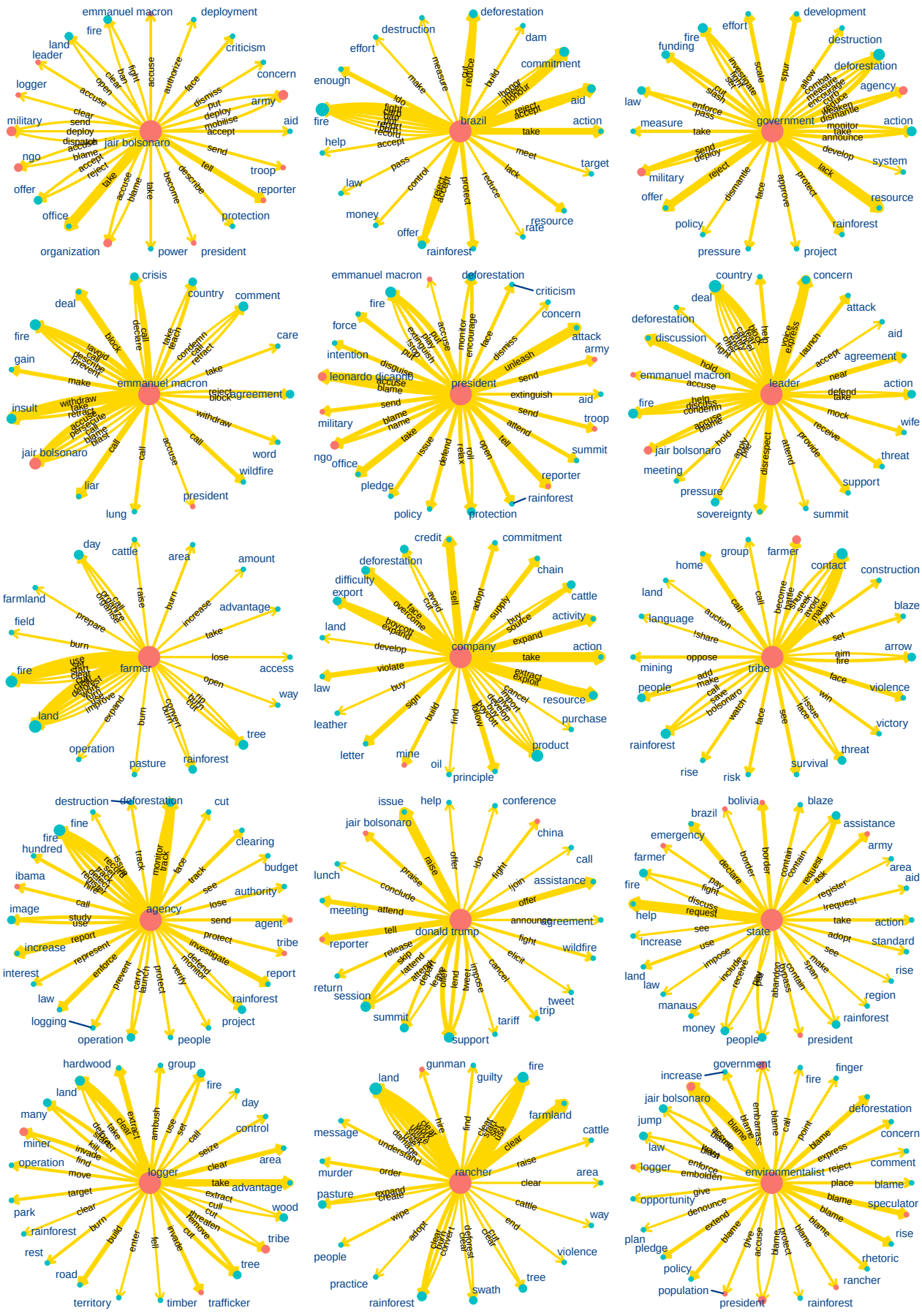

Figure B.12: SVO triplets for Amazonia (2010 - 2020).

