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Exploring the potential of the telecoupling framework for understanding land change

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Farmers harvesting rice in Ban Houay Kong, Luang Prabang Province, Lao PDR.
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Cecilie Friis & Jonas Østergaard Nielsen (IRI THESys)

Abstract

The concept of telecoupling has recently been proposed in Land System Science as an analytical framework to address the increasing importance of distal connections and flows in driving current land use change. In this IRI THESys Discussion Paper the emergence and development of the telecoupling concept is traced. Particular attention is given the two telecoupling frameworks currently proposed in the literature. The paper then illustrates the applicability of these two frameworks using the case of rubber expansion in the Uplands of Northern Laos as an example. There, local land use change is increasingly influenced by a complexity of globalised drivers that transcends multiple spatial and temporal scales. Based on the case, the potentials, as well as the caveats of the frameworks are discussed. Regarding the latter, focus is on issues of simplicity and holism, temporal and spatial scales and the establishment of system boundaries. The paper concludes by discussing the potential for addressing these challenges by looking beyond Land System Science.

Keywords: Teleconnections, Telecoupling, Literature Review, Land systems, Scale, Laos

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1. Introduction

In this first paper of the THESys Discussion Paper Series, we deal with the emerging concept of telecoupling in Land System Science (LSS). The telecoupling concept comes from an increasing awareness of the growing complexity of the factors driving land change. Understanding the enhanced pressure on the Earth's limited land resources have long been a key objective of LSS (Rindfuss et al., 2004b; Turner et al., 2007). Significant attention has also been given to understanding drivers of land use and land cover change from the local to the global scale. Increasing movements of raw materials, products, people, information and capital over long distances have, however, spurred a need for new theoretical and methodological approaches to the analysis of causal relations in land change dynamics. In addition, there has been an effort to integrate the more place-based approaches within LSS that focus on linking people and actions to pixels (Rindfuss et al., 2004a) with more process-based understandings of key drivers of land change including feedbacks, multi-directional and circular flows of influence over distance.

These two developing agendas were evident at the recent Global Land Project Open Science Meeting (GLP-OSM) held in Berlin in March 2014. At this conference, substantial attention was given to both long-distance influences in land system change and to the theoretical and methodological challenges of moving towards process-based approaches for understanding land change. The recent edition of the journal Current Opinion in Environmental Sustainability entitled "Human settlements and industrial systems. Land System Science: Between global challenges and local realities." (Verburg et al., 2013), published as a prequel to the GLP-OSM, likewise demonstrates the needs within LSS to integrate distal drivers and process-based understandings of land change processes (e.g. Güneralp et al., 2013; Meyfroidt et al., 2013; Sikor et al., 2013). The concept of telecoupling plays a central role in these efforts.

The aim of this Discussion Paper is to trace, apply and discuss the development of the telecoupling concept. The paper begins with a brief description of the prominent notions of land use change within LSS. It then moves on to present the two versions of the telecoupling framework currently proposed in the literature. This presentation highlights: a) how the authors define the concept; b) what their main arguments are for the present need for the framework; and c) what main analytical components the framework consists of. Special attention is given to the way notions of 'scale', 'hierarchy' and 'distance' are treated. Subsequently, the applicability of the framework is laid out using the case of rubber expansion in Northern Laos. The Uplands of Northern Laos have experienced a substantial rubber boom during the past decade. This rubber boom has played a prominent role in transforming landscapes and local livelihoods, and presents a good example of how local land use systems are becoming increasingly influenced by a complex mix of global and local drivers of change. Based on the example of this case, the main potentials and limitations of adopting the telecoupling framework are discussed. The Discussion Paper is concluded with a discussion of how to develop the framework further by including other theoretical approaches for understanding cross-scalar linkages in a globalised world.

2. Prominent notions of land use change

Over the past three decades, Land System Science has consolidated its position as a research field exploring the functioning of land systems and the role of land change in the transformation of the Earth System

(Rindfuss et al., 2004b; GLP 2005; Lambin & Geist 2006; Turner et al., 2007; Verburg et al., 2013). Land systems are understood as dynamic coupled human and environmental systems constituting the terrestrial component of the Earth System and spanning the local to global level, from fields over landscapes to regions (GLP 2005). A coupled system is generally understood in this body of literature as a unit of analysis comprised by both socioeconomic and biophysical components. The notion of a coupled system indicates that components within it interact and shape each other fostering an analysis that requires attention to both aspects (GLP 2005; Liu et al., 2007; Turner et al., 2007). The central areas of study have been the investigation of causal relationships in land use and land cover conversions, land use transitions and the human-environmental interactions that shape the use of the Earth's land based resources. Human decision-making processes related to such use have also been pivotal, as has an analytical focus on how these processes interact at and across multiple temporal and spatial scales.

The complexity of causes, processes, scales and outcomes in land system change has made it difficult to establish a comprehensive theory of land change (Lambin & Geist 2006). However, two conceptual notions have been prominent in the literature over the last decade. Firstly, the idea of land use transitions has been denoted to account for a stylised vision of a sequential transformation of land uses from pre-settlement extensive use to highly industrial intensive use of land (Figure 1) (DeFries et al., 2004; Foley et al., 2005). The land use transition notion has been useful in pointing out the various stages of land use transformations that regions are expected to go through in the development from a predominantly agrarian to an industrial or even post-industrial society. As such, land use transitions are linked to both historical and ongoing biophysical and societal changes. These changes have been convincingly captured by the "social metabolism" concept, denoting the "entire flow of material and energy that are required to sustain all human economic activities" (Haberl et al., 2011: 3) (See also, Fischer-Kowalski & Haberl 2007; Krausmann et al., 2008a). This transition has also been conceived in terms of regime shifts, a notion adopted from systems ecology (Scheffer & Carpenter 2003), to describe the occurrence of sudden transitions between distinctly different states of socio-ecological systems in response to unforeseeable events, thresholds and tipping points (Fischer-Kowalski & Haberl 2007; Krausmann et al., 2008b).

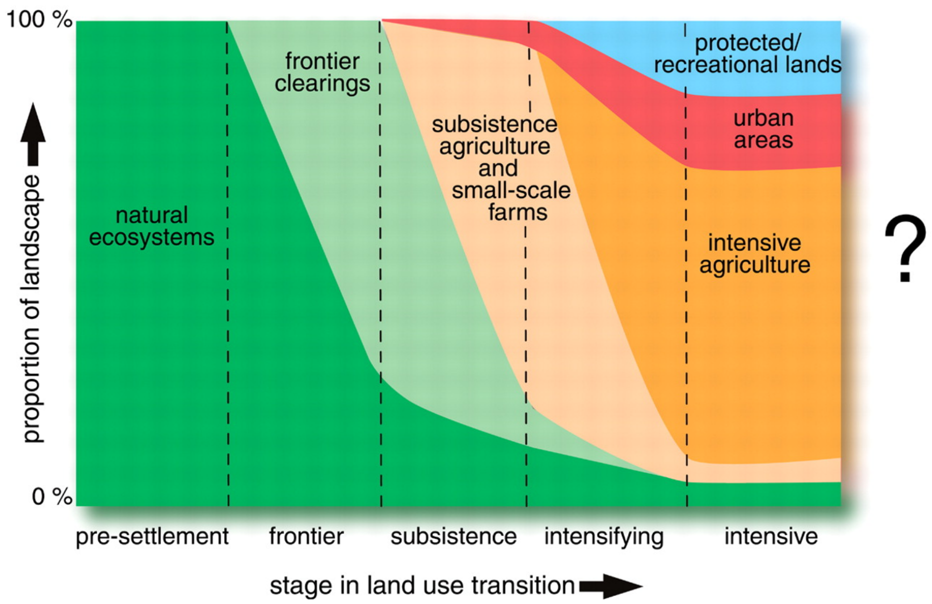

Figure 1. Land use transition model (Foley *et al.,* 2005: 571).

