Governing flows in telecoupled land systems

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Abstract
The increasing global interconnectivity influencing land system change brings with it new challenges for land-system science. We evaluate whether recent land-system science (LSS) research into telecoupling provides a basis to set normative goals or priorities for addressing sustainability in coupled human-natural systems. We summarize the challenges for sustainability in an increasingly telecoupled world, particularly the coordination of multisited, multiscalar networks of public and private sector actors. Transnational flows of capital, commodities, energy, people and waste often span multiple territorial jurisdictions. Thus, effective governance of such systems requires attention to collective decision-making and negotiation among governments, firms, land users, consumers, financial actors and others.

Introduction
How are significant environmental changes linked to larger trends in production, consumption or investment thousands of kilometers away? That land systems and land-system change are embedded in networks with international reach is not new, but the speed, scale and scope of late 20th and early 21st century globalization is arguably unprecedented. Land-system science (LSS) theories and approaches are actively grappling with an emerging body of knowledge on telecoupling, or the flows and feedbacks through which dynamic, social-natural systems are reciprocally connected over great distances (1,2**,3). Traditional land-system science analyses arguably prioritize local land users and policies that affect them, yet current trends are also enacted by globally-nimble private sector organizations, such as in the modern agricultural frontiers in South America, driven by capitalized corporate agriculture with little government intervention (4**).

This increasing interconnectivity influencing land system change brings with it new challenges for land-system science. Key questions related to linkages between distant land systems include: how do policy changes in one state or region affect land systems elsewhere? What are the social and environmental benefits and tradeoffs of increasingly global flows of agricultural and forest products? How are smallholders negotiating an increasingly global marketplace for their goods? Underpinning such questions are important normative questions, and even dilemmas, that increasingly confront land system scientists working on addressing the sustainability challenges brought by globally connected land-use change. One of the most pressing concerns is the lack of coordinated, transparent, international leadership to tackle environmental problems. Moreover, some attempts at internationally coordinated responses to environmental challenges are actively manipulated by powerful actors. For instance, climate change denial is in part fueled by global corporate actors seeking to continue a political economy of deregulating industry (5).

The global economy is comprised of complex networks of actors and institutions spanning over variable spatial extents, leveraging natural resources to generate value (6), with a constantly evolving institutional context incorporating individual producers, consumers, nongovernmental organizations, firms, financial intermediaries, other civil society actors and governments of

various territories. In such an interconnected system, defining sustainability is difficult (7,8*,9). Developing a research agenda for sustainability (10) requires the identification of leverage points and governance options for land system transformation (11). It is fair to say that we have accumulated much knowledge in several years of telecoupling research (12), yet that knowledge remains partial. Likewise, there are substantial innovations happening to response to negative social and environmental outcomes from globalization of land systems, yet the full potential of these innovations to drive better system outcomes is still unclear.

In this paper, we evaluate whether recent land-system science (LSS) research into telecoupling provides a basis to set goals or priorities for addressing sustainability. To do so, we review empirical examples of how telecoupling challenges conventional notions of environmental sustainability and the governance mechanisms to address it.

Recent literature on socioecological systems emphasizes dynamic interactions and feedbacks, including spillovers to other places distinct from the sites of production and consumption (13). Underlying these flows and feedbacks are various actors, who exhibit varying degrees of influence on how land is used and what is produced, where and how, and how costs and benefits are distributed within socioecological systems. Moreover, the ability of particular actors to influence or transform these telecoupled land systems emerges from their relative position within the flows of commodities, capital and information. For instance, we might think of large agribusiness companies driving soy production as powerful decision-makers in driving South American deforestation policies (14). At the same time, these companies themselves are facing razor-thin profit margins and facing consolidation pressure within their industries (15).

Confronting these large-scale changes involving spatially mobile actors, significant capital value in production and investment, and massive land transformations requires us to think of governance emanating from beyond territories to the flows themselves (16). Further, governance encompasses more than particular policies to alter incentives of particular actors within large, spatially connected land systems. More broadly, the interactions and interconnections of actors within telecoupled land systems can be thought of as collective decision-making (17): the ability of a given actor to alter, adapt or respond to land changes depends on their connections to other actors and systems. We consider the implications of finding leverage points for sustainability within networks of actors (exchanging commodities, information, capital, etc.) across distal and local land systems. Finally, we distill key research priorities to grapple with the normative dimensions of telecoupling.