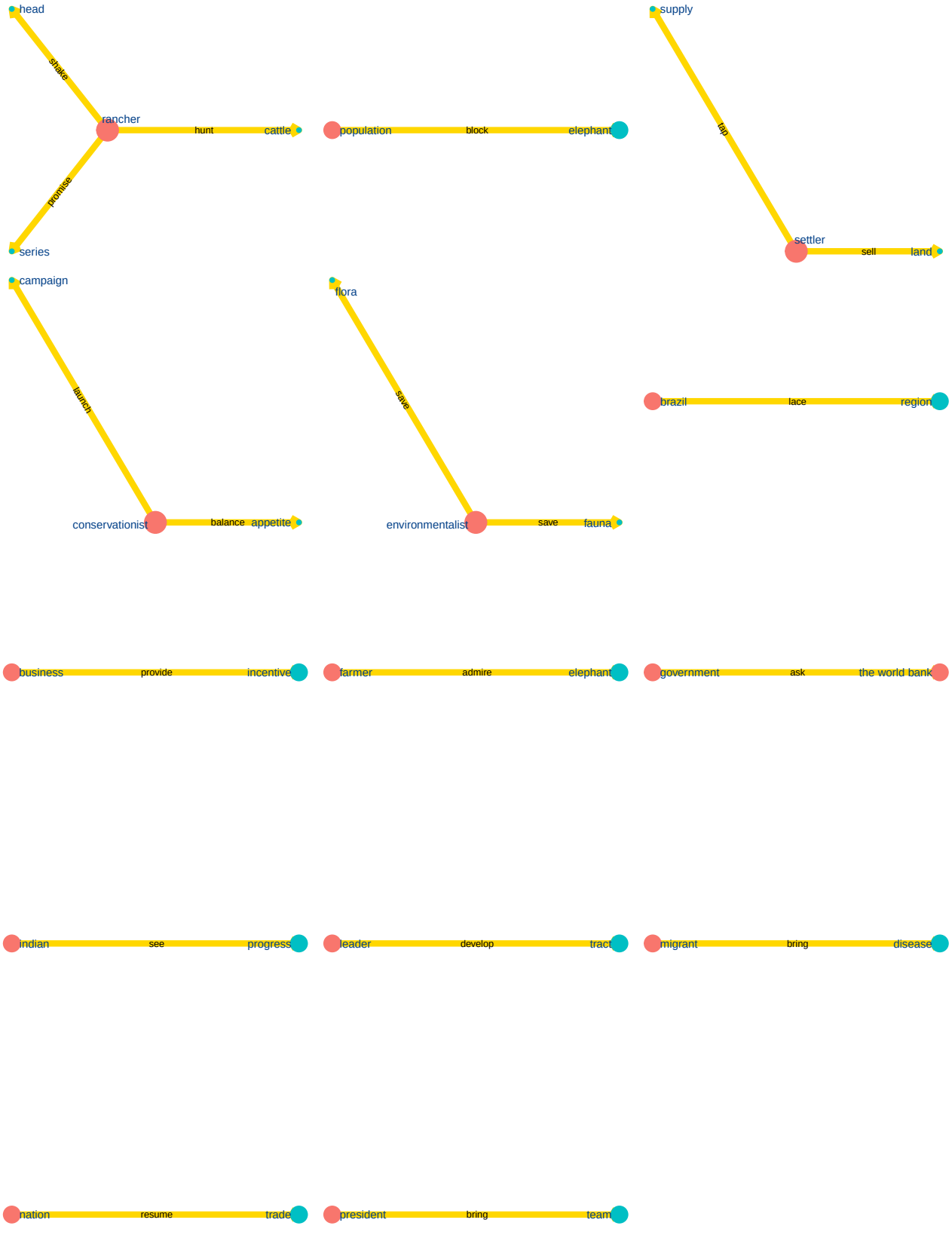

Figure B.13: SVO triplets for Cerrado (1980 - 1989).