Secondly, the notion of proximate causes and underlying driving forces, first proposed in a study on tropical deforestation by Geist & Lambin (2002), has broadly been accepted as a useful way of framing the analysis of drivers of land change. Proximate causes are generally viewed as direct and immediate influences on land use, e.g. agricultural expansion, while underlying driving forces are understood as large-scale, distant processes operating at longer temporal scales, e.g. population growth or international trade agreements (Figure 2). As such, the framework has helped to point out cause and effect patterns of land use change, as well as highlighting the complexity of drivers working together to create single or multiple outcomes of land change (Geist & Lambin 2002; Lambin & Geist 2006).

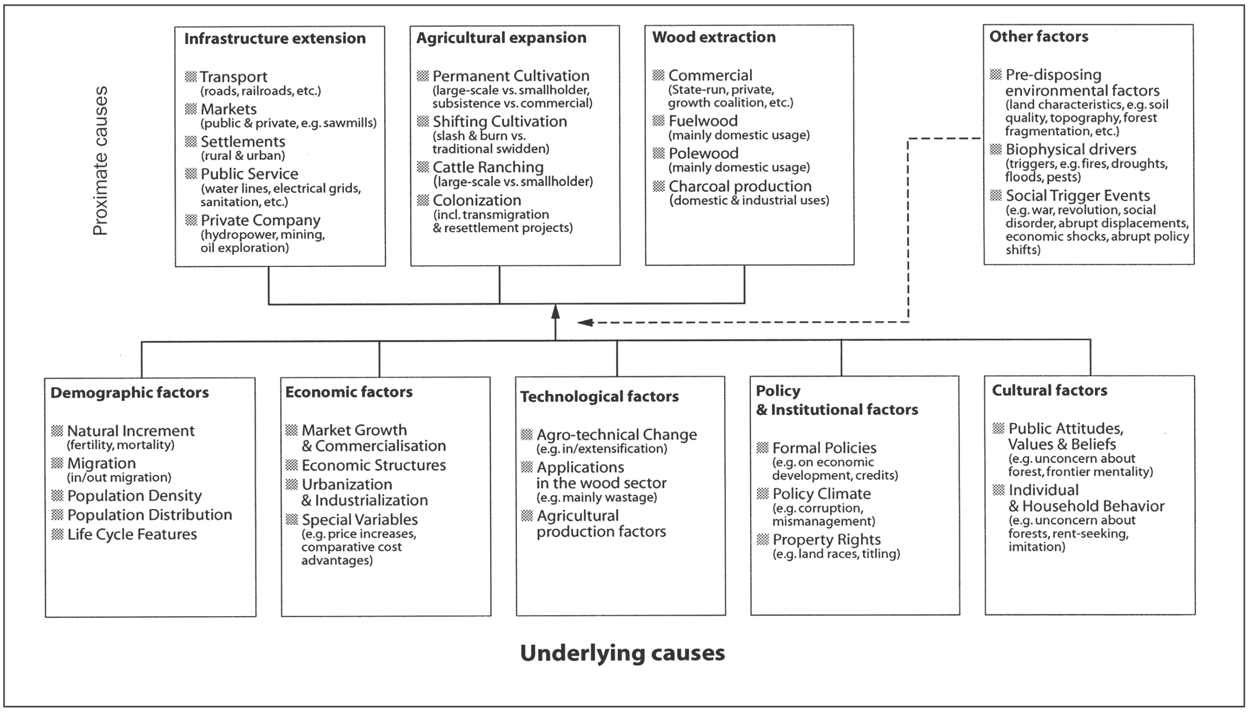

Figure 2. Conceptual framework for proximate causes and underlying driving forces of deforestation (Geist & Lambin 2002: 144).

The land transition notion and the framework of proximate and underlying driving forces have been, and are still, highly influential within the land system scientific community. However, it has been argued that the land use transition notion portrays land use change as a linear process that does not take the potential for non-linear developments including feedbacks, loops and thresholds into account (Turner et al., 2007; Seto et al., 2012). Moreover, the framework is essentially a modernist vision of change that does not account sufficiently for cultural and historical differences across the world. In addition, the complexity of the processes involved in shaping current land changes challenge the distinction between proximate and underlying drivers, as they interact across spatial, institutional and temporal scales. This calls for new complementary perspectives to address the global complexity of causal relations in land system change.

3. Exploring globalisation of land change processes

One of the key factors shaping the complexity of land use change is the process of globalisation and its various economic, political, technological and cultural dimensions (Lambin & Geist 2006; Young et al., 2006; Reenberg et al., 2010). In Land System Science, globalisation has been defined as “the worldwide interconnectedness of places and people through, for example, global markets, information and capital flows, and international conventions" (Lambin et al., 2001: 266; Geist et al., 2006: 64), and Lambin et al., (2001: 266) indicate that globalisation is "a unifying theme" that encompasses both proximate and underlying driving forces for land use and land cover change processes. Along the same lines, Najam et al., (2007) propose three distinct manifestations of contemporary globalisation that underpin land change processes: 1) economic globalisation including international market integration; 2) globalisation of knowledge and the dissemination of information and technology; and 3) globalisation of governance with the increasing importance of national and international governance institutions for regulating local landscapes and land uses. Additional manifestations of globalization such as various forms of cultural flows are also discernable but less obvious for analysis of land use change and as such left out here (e.g., Appadurai 1996).

In relation to the first of these manifestations, an increasingly integrated world economy has spurred a growing international trade, and places of supply, production and consumption of land based products are often separated over large distances. This implies that local land use and production are typically part of international production networks with large spatial extents (E.g. see; Erb et al., 2009b; Lambin & Meyfroidt 2011; Yu et al., 2013). Regarding the second manifestation, globalisation of information and knowledge has enabled public responses and policy changes as a result of, for example, media reports of the effects of land use in faraway places. An example of this is European consumers' and non-governmental organisations' concern for environmental degradation and labour conditions in the soybean industry in the Amazon, leading to the adoption of new standards for production (Nepstad et al., 2006). This observation is closely linked to the third manifestation of globalisation cited by Najam et al., (2007), where changing policies or changes in governance structures influence the outcome of land use to an increasing extent. Meyfroidt & Lambin (2009) have shown how a new policy regime and new regulations in one country have direct consequences for the land use in others. With their case, they show how the Vietnamese Government's effort to enhance reforestation has led to increasing forest extractions abroad. National-scale governance and regulations have hence lead to a leakage of land use and created land use change in countries not directly influenced by the policies (Meyfroidt & Lambin 2009; Meyfroidt et al., 2010; Meyfroidt et al., 2013). Others have shown how international trade regulations and international standards of production influence land use outcomes at a local level, e.g. the abolishment of the international coffee trade agreements and the growing influence of organic labelling (Rueda & Lambin 2013). The latter insights have turned attention towards indirect effects of land use decisions between seemingly disconnected places. Lambin & Meyfroidt (2011) have proposed to systematise these into four distinct mechanisms, namely: Displacement effects when land use change in one place creates associated change in a disconnected location, cascading effects, when land use change driven by factors originating in one place sets a chain of change events in motion that involves the entire land system, rebound effects, when new technologies are introduced to reduce resource use, but instead leads to more efficient use of the resource driving up demand and consumption, and remittance effects, when outmigration of people reduces the pressure on resources and creates inflow of capital for investment in new technology or improvements. In sum, these various direct or indirect manifestations of globalisation have aided a spatial decoupling of main driving forces of land change and the actual land use decisions and outcomes in various localities (Haberl et al., 2009; Reenberg et al., 2010).