Sustainability in a telecoupled world

Telecoupling presents new sustainability challenges and opportunities that transcend state territories (18), involving diverse groups of agents and dynamic interconnections across public-private sectors (8), and connecting production and consumption in distant regions (19–21). It is no longer tenable, if it ever was, to define sustainability of socioecological systems at the scale of a given territory; rather, we must consider a dynamic set of relationships and spillovers that link multiple places near and far (22**,23,24). Telecoupling frameworks (25) require us to explicitly detail direct and indirect effects of new and old flows including those of capital,

commodities, energy, information, people, and waste (26,27). For instance, the price of conservation in one place may be environmental destruction in another (28,29). Likewise, vulnerability or resilience of individuals and communities are inseparable from larger processes of market integration and social change (30).

Research into telecoupled land systems has also identified some of the key drivers of telecoupling, which include the unprecedented reach of urban systems (31), high-valued agricultural commodities (32,33*,34,35), boom and bust cycles in natural resources (36), and the financialization of land-based commodities (37–39). Private-sector actors are increasingly taking deliberate action to address environmental problems; e.g., through environmental or social certification or production standards (16). For instance, if addressing forest degradation and deforestation is a policy goal, supply chains that draw on forest products are a key point of intervention (40), as is to stop sourcing soybeans from recently deforested lands (26).

Cumulatively, the adaptations by individual firms can add up to significant benefits. Gardner et al. (41) examined the relationships between transparency and supply chain sustainability, with examples from agricultural supply chains and the zero-deforestation agenda, showing that transparency creates opportunities for sustainability but also important risks to manage. A recent survey found that about half of companies incorporate sustainability concerns, usually in response to civil society or consumer concerns, into their supply chains, although these "sustainable" sourcing practices remain limited in scope, particularly when compared to the UN's Sustainable Development Goals as a benchmark (42).

Despite such efforts, the complexity of global production networks makes them unwieldy to manage and renders transparency in practice difficult to achieve. There can be mismatches in scale between institutional extent and ecological process (e.g., a forest or a watershed) (43). Even when private sector actors incorporate conservation goals into their supply chains, cascading effects can occur that ultimately displace deforestation into spillover systems (26). New agricultural commodities responsive to international markets alter incentives to clear land or conserve land nationally or regionally, and local property rights regimes may evolve according to these new pressures (27,44). The cumulative effect of any technological land-sparing innovations will depend upon how the prices of the land-based commodities, wages and their opportunity costs in terms of alternative land uses match up to global market trends (22,45).

Because of territorial mismatches and coordination challenges, governments are often not able to keep up with the comparatively quicker adaptations of private-sector actors. For instance, in the Gran Chaco and Chiquitano regions, companies that are prone to deforestation dynamically target their agricultural investments to the least regulated spaces, so-called "deforestation havens" (46*). The soy moratorium negotiated by some companies (including Cargill, ADM and Bunge), a supply chain agreement not to source soy from fields deforested after 2006 in the Brazilian Amazon, was coupled with a sharp rise in global demand. Eventually, although soybean expansion on already cleared pastures still continues in the Brazilian Amazon, soybean expansion on natural vegetation shifted to other regions such as the Cerrado (4,47), the Gran

Chaco (48), and even farther such as in Southern Africa (33). Demonstrating the causal linkages and mechanisms between interventions in the Amazon and distant spillovers remains challenging (49,50). Recent policy changes to regionalize the markets for forestry products in many South American countries, or retain more of the value added from timber domestically, is part of a nationalist backlash to structural adjustment policies, and they have been only partially successful (51). In the next section, we discuss in more depth how any attempt to manage the social and environmental tradeoffs of telecoupled land systems would require a holistic synthesis of significant decision-makers at multiple levels of governance and across varying organizational and spatial scales.

Governance as collective decision-making

Telecoupling challenges established notions of governance within land-system science and allied fields, in that we must consider formal arrangements, existing and emergent structures or organizations, particular types of vexing environmental problems, and the production and consumption processes of global commodities themselves (17,31,40,52). Sikor et al. (16) defined a shift in focus from how territories have managed socioecological systems, to how we manage a variety of flows. The flow-based approach requires tracing environmental problems to broader drives of change; e.g., through trade in natural resources or agricultural and forest commodities. This new focus has led to sustained discussions about how such systems are governed in practice, and what priorities the land-system science community should set in guiding them toward sustainability (10,17).