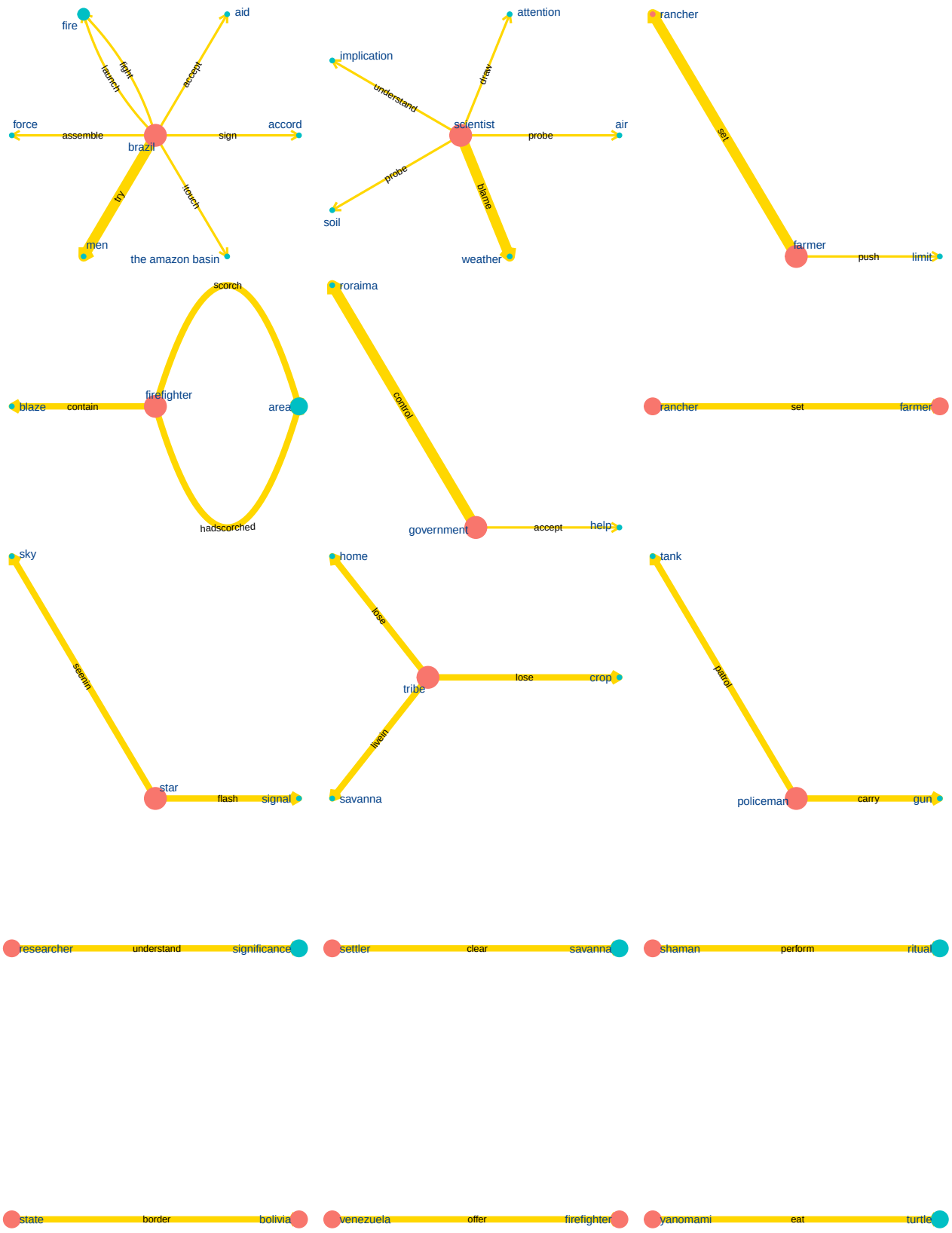

Figure B.14: SVO triplets for Cerrado (1990 - 1999).