4. Teleconnections

The concept of land teleconnection has been suggested to capture this supposed decoupling of land change drivers and outcomes described in, for example, the paper by Lambin & Meyfroidt (2011). The concept originates from meteorology, where it is defined as "any transmission of a coherent effect beyond the location at which a forcing occurred" (Chase et al., 2006: 1). In the 1990s and 2000s the concept began to spread. A number of studies within climatology and biophysical land system science used it, for example, to explain relations between changes in land use, land cover and climatic outcomes elsewhere (Avissar & Werth 2005; Feddema et al., 2005; Pielke et al., 2007). In recent years, the teleconnection concept has slowly gained prominence in the more socio-economic orientated land system studies to account for distal environmental, as well as socioeconomic linkages. In this branch of research, teleconnections have been defined as "the correlation between specific planetary processes in one region of the world to distant and seemingly unconnected regions elsewhere" (Steffen 2006: 156). As captured in the prefix 'tele', the teleconnection concept implicitly invokes a sense of geographical and spatial distance between the systems that are interacting to produce the connection. Common for many of the studies currently employing the concept is also an occupation with international trade flows or flows in market information, which are used as analytical proxies for understanding these connections "at a distance".

For instance, Haberl, Erb and colleagues have applied the teleconnection concept to the increasing disconnection of production and consumption of land based products using the embodied Human Appropriation of Net Primary Production (eHANPP) tool to account for biomass trade on a regional and global scale (Haberl et al., 2007; Erb et al., 2009a; Haberl et al., 2009). Based on an upgraded global dataset on bilateral trade flow eHANPP studies have recently advanced the understanding of such trade related teleconnections further (Haberl et al., 2012a; Haberl et al., 2012b; Kastner et al., 2014a). Teleconnections between local consumption and global land use have also been explored recently by Yu et al., (2013) using a global multiregional input-output (MRIO) model for international trade flows, though it should be noted that substantial methodological challenges remain in relation to the MRIO methods (Kastner et al., 2014b). Nepstad et al., (2006) discuss the increasing importance of what they term "economic teleconnection" in relation to deforestation in the Amazon as a result of growing demands for land for beef production, while Reenberg & Fenger (2011) explore land teleconnections in relation to the global land use transition for soybean production.

Adger, Eakin and colleagues have used the concept to explore and discuss distal linkages between local land use change and livelihood transformations in relation to vulnerability and adaptation of local coffee farmers (Adger et al., 2009; Eakin et al., 2009). Eakin et al., (2009: 400) argue that while "the label of 'teleconnection' is not explanatory in and of itself, [it] signifies the existence of a correlation in events, and highlights the need to explore the connecting mechanisms and drivers in order to anticipate outcomes". Vulnerability of local people, livelihoods and land systems are viewed as teleconnected through nested networks, and Adger et al., (2009: 151) argue that "by framing vulnerability in terms of nested relationships, we emphasize not only the synergistic and interdependent nature of social–ecological relationships at different scales, but also illustrate how the forces of globalization are making such interdependencies critical determinants of local vulnerability".

Finally, the teleconnection concept has gained prominence in studies on urban dynamics and land use changes, since urban expansion and the sustainability of cities “can no longer be considered in isolation from the sustainability of [the] human and natural resources it uses from proximal or distant regions” (Seitzinger et al., 2012: 787). Global urbanisation processes and the associated changes in global urban lifestyles and consumption patterns influence land change outcomes in distant locations around the world. Seto et al., (2012: 7689), therefore, propose the urban land teleconnections framework, defined as “a process-based conceptualization that intertwines land use and urbanization by linking places through their processes” (see Figure 3).

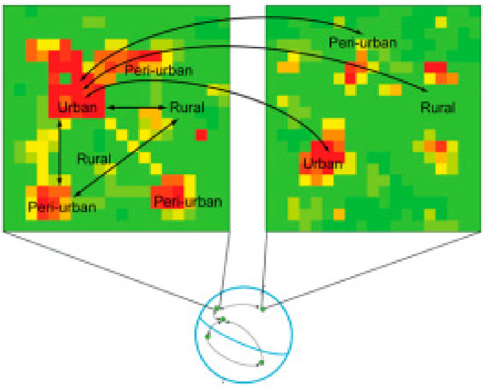

Figure 3. Urban land teleconnections framework (Seto *et al.,* 2012: 7589).

The reconfiguration of urbanisation analysis from a place-based to a process-based approach captures the “changes in nonurban places that affect urban places, and vice versa” (Seto et al., 2012: 7689). Here, the tele-prefix becomes less a question of geographical and spatial distance, than of the processes that link urban spaces and their rural hinterlands independent of the location of these. This notion is underscored by Güneralp et al., (2013: 445) highlighting that urban land teleconnections “can extend from short-distances such as the continuum between a central urban area and peri-urban areas to longer-distances such as those between places across nations or continents”. The urban land teleconnection approach thus captures the importance of recognising the possibility of simultaneous and multi-directional streams of flows when analysing transitions and pathways in land use systems. In this respect, it moves beyond the “classical” land transition notion and its emphasis on sequential stages of transformation, highlighting instead the possibility of feedbacks and multi-directional processes in contemporary land change.

5. Telecouplings

The reconfiguration of the teleconnection concept alluded to in the studies on urban-rural relations is captured in the emerging concept of telecoupling. Building upon the teleconnection concept, telecoupling is put forward to better account for and incorporate feedbacks between distantly connected human-environmental systems (Liu et al., 2013; Eakin et al., 2014). As such it is less unidirectional than the teleconnection framework. Eakin et al., (2014) notes that the telecoupling concept is useful since it “captures not only the ‘action at a distance’ but also the feedback between social processes and land outcomes in multiple interacting systems” (Eakin et al., 2014: 143). Currently, three versions of the telecoupling framework are presented in the literature.

Firstly, Liu et al., (2013: 2) propose what they term "an integrated framework for advancing our understanding of various distant interactions" that has implications for "research and policy on sustainability from local to global levels". Arguing that research on environmental sustainability has so far treated distant connections as exogenous variables, they call for research based on the telecoupling framework to bridge this gap. A key feature of this framework is a distinction between natural, human and coupled human-natural systems. This leads Liu et al., (2013) to suggest that while economic globalisation have been used to denote distant interactions in the human and socio-economic systems, and teleconnections to long-distance interactions in natural-environmental systems, telecouplings can capture both "socioeconomic and environmental interactions among coupled human and natural systems over distances" (Liu et al., 2013: 3, see Figure 4). Hence, the telecoupling concept builds on the recognition that land systems are coupled human-environmental systems (Liu et al., 2007) and that these systems are increasingly interacting over large distances.