Indeed, policy changes in one state or territory have broad impacts on distant states or territories, often in unexpected ways. The effectiveness of policies must therefore be evaluated in the context of system outcomes (53) such as rebound effects, i.e., how land-saving technologies lower consumer costs and alter land-use incentives, and cascading effects, or multiple feedback effects (54). In some cases, policies designed to move toward greater sustainability result in environmental degradation elsewhere, such as new deforestation frontiers (33). Leakages, displacements and complex feedbacks among different sectors of land-based commodities can also occur (13,55,56), and result in counterintuitive and surprising impacts (22,26,57). For instance, agricultural intensification is often encouraged to grow more food on less land, and spare land for conservation, protecting biodiversity (58). Policies to encourage reforestation in Costa Rica led to more forest plantations, and the replacement of extensive agricultural production with more intensive agriculture in the form of high-valued fruits for export. This increase in efficiency did spare land for reforestation (59). However, growing fruit exports then generated a demand for wood pallets, which had to be met by the new short-rotation forest plantations. Thus, through a cascading set of interactions in situ and internationally, forest transition policies ultimately led to a new round of timber extraction (60*).

Therefore, governance, in its most broad form must incorporate the networked and multiscalar agreements among multiple state and nonstate actors, as well as novel, hybrid governance tools involving corporate and civil society actors, like certification programs, public-private partnerships, and multi-stakeholder initiatives (including commodity roundtables) (16,41,61),

and ultimately, the resulting decision-space of the land users themselves, who are responding and adapting to all these changes. A key research priority is to expand the traditional purview of governance analysis (62) to consider how places become connected to new international markets, and how new telecouplings arise and can be governed through dynamic interactions among firms, nongovernmental organizations, policy makers, producers, consumers and civil society at large (17).

[Figure 1 about here]

Figure 1 presents a graphical description of hypothetical connections across actors within telecoupled land systems. In particular, there are both commodity flows from producing, consuming and spillover systems, as well as information flows. All of these linkages may be highly asymmetrical: value may be captured disproportionately through a particular flow, or information may not be fully available to the public on social and environmental tradeoffs to a particular commodity.

Taking stock of insights gathered to date, we see key actors traditionally considered outside the formal policy arena collectively exhibiting strong influence on how telecoupled land systems work in practice, and how costs and benefits are distributed across people and places. Agribusiness actors are key decision makers linking agricultural frontiers to consumer markets (4,46). Knowledge transfer is an underappreciated component of soybean expansion, and corporate actors may be coordinating behavior across spatially disparate production frontiers (33). The behavior of financial agents in agricultural investments is an understudied dimension of land "grabbing" (63,64). Wiegink (65) describes how, in a mining project in Mozambique, the expectations of international firms, local economic development authorities, and local people all differed in terms of the time horizon over which they expected to see benefits, which contributed to differing perceptions of the value of resource extraction. Land users, in turn, are responding not just to formal policies, but also to meet the opportunities set out for them by private sector actors. For instance, coffee producers in Colombia have made decisions about planting niche "sustainable" coffee to reach "eco-consumers" as an effective method of combating price volatility in the conventional coffee markets (66). The resilience of local land users that emerges from such telecouplings should then be central to conversations about governance for sustainability (67). In summary, we advocate for a broader definition of governance as collective decision-making, involving a constellation of multiple actors, with the goal of negotiating some acceptable outcome among competing interests (17).

Does telecoupling research provide a basis for sustainability?

If the conceptual and empirical insights of telecoupling research are to provide leverage points for sustainability interventions, we must reflect on how social-environmental outcomes emerge through constellations of actors and flows. Table 1 describes some evolving institutional fields, or particular arenas of novel social organizations or interactions, that represent key actors and nodes in telecoupled land systems. For each of these institutional fields, examples are given with associated environmental and social outcomes.

Table 1. Collective decision-making in telecoupled land systems with potential outcomes.

Institutional fields	Example	Outcomes
Civil society	Niche demand for specialty coffee	Facilitates reforestation in Colombia (66)
	Public outcry on oil palm production after news of orangutan deaths	Volunteer corporate agreements for cruelty-free production are innovative but fall short for smallholders (68)
Public-private sector interactions	Soy moratorium among agribusiness firms in the Brazilian Amazon	Deforestation is displaced into states with less restrictive policies, so-called deforestation havens in Gran Chaco (46)
	Accelerating sustainability standards in private sector	Transparency challenges (41)
	Environmental regulations to favor forests enacted in Brazil	Local producers meet these new forest targets with eucalyptus plantations (69)
Firms (commodity flows)	Forest conservation in Costa Rica increased food / timber exports	New forest clearing for pallets (60)
	Mozambique mining as economic development	Clashing expectations of benefits by firms vs. communities (65)
	Ascending power of financial actors seeking investments	Deforestation as money laundering (70)
Firms (information flows)	South Africa copies South American soy experience	Success of diffusion (33)
	Mobile business actors bring market knowledge	Speed of diffusion (52)