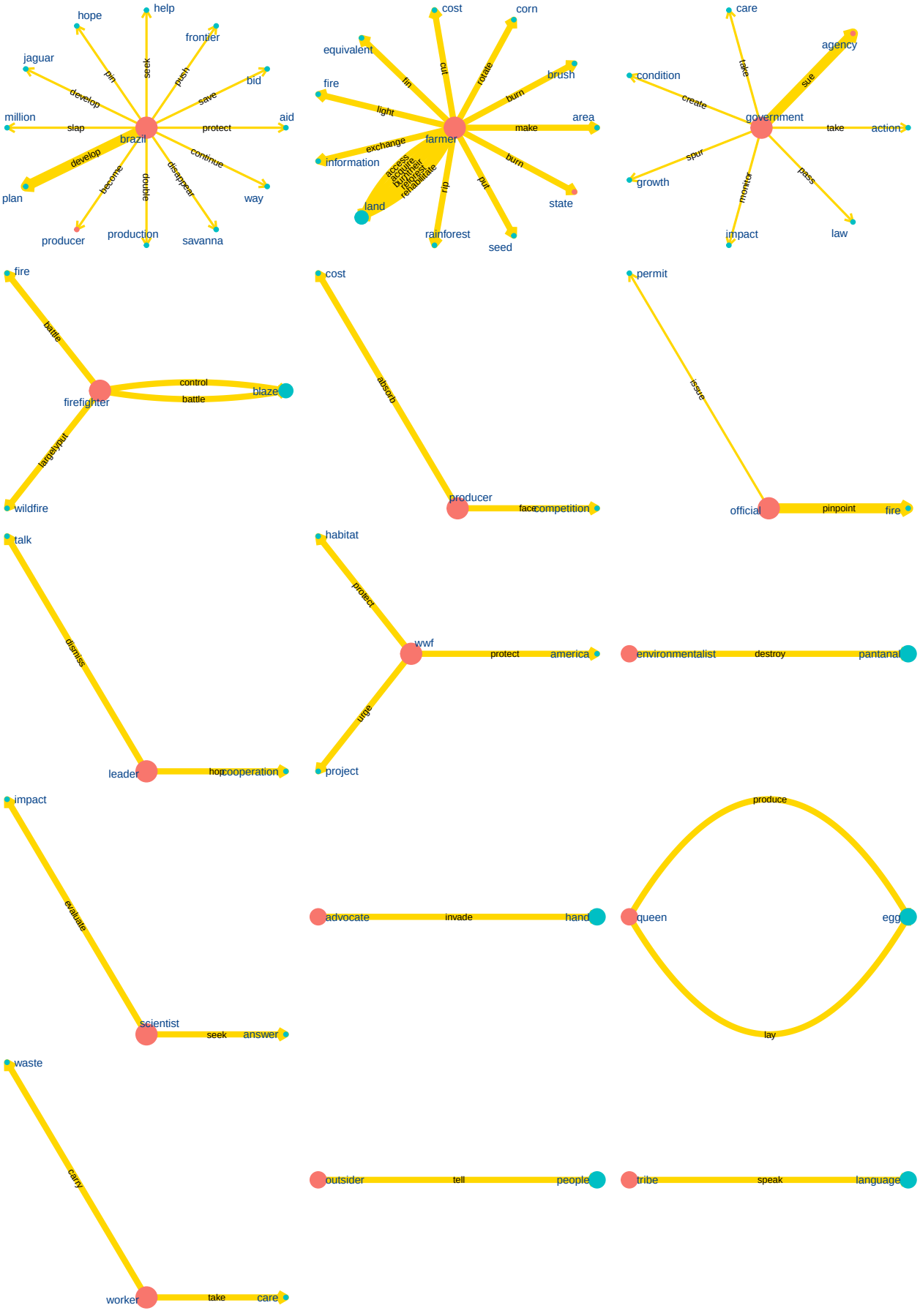

Figure B.15: SVO triplets for Cerrado (2000 - 2009).