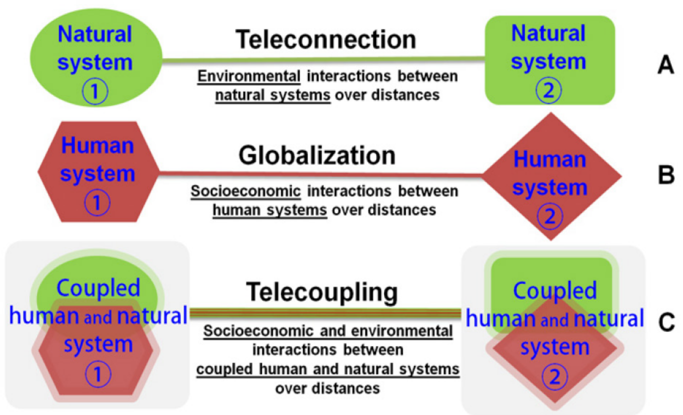

Figure 4. Conceptual difference between teleconnections, globalisation and telecouplings as presented by Liu *et al.,* (2013: 2).

For Liu et al., (2013) telecoupled systems are hierarchical systems, and they propose a structured framework with a multilevel analytical approach. The highest level of analysis is the telecoupling component, where multiple coupled human-environmental systems interact over distances. Each coupled system includes five main components of analysis, i.e. systems, flows, actors[1], causes and effects (Figure 5). A telecoupling arises when a cause produces flows between two or more place-based coupled human-environmental systems which create a change and response in either or both of the systems. Within each seemingly independent system a variety of actors can create or hinder the flows, and hence set in motion a variety of causes and effects. Through interactions between causes and effects, and between the actions of actors and the other components, feedback mechanisms arise, and Liu et al., (2013) argue that the telecoupling framework can generate valuable insights for policy, since it considers distal flows as feedbacks rather than unidirectional influences.

The systems in each telecoupling are classified as either sending, receiving or spill-over systems; where sending systems refer to places of origin of the interaction and receiving systems represent the recipient of the flow. Spill-over systems are understood as places or systems that affect or are affected by the flow of interaction between sending and receiving systems, but without direct influence on the nature or direction

[1] Liu et al. (2013) use the terms agents and actors interchangeably.

of the flow. The complexity of the simple schematics increase as multiple sending, multiple receiving and multiple spill-over systems interact over distances.

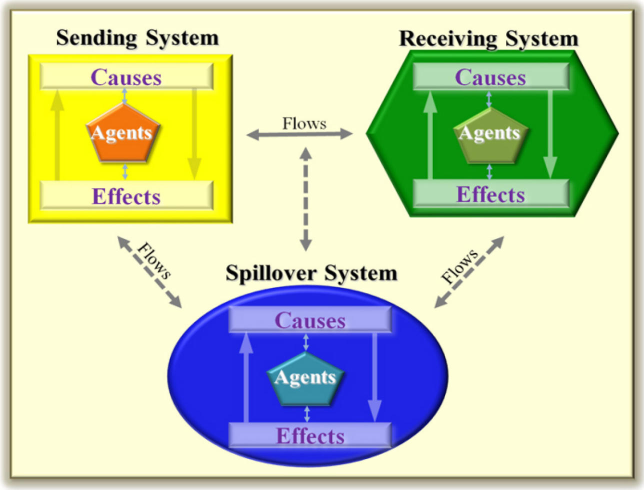

Figure 5. The telecoupling framework as presented by Liu *et al.,* (2013: 3) with the five main components of analysis, namely systems, flows, actors, causes and effects.

Liu et al., (2013) note that any particular place or system can act as sending, receiving and spill-over system depending on the particular flow being analysed, indicating that systems can maintain several roles simultaneously in different telecouplings, which adds to the analytical complexity. Though the spatial scale of telecoupling is not addressed explicitly in the framework, telecouplings are implicitly characterised as interactions over large geographical distances. The examples given by Liu et al., (2013) highlight connections across continents such as the soybean trade between the US and China, or invasive fire ants introduced by accident into the US from South America.

The second version of the telecoupling framework is also presented by Liu and colleagues (Liu et al., 2014), in the recently published book “Rethinking global land use in an urban era” (Seto & Reenberg 2014), and follows the first version closely. A telecoupling is again defined in terms of “environmental and socioeconomic interactions among coupled systems over large distances” and as a “logical extension of the coupled systems thinking” (Liu et al., 2014: 115). Continuing the argument of Liu et al., (2013), it is proposed that the rapid increase in the linkages between places and systems around the world, especially in land use systems, calls for new conceptualisations that adequately take distal couplings into account. A rigorous telecoupling framework, it is again argued, presents a systematic analytical tool for researchers to address each system’s components and their relationship with one another (Liu et al., 2014: 134). Though Liu et al., (2014) retain the basic structure of the first version of the telecoupling framework, developments are made to advance the idea that systems can be simultaneously acting as sending, receiving and spill-over systems illustrated by the generalised schematic in Figure 6. Furthermore, more emphasis is put on the fact that systems are interacting in multiple telecouplings simultaneously, though Liu et al., (2014) call for further research into the implications of this multiplicity.

Liu et al., (2014) also now stress the challenges that telecouplings present for governance in coupled human-environmental systems, which calls for continued engagement by research communities to unravel the complexity of multiple telecouplings acting together.

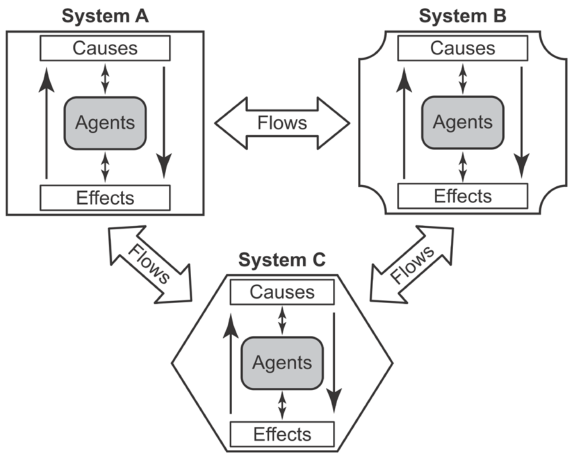

Figure 6. The telecoupling framework as developed by Liu *et al.,* (2014: 121).

The third version of the telecoupling framework is proposed by Eakin et al., (2014) (also published in Seto & Reenberg, 2014). Elaborating on the previous versions, Eakin et al., (2014: 142) suggest that "the process of telecoupling is different to the concept of coupling in that there is an element of social and spatial distance; that is, geographic separation between systems as well as a separation of social networks, institutions, and governance". As place-based social-ecological entities, the systems interacting in a telecoupling are assumed to be independent and are therefore governed separately, despite interactions through flows and processes within existing institutional arrangements. In this sense, the social distances inherent in separated governance structures become especially important for characterising systems as telecoupled, rather than seeing them as one integrated system. This emphasis on a functional distance in terms of governance therefore becomes more important than the spatial distance in terms of kilometres. Eakin et al., (2014) propose that a telecoupling arises when a disturbance to one system creates a reaction in the flows and processes linking it to other distantly connected systems. In some cases this disturbance sets change processes in the other systems in motion, which create feedbacks that return the process of change. This could be a change in land use policy, for example, that facilitates a change in cultivation practices and creates downstream environmental disturbances, which then trigger a policy response feeding back into the system of the original change. A central notion in the framework is that such a response and coupling occurs in a way that could not be expected a priori (Figure 7).

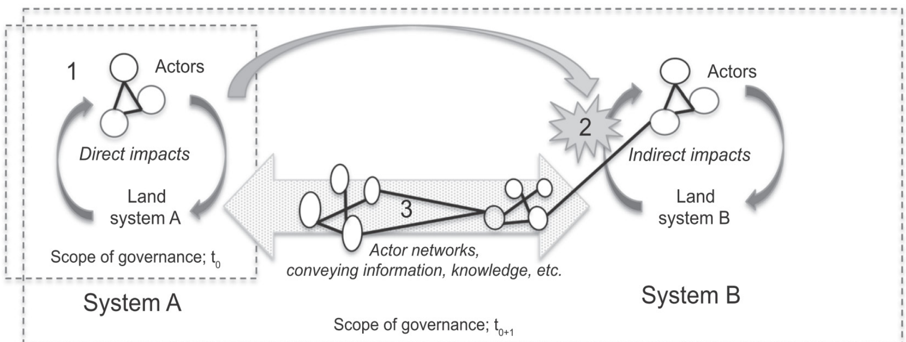

Figure 7. The telecoupling framework as presented by Eakin et al. (2014: 147).

The outcomes or results of telecoupled interactions and feedbacks are often indirect, emergent or of a second or third order, because governance in the social component of the different land use systems are principally independent of each other, e.g. changes in the governance of the bio-energy production system in one location might indirectly affect the land use outcomes in food production systems in another location (Eakin et al., 2014). The five key features of a telecoupling process are therefore the trigger setting the telecoupling in motion, the direct impacts in the system with the initial change, the indirect impacts in the distantly coupled system, the feedback processes returning the "signal of change" as a response to the system of the initial trigger, which influence the existing governance structures and potentially create institutional change as the final outcome. Eakin et al., (2014) suggest that institutional arrangements include the policies regulating a given system, the laws of resource use, the standards of a production and the trade arrangements between partners in various locations.

In this conceptualisation, emphasis is placed on the networks, actors and processes of interaction in the system and the way they produce linkages and changes in spatially separated localities. The spatial hierarchy or specific scale of analysis featuring prominently in the framework proposed by Liu and colleagues has by Eakin et al., (2014) been replaced with an emphasis on the networked interactions and their implications in telecouplings. For example, Eakin et al., (2014) note that the rising influence of information technology and social networks have made it possible for actors to "skip scale" and interact, influence and innovate outcomes in telecoupled systems. In order to fully understand the range of dynamics and outcomes at play multiple entry points for a telecoupling analysis are therefore often necessary, as are different theoretical approaches and methodologies. Hence, Eakin et al., (2014: 153) argue that "the concept of telecoupling potentially offers a new heuristic from which to evaluate and think about land-use change".

Although based on the same theoretical foundation, the three versions of the telecoupling framework essentially present two approaches to how a telecoupling analysis should be conducted. Where the framework presented by Liu et al., (2013) and Liu et al., (2014) offers a structured analytical approach and place-based conceptualisation that stresses the systemic nature of coupled human-environmental systems, the relations between their components and their interactions over distances, the framework proposed by Eakin et al., (2014) offers a processual analytical approach that emphasises the processes involved, as well as the actors, networks and flows of interaction that produce telecouplings. This difference also presents itself in the authors' approach to the spatial hierarchy and scale of analysis. Where Liu, et al. frame telecouplings within a structured vertical hierarchy, Eakin, et al. define them as the outcomes of multi-scalar networks and interactions. Furthermore, Liu, et al., in essence, produce a framework that is a type of "check list" of components to include in an exhaustive analysis, while Eakin, et al. present a heuristic tool and a mindset for analysing distant connections in land use change with the analytical entry point depending on the aim of the specific research.

6. Applying the telecoupling framework – the example of rubber expansion in Northern Laos

To illustrate how a telecoupling analysis could be carried out we present an example of recent land use change from the uplands of Southeast Asia. The case is taken from the People's Democratic Republic of Laos (Laos), where the country's vast forested areas, relative low population density and high poverty rates have facilitated a push for large-scale land use conversion from forest to rubber plantations by the government and by international investors. After a brief – and general – introduction to the case, the two approaches to the telecoupling framework will be used to analyse the telecouplings involved in rubber expansion in northern Laos. The account will attempt to "run through" the steps of the proposed structural and processual frameworks with special attention to their analytical entry points and the challenges of delineating the temporal and spatial scale of analysis. Both analyses will compare the case across two analytical scales in order to highlight some of the potential caveats of the telecoupling analysis.

Rubber cultivation in Laos has expanded considerably since the mid 1990s. Rubber was first introduced in the north-western province of Luang Namtha by smallholders with cross-border ethnic and family ties to the Xishuangbanna Prefecture, Yunnan Province in southern China, as well as by small-scale Chinese investors. However, a series of political and economic changes, including a transformation from a centrally planned to a socialist market-oriented economy in the late 1980s, a re-opening of regional borders by the mid 1990s, and improvements of road infrastructures, have resulted in a rubber boom (Fox et al., 2009; Thongmanivong et al., 2009; Lestrelin et al., 2012). Foreign investors, especially from China, Vietnam and Thailand have sought and been granted concessions to large areas of land for rubber cultivation on very favourable terms. Others have set up contract farming schemes with local farmers on household and village forest land (Schönweger & Üllenberg 2009; Schönweger et al., 2012). These investments have been aided by the Government of Laos' current policy for "Turning land into capital" aimed at attracting foreign direct investments in land and other natural resources. The Government of Laos views this policy as an essential tool for transforming extensively used upland agro-forestry systems into intensive and 'profitable' industrial plantations (Dwyer 2008; Lestrelin et al., 2012).

In the Northern Provinces of Laos, the rubber investors are mainly Chinese from the Yunnan Province, where rubber cultivation has taken place since the 1950s. The rubber tree (Hevea brasiliensis) cultivated in mainland Southeast Asia stems from the Amazon and has a natural habitat in the tropics around the Equator (10° N/S). However, in response to US economic sanctions following the 1949 establishment of the People's Republic of China and to a rising military need for natural rubber during the Korean War in the 1950s, the Chinese Government began experimenting with rubber cultivation in non-traditional rubber growing areas on higher latitudes and altitudes (Fox & Castella 2013; Sturgeon 2013). Pushing the rubber growing areas as high as 22°N in the Hainan and Yunnan Provinces made a rubber boom in the Xishuangbanna Prefecture in the southern part of the Yunnan Province, among other places, possible (Fox & Castella 2013). The rubber was initially produced on large state collective farms and later on by farmers' communes. Following the dismantling of the farming communes, the Xishuangbanna Prefecture started promoting rubber cultivation among smallholders.

To protect this newly established domestic market, the Chinese government provided subsidies and banned rubber imports. However, in the late 1980s and 1990s, these subsidies were phased out and tariffs on imported rubber were reduced. Furthermore, the production sections of the state rubber farms were privatised in 2003, enabling these private companies to take advantage of investment opportunities abroad (Sturgeon 2013). These developments created cross-border rubber investments and trade between Chinese rubber investors seeking plantation land on concessional terms and local farmers as well as state landholders in northern Laos. The Chinese Government's "Opium eradication programmes" contributed to this development by providing loans to Chinese businesses investing in agricultural or forestry projects in Laos and Myanmar to replace opium production among smallholders (Fox et al., 2009; Hicks et al., 2009; Mann 2009; Thongmanivong et al., 2009). Today, China has surpassed the US as the world's largest consumer of natural rubber. Due to increasing domestic land constraints, however, it is estimated that Chinese production will only be able to supply a third of the country's demand for rubber by 2020, causing scholars to suggest that China will continue to seek land for rubber cultivation abroad for years to come (Manivong & Cramb 2008; Shi 2008; Hicks et al., 2009; Mann 2009; Fox & Castella 2013).

6.1 A structured approach to telecoupling analysis

A telecoupling analysis of the rubber expansion in Northern Laos, based on the framework presented by Liu et al., (2013) and Liu et al., (2014), should start by identifying or defining the nature of the distant connection between the two coupled human-environmental systems that are the focus of the inquiry. Focusing on the large-scale expansion of rubber in northern Laos, mainly by Chinese investors, the main connection in our case becomes the flow of rubber investments from Yunnan to northern Laos since the start of the 2000s. This flow created the linkages that produced the telecoupling between the two rubber production systems. The analysis would then continue by going through each of the five main components presented by Liu et al., (2013) as exemplified in Table 1 for two analytical scales.

Once the main connection is identified, the systems in the interaction can be classified as sending, receiving or spill-over systems. In our case, the southern Chinese rubber production system is the main sending system and the northern uplands of Laos the main receiving. Rubber expertise, know-how, technology, investment capital and market information form the main flows from China to Laos, whereas the rubber produce (latex) and revenues from the rubber production constitute biophysical and monetary 'counter-flows' back to Yunnan. A feedback process from Laos to Yunnan is set in motion when the growing production of rubber in Laos increases the supply of latex on the Chinese market which drives down prices locally and increases competition with Chinese producers.

The next step in a structured telecoupling analysis is to investigate the actors involved and their role in either enabling or hindering the connection. In this case, key actors are the Chinese investors and policy makers, as well as their Lao business partners and the Lao government officials that play a role in negotiating the agreements for rubber investments and survey for land availability. The local village leadership and the farmers involved are also important, since they have the potential to influence the implementation of the investments and their outcomes. Subsequently, the causes and effects of the interaction at both "ends" of the coupling should be traced. For example, to fully understand the causes of a telecoupling, a deeper analysis of the institutional setting and the political objectives governing the regulatory context in each coupled system is needed. Likewise, information on the global rubber industry, its production patterns, trade flows and environmental impacts locally, regionally and globally, as well as developments over time, is required to shed light on the wider implications, outcomes and effects of the telecoupling in both sending and receiving system. This is also important with regard to exploring any effects on potential spill-over systems. In the analysis sketched out here, the temporal frame of analysis is implicitly set on the past two decades when rubber production took off in northern Laos, and it is spatially confined to the interaction between the Xishuangbanna rubber production system and the rubber production system in northern Laos. This is the result of focusing on the flow of rubber investments into Laos as the central linkage in the coupling between the two systems.

However, if a 50-60 years temporal perspective is adopted to account for the rubber development in Xishuangbanna and a larger spatial focus including the origin of the Chinese demand for rubber is used,

Table 1. The five components of the telecoupling framework (Liu *et al.,* 2013) for the case of rubber expansion in Northern Laos. Two different analytical outcomes are presented depending on the initial flow focused on.

Tele-coupling		**Large-scale rubber expansion in Northern Laos**	**Rubber development in Xishuangbanna**
Systems	Sending system	Xishuangbanna rubber production system	Beijing, political and economic power centre in China
	Receiving system	Northern upland agro-forestry system in Laos	Xishuangbanna rubber production system
	Spill-over system	- - -	Northern upland agro-forestry system in Laos
Flows	Material	Investment capital Technology	Research investment capital
	Infor-mation	Rubber expertise Price and trade information	Policy changes promoting rubber in state farms and among smallholders Policy changes to support investors going abroad
	Counter-flows	Rubber produce (latex) Revenues	Rubber produce (latex) for industrial and military purposes Information on rubber production ad-vances
	Feedbacks	<u>From Northern Laos to Xishuangbanna</u> Increasing supply of latex in Xishuangbanna → increased competition with Chinese producers and price decreases → import restrictions on Lao rubber produce at the Chinese borders	<u>From Xishuangbanna to Beijing:</u> Increasing land constraints in Xishuang-banna → policy adaptation to facilitate land investments abroad
Agents/ actors		Chinese companies, Chinese policy makers, Lao government officials at all administrative levels, village leadership, local farmers	Chinese Central Government Official; Yunnan government officials; rubber investors; smallholders
Causes	Economic	Continuously increasing rubber demand in China Rising per capita income in China Growing industrial demands	Continuously increasing rubber demand in China Rising per capita income in China Growing industrial demands
	Political	Shift in economic politics → transformations to market economy on both sides of the border Opium replacement policies Government of Laos' policy for "Turning land into Capital"	Military needs exposed in the Korean War
	Techno-logical	Increasing "natural" habitat for rubber produc-tion	Increasing "natural" habitat for rubber production
	Environ-mental	Land constraints in Xishuangbanna	Rubber production suitability in Xishuangbanna
	Cultural	Close cross-border relations	
Effects	Environ-mental	Soil degradations, changing catchment hydrol-ogy, chemical and fertiliser pollution	Soil degradations, changing catchment hydrology, chemical and fertiliser pollu-tion (in Xishuangbanna, as well as in Laos, the spill-over system), increasing land constraints
	Socio-economic	Loss of upland agricultural and forest resources Forceful displacements Increasing income among smallholder rubber producers Infrastructure development	Rising household income Decreased reliance on world market rub-ber production

then the analytical focus shifts and the telecoupling narrative changes. In this case, the main flow in the telecoupling is the policy change originating in Beijing, which facilitated the rubber boom in Xishuangbanna back in the 1950s. The main sending system is therefore Beijing, whereas the rubber production system in Xishuangbanna is the main receiving and the northern uplands of Laos consequently a spill-over system of this coupling. The key flows would now be the research investment capital for experimenting with rubber production in “unnatural” habitats and policies promoting rubber production among Xishuangbanna farmers and investors. Counter-flows of information on advances in production technology, for example, are feedbacks from Xishuangbanna to Beijing, which, in turn, create policy adaptations and new flows in the telecoupling. When Xishuangbanna, as the main receiving system, began experiencing severe land shortage, Chinese farmers and investors began seeking land abroad thus causing a leakage of land use (Lambin & Meyfroidt 2011), and initiating a spill-over to the northern uplands of Laos. The causes of this development include the large Chinese political and economic shift (i.e. the opening up of the economy and the entrance into the WTO), and the associated exposure to the global rubber market, as well as the factors discussed above, that facilitated rubber investments abroad. This analysis is also outlined in Table 1.

Both analyses sketched out here follow the schematic presented by Liu et al., (2013) and Liu et al., (2014) closely and exemplify the kind of insights a structured telecoupling framework can provide. Notably in this respect is how the framework draws attention to different relevant components that play a role in mediating or creating the telecoupling between the systems, as well as the feedbacks and spill-overs resulting from the main interaction and flows. However, the Lao example also illustrates the complexity of analytical choices facing researchers working on telecouplings, especially when it comes to setting temporal and spatial analytic system boundaries. Such boundary choices have, as shown, significant implications for any telecoupling analysis. Is the rubber expansion in Northern Laos the receiving system or a spill-over system? Moreover, the notion of spill-overs implies that these systems are somehow outside the main interactions in the coupling, and as such do not have a direct influence on the flows involved. This creates, in turn, a risk of “missing” important interactions in the coupling, such as the impact of the increased rubber imports on the market price for rubber in Xishuangbanna.

6.2 A processual approach to telecoupling analysis

The telecoupling framework presented by Eakin et al., (2014) captures these important flows somewhat better, by shifting the analytical focus towards the actors and networks involved in the telecoupling process, rather than focusing on the ‘systems’. Again, however, multiple analytical entry points are possible.

One possibility is to start from an observed land use transformation in a given locality, in our case the widespread transformation of the upland landscapes from extensive swidden to rubber plantations. By investigating the actors involved, the causes behind and the effects of this land use transformation, it becomes possible to unravel distant interactions that might or might not be classified as telecouplings and thus open up new explanations of the transformation. In our case, the key actors are the companies and investment organisations that push for access to concessional land. Tracing the origin of such companies reveals the extent of the coupling involved, e.g. to Xishuangbanna or to Beijing. Likewise, the Lao Government Officials at all administrative levels are central actors linked to networks outside the specific place of land use transformation. Disentangling their interactions with other actors will reveal how they are influenced by, for example, international financial institutions, the Asian Development Bank, international NGOs or donor organisations. A third group of actors are the small-scale farmers with close familial and ethnic ties on both sides of the Lao-Chinese border. Looking into networks and linkages among these smallholders, as well as farmers in traditional patronage-relations, reveals their role in mediating the initial introduction of rubber into upland agricultural system in northern Laos (Sturgeon 2013). The success of these smallholders illustrates, for example, the potential of rubber for raising household incomes and reducing rural poverty rates, a fact later adopted by both Chinese rubber investors and Lao government officials as an argument for promoting large-scale rubber concessions and structured contract farming arrangements.

Having identified the key actors involved in the telecoupling process, the next step is to follow the telecoupling "back" to its origin, e.g. Yunnan or Beijing, and focus on the trigger, the initial "signal of change", that set in motion the processes of transformation and the distal connection. Again, the choice of temporal perspective becomes essential. Depending on the chosen timeframe, different "triggering events" can be identified. First, from a long-term perspective, the evolving Chinese industrialisation and the Korean War in the 1950s led to intensive research efforts in Xishuangbanna, which facilitated the push of rubber growing habitat (Fox & Castella 2013; Sturgeon 2013). Second, from a medium-term perspective, the dismantlement of the farming communes in China, coupled with changing rural and agrarian policies in the 1980s that aimed at teaching local minority farmers to plant rubber, triggered a skilling of farmers in Xishuangbanna and a further transformation of the rubber production system. The minority farmers in Xishuangbanna with strong familial ties to minority farmers in Northern Laos passed on their newly acquired skills, thus setting in motion the land use transformation to rubber plantations across the border. Third, and adopting a short-term perspective, the privatisation of the state rubber farms in 2003 enabled Chinese businesses to engage in investments abroad. Similarly, growing land constraints in Yunnan and the continuing demand for natural rubber in the Chinese industry triggered large-scale industrial rubber production in Laos. In this case, a feedback process arose when the Lao rubber production increased the supply of rubber in Yunnan, leading to a drop in prices that caused the Chinese authorities to set up counter-measures to protect domestic production by raising tariffs on imported rubber or completely closing the international borders for rubber trade (Manivong & Cramb 2008; Vientiane Times 2013). This, in turn, has been reported to influence rubber smallholders in the Northern provinces in Laos, where some farmers have uprooted their rubber trees and started cultivating alternative crops. In fact, all of the above factors and actors have played a role in facilitating the land use transformation to rubber in Northern Laos. However, the temporal perspective applied in the analysis affects the identification of the main trigger of change that sets in motion the telecoupling process. This requires, as with the version of the framework proposed by Liu et al., (2013), that researchers are very specific regarding their choice of temporal, as well as spatial scales.

Another possible analytical entry point is an observed event or an observed change in policy (Eakin et al., 2014). In our case, the privatisation of state rubber farms, the changing policy environment for foreign investments or the continuing demand for natural rubber in China could be identified as events that could be expected to act as the trigger of change. By analysing the ramifications of such an event and by following its implications, it would be possible to point towards areas and land use systems that are likely to be affected and which could be expected to create a response, eventually leading to a feedback process and a telecoupling. An overview of a processual telecoupling analysis is presented in Table 2. Such an schematic approach provides a structured guideline for analysis similar to Liu et al., (2013) and presents a similar overview of the factors involved.

Table 2. Two examples based on the trigger of a telecoupling and analysing the key features of that telecoupling as presented by Eakin *et al.,* (2014).

Telecoupling	**Small-scale rubber expansion Xishuangbanna, China to Luang Namtha, Laos**	**Large-scale rubber investments from Xishuangbanna to northern Laos**
Trigger	Dismantling of farming communes in China; promotion of rubber to small-holders in Xishuangbanna; border trade policy changes	Growing demand for natural rubber in China and privatisation of state rubber farms in the context of deregulated markets
Direct impact	Skilling of minority farmers in Xishuangbanna; increasing investment in ethnic and familial networks across the border; introduction of rubber among smallholders in Luang Namtha	Encouragement of Chinese rubber companies to invest abroad; increasing number of rubber concessions granted in Laos; large-scale land use conversion
Indirect impact	Increasing land use transformation in Laos; rising income; new visions of modernity among Lao smallholders	Large-scale environmental degradation; displacement of farmers and poverty aggravation
Feedback process	Increasing export of rubber to Xishuangbanna	Increasing export of rubber to the Chinese market; falling rubber prices in China
Institutional change	Laos: Government promotion of large-scale rubber plantations	China: Changing border-trade policies; Chinese protectionism Laos: Moratorium on rubber concession

7. The prospects of telecoupling analysis – advantages and limitations

The examples presented above show how the two telecoupling frameworks steer the researcher towards a focus on the multi-directional flows between separated land systems that are fundamental for land change processes today. Building on the coupled human-environmental system approach (Liu et al., 2007), the telecoupling concept moves one step further towards addressing the current global context of connectivity and inter-linkages by incorporating not only the "action at a distance" but also the counter-flows and feedbacks inherent in tightly linked couplings. As argued by Eakin et al., (2014: 143), "the idea of connectivity between actions and actors in one specific geographic location and land outcomes in another is not new in the history of human environment interactions". What has given rise and relevance to the telecoupling framework is, however, the increasing scope and level of global connectivity. What is exactly implied by this scope and level is currently debated, but arguably the current degree of interactions and the pace of flows and linkages between places around the world have created a considerably different and more complex context for local land use change today than at any other point in time. Returning to the influence of globalisation (Najam et al., 2007), the developments in the global telecommunication infrastructure and the global media stream have, for example, made it possible for people to learn about the outcomes of their actions for distant societies or environments allowing "feeling (empathy) at a distance" (Eakin et al., 2014: 144). Such feelings might in turn create important feedback mechanisms, for example in relation to consumption patterns or environmental activism. In relation to this, one of the advantages of the Eakin et al.,

(2014) framework is its explicit attention to the actors and networks involved in creating the telecoupling processes. Another key strength of the framework is its relative flexibility with regard to the analytical entry point. This flexibility presents scholars with ample opportunities to engage with land system change from their disciplinary vantage point, while simultaneously presenting a relatively open and integrative platform for land change scientists to work interdisciplinary, when addressing the various aspects of telecoupling processes. In general, the telecoupling framework thus presents a heuristic device for analysing new causal relations in land system change over distances that can prove very useful for future LSS research. Yet, the rubber expansion case also pointed towards some of the challenges embedded in the two versions of the telecoupling framework.

The first of these challenges relates to the Liu et al., (2013) framework. While being a relatively simple and structured approach, breaking the telecoupling process into separate components and thus giving the researcher a general idea of the telecoupling process, its causes and effects and the actors and flows involved, the structured simplicity reduces the framework to some extent to a simple check list. Consequently, this might result in reducing the complexity of the coupling and in the production of a rather superficial analysis. One way to avoid this would be to engage in extensive in-depth analysis of all components. Yet, attempting to embrace the whole telecoupling process presents a “holistic trap”, in which everything ends up being important and connected to everything else.

A second challenge is the clear analytical distinction between sending, receiving and spill-over systems. As illustrated by the Lao rubber production example, the categorisation of systems depends to a large extent on the predefined analytical entry point, the scale of analysis and the specification of the initial flow that triggers the telecoupling. Since many of the flows investigated in relation to telecouplings are multi-directional or a matter of exchange, e.g. capital investments for material or information, it becomes a matter of analytical choice whether a system gets categorised as the sender or the receiver in the interaction. In one of the examples highlighted by Liu et al., (2014), transnational land deals are investigated as a case of telecoupling. Liu et al., (2014) identify the main flow of interest as the ‘flow’ of land titles from land-rich to land-poor countries. Land title providers are categorised as the sending system, while the ones obtaining the land titles are categorised as receiving. ‘Counter-flows’ of money, material and technical know-how are identified from the receiving countries to the sending. If the initial analytical focus had been on the flow of the monetary investments instead, as is often the focus in the literature on transnational land deals (e.g., Deininger 2011; Cotula 2012; Messerli et al., 2013), the analysis would have been reversed. This is an important point. There is an implicit power asymmetry inherent in the distinction of systems based on their role in the interactions; senders are implicitly cast as the active part, while receivers, and especially spill-over systems, are cast as the passive part. To some extent, this distinction places the agency in the hands of the actors in the sending system, as they trigger the initial flow that creates the telecoupling. Though Liu et al., (2014) acknowledge that the role of the sender and the receiver depends on the flow under enquiry in the specific analysis, the strict analytical distinction risks categorising systems in a mechanistic and inflexible way that blurs the complexity of their interactions and exchanges, and simplifies the role and agency of the various actors at both ‘ends’ of the telecoupling. To some extent, the same type of criticism could be directed towards the distinction between direct and indirect impacts in the framework proposed by Eakin et al., (2014). The conceptualisation of a telecoupling as something arising indirectly or unexpectedly implies a degree of unintentionality in the actions by the actors in the initially changing system, and again implicitly applies a power asymmetry in the distinction between systems interacting in the telecoupling.

This leads us to the third challenge, namely how and where to demarcate system boundaries and define the temporal and spatial scale of analysis. As highlighted in the rubber expansion example, scale-issues are a central aspect of telecoupling analysis and researchers need to explicitly account for and be aware of the consequences of their scale-choices. A number of challenges are related to this. Firstly, both frameworks emphasise the importance of feedback processes as a prerequisite for the creation of telecouplings. This presents a challenge in relation to potential inertia in some processes and interactions. While a 'trigger of change' might set in motion rapid responses and feedbacks between systems, some processes work more gradually and only manifest themselves after longer time spans. Secondly, though related, the inertia of some processes and feedbacks might only be recognised retrospectively. This also holds implication for the identification of analytical entry points, especially if the analysis takes point of departure in an observed land use transformation. Telecoupling research needs to overcome the challenge of dealing with rapid changes taking place now, but only manifesting themselves as feedbacks in the future. Thirdly, as any kind of research on dynamic systems, telecoupling research faces the challenge of presenting linkages and interactions between the systems as a static 'temporal snapshot'. These points highlight the need for adopting the framework in a continuous and iterative research process.

8. Looking beyond Land System Science

In order to address the challenges discussed above, there is a need to look beyond the conventional LSS approaches. Eakin et al., (2014: 161, emphasis in the original) argue that "whilst it is by no means clear that the concept of telecoupling can be operationalised in an effective way within land science as it is currently constituted, the global significance of the phenomenon lays obligation upon the land science community to find ways to engage with the necessary concepts and analytical tools. This may require the development of a transdisciplinary land science, with profound implications for methodology and reporting". In order to achieve this, Eakin et al., (2014) propose a list of theoretical concepts and analytical methodologies from other disciplines worth looking towards (see Appendix 1). This list spans a wide range of approaches from sociology, anthropology, political and economic sciences that could enable a deeper theoretical conceptualisation of the various telecoupling components, including social networks and actors (e.g. actor-network theory; social network analysis; organisation theory), globalisation and scalar issues (e.g. world city network theory; global assemblage theory) and flows and processes (e.g. commodity/supply chain analysis; production network analysis; life-cycle assessment). Adopting elements of these various approaches would give telecoupling analysis more theoretical depth and present options for methodological operationalization, but simultaneously present the new challenge of bridging possible epistemological and ontological differences.

One recent effort in addressing some aspects of this challenge is a Geoforum paper by Munroe et al., (2014). In this paper, Munroe et al., (2014) discuss the potential benefits for LSS of embracing conceptual advances within economic geography. Munroe et al., (2014: 12) start with a critique of what they term "the almost [exclusive reliance] on neoclassical definitions of what the economy is, who economic actors are, and how those actors, in turn, make decisions about resources" within LSS. This adherence to neoclassical framings extends, they argue, to the understanding of space and scales. By defining these as nested entities, LSS often conflates scale with agency producing a picture of the local as the specific and the global as the universal, framing a modernist understanding of change processes that "set the experience of developed nations to represent the "future" of developing nations" (Munroe et al., 2014: 15) as a sort of space proxy for time.

In relation to the potential of the teleconnection and telecoupling concepts, Munroe et al., (2014: 14) maintain that there is a need for analytical techniques that move beyond a "closed" understanding of systems. They argue: "One cannot close the system to conduct economic analysis when the system itself is produced through cascading activities of actors intimately connected across great distances". They emphasise the potential of adopting methodological approaches coming out of the research on Global Production Networks (GPN) (Henderson et al., 2002; Coe et al., 2008), which provides a framework to conceptualise the networks and nodes of production and consumption that influence land use. GPN can also be useful in identifying how value is distributed across space and between actors with a varying degree of power to control these processes. In this sense, the paper by Munroe et al., (2014) addresses part of what is needed in terms of conceptual development for interdisciplinary research on telecouplings, and what Eakin et al., (2014) have called the critical need for integrating "different epistemological perspectives on space and spatiality—one in which Cartesian space is the primary frame and point of departure, and one in which social space and its contingent aspects of agency and power are critical" (Eakin et al., 2014: 153).

Other LSS scholars have also begun to integrate conventional place-based land change analysis with the flow-based Global Value Chains (GVC) analysis (Bair 2005; Gereffi et al., 2005). Rueda & Lambin (2013) link value chain perspectives to land use change in the study of the role of eco-consumers in restructuring the Colombian coffee production landscape. In the Lao rubber expansion example, a GVC/GPN analysis could provide valuable insights into the organisation of the rubber production companies investing in plantations in Laos, as well as their Laotian counterparts, and thus shed light on strategies of location and sourcing practices, for example, as well as the distribution of value and power between producers, traders and buyers in the production network.

In another strand of research on land change, scholars have focused on