Within and across telecoupled land systems (sending, receiving and spillover systems), different actors are connected within and across particular places, and these interactions collectively and relationally (i.e., through negotiations and often asymmetric influences on outcomes) drive system outcomes, and to a large degree structure the levers for intervention toward greater sustainability. The most well-known contemporary example would be efforts to govern global value chains for key agriculture commodities (e.g., soybean, palm oil, beef, eucalyptus, sugar cane). One key lesson from such efforts is an enhanced understanding of the many connections and complications between and among the land uses and producers themselves and the ultimate commodity uses and consumers.

In order for telecoupling research to provide a normative basis, i.e., to illuminate what governance will move us toward greater sustainability, we must first understand how the decision-spaces of the telecoupled actors in place are created through linkages and flows.

Conclusion: reflections on our readiness to guide policy for sustainability

The emerging research focus on telecoupling grew out of the recognition that significant, regional environmental problems were linked to globalization (71). Our review of the literature points to a few ongoing and emerging research priorities.

First, research to date has provided significant knowledge on how land-system change in one place can lead to systematic spillovers in other places. For normative research, e.g., on the ultimate sustainability of socioecological systems, the winners and losers of these changes can be distant and unexpected or surprising.

Second, despite an acknowledgement of the potential for "governing flows," to be effective, these sustainability interventions require enabling conditions and supportive government policies. Moreover, the relative power and flexibility of corporate actors means that they are moving targets. In particular, the dynamic relationships between formal governmental policies and private-sector standards requires much more empirical attention (8) – made more difficult by the often proprietary nature of private firms' information. Likewise, several international NGOs from a limited number of countries have a disproportionately large effect on evolving ecosystem management regimes (72). Thus, while telecoupling research should retain its analytical focus on coupled natural-human systems, a critical knowledge gap is understanding the dynamics of actor-to-actor power and influence: how asymmetries in financial value capture or information make particular adjustments to the system more or less feasible. Another research priority is to explore the effects of combination and complementariness of different policy tools. Arrangements can be found in other sectors as mining and fishery, which should be brought to bear on studies of telecoupled land-use systems (14).

Third, complexity of global production networks complicates governance. Transparency is a tool to address this complexity, but more transparency does not in itself guarantee sustainability -- the actors most likely to implement more sustainable practices must benefit from how greater transparency is introduced (41). Applying institutional analysis tools (73) to understand the organizational structures, behavior, incentives and adaptations of firms would be a fruitful avenue of research. The prevalence of global media and information flows present another point of intervention into unsustainable land-use practices. In some ways, a telecoupled economy in the context of global media and information can put pressure on powerful actors to respond to negative social or environmental outcomes.

Fourth, increasing financialization of land systems, in context of supply chain complexity and multiple telecouplings implies that short-term surprises and shocks are likely to become more common (38). Finally, whatever the normative priorities, e.g., for sustainability targets, it is clear that coalitions of public and private actors (including civil society), local and distant, will be required for effective governance.

Acknowledgements

This work was supported by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (Grant agreement No 677140 MIDLAND), the Marie Skłodowska-Curie (MSCA) Innovative Training Network (ITN) actions under the European Union's Horizon 2020 research and innovation programme (Grant agreement No. 765408 COUPLED), the São Paulo Research Foundation (Fapesp 2014/50628-9 and 2015/25892-7),the

US National Science Foundation, Michigan AgBioResearch and it contributes to the Global Land Programme (https://glp.earth).

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*of special interest
**of outstanding interest

**2: Current state of knowledge on telecoupling empirics and science
**4: Demonstrates the key role of corporate actors in the / soybean frontier
*8: Comprehensive analysis of public sector, firm and civil society governance of sustainability
**22: Synthesis of land-system science theory
*33: Describes the key role of information flows among firms in deforestation
*46: Discusses the key role of financial intermediaries and investments in ongoing deforestation
*60: Demonstrates cascading effects of forest conservation policies due to forest-agricultural sector interactions

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Figure 1. Collective decision-making and the sustainability of telecoupled land systems