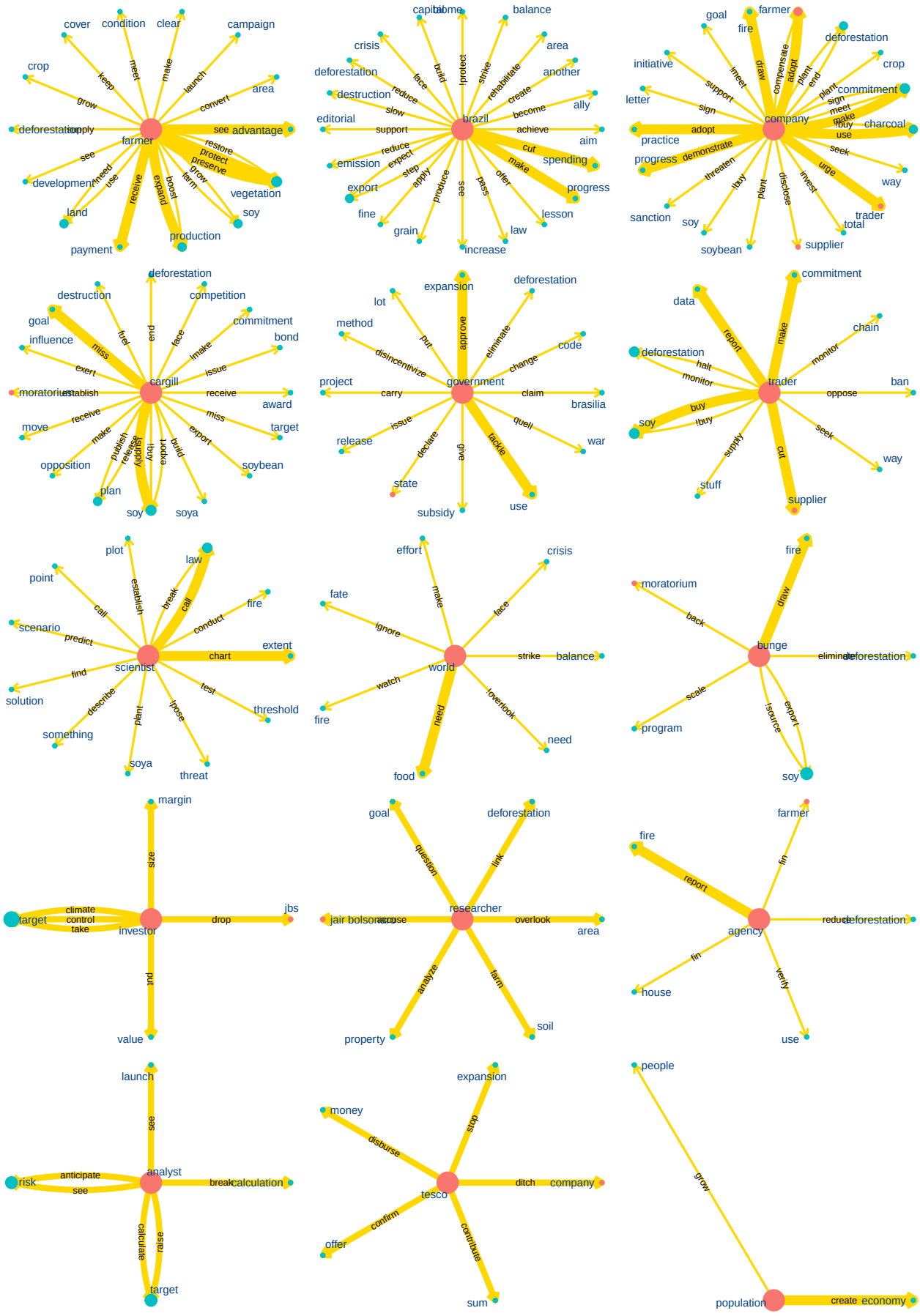

Figure B.16: SVO triplets for Cerrado (2010 - 2020).

Appendix C

CURRICULUM VITAE

EDUCATION

Ph.D. Candidate, Institut de Ciència i Tecnologia Ambientals (ICTA), Autonomous University of Barcelona

July 2018 - present

Thesis title: Disentangling the Global Soybean Complex - Land use change in the era of reflexive modernity

Thesis Supervisors: Esteve Corbera and Beatriz Rodríguez-Labajos

M.Sc. in Ecohydrology, Kiel University and University of the Algarve

September 2014 - November 2016

Thesis title: Macroalgae habitat mapping in a rocky shore environment - a look-up-table approach using hyperspectral imagery

Thesis supervisors: Natascha Oppelt and Inka Bartsch

B.Sc. in Environmental and Resource Management, Brandenburg University of Technology

October 2010 - October 2013

Thesis title: Case Study on Communally Managed Water Suppliers in Colombia: Institutional Design, Performance and Legal Framework

Thesis supervisors: Lutz Laschewski and Daniel Häfner

PUBLICATIONS

PUBLISHED

Mempel, F. & Bidone, F. (2022). Re-MEDIAting distant impacts - How Western media make sense of deforestation in different Brazilian biomes. *Environmental Sociology*. 1-16.

Pedersen, A. F., Nielsen, J. Ø., **Mempel F.**, Bager, S. L., Jønsson, J. B., & Corbera, E. (2021). The ambiguity of transparency in the artisanal and small-scale mining sector of Tanzania. *The Extractive*

Industries and Society, 8(4), 101004.

Mempel, F., & Corbera, E. (2021). Framing the frontier – Tracing issues related to soybean expansion in transnational public spheres. *Global Environmental Change*, 69:102308.

Corbera, E., Rodríguez-Labajos, B., **Mempel, F.**, Busck-Lumholt, L.M. 2019. Environmental Justice in Telecoupling Research. In: C. Friis, J. Ø. Nielsen, *Telecoupling: Exploring Land-Use Change in a Globalised World*. Palgrave Macmillan, Springer Nature Switzerland AG, Switzerland.

Lehmann, J., **Mempel, F.**, Coumou, D. 2018. Increased Occurrence of Record-Wet and Record-Dry Months Reflect Changes in Mean Rainfall. *Geophysical Research Letters* , 45 (24): 13,468-13,476.

IN PRESS/SUBMITTED/UNDER REVIEW

Castro-Vargas, S.M., **Mempel, F.** (in press). Latin America in the chemical vortex of agrarian capitalism. In Bustos-Gallardo, B., Ojeda, D., López, G. G., Milanez, F., and Di-Mauro, S. E., editors, *Routledge Handbook of Latin America and the Environment*.

Mempel, F., Corbera, E., Rodríguez-Labajos, B., Challies, E. (2022). From railroad imperialism to neoliberal reprimarization: lessons from regime-shifts in the global soybean complex. *Manuscript in review*.

Shattuck, A., Werner, M., **Mempel, F.**, Dunivin, Z., Galt, R. (2022). Improved estimates of global pesticide use show no sign of leveling off, with strong growth in low-income countries. *Manuscript submitted for publication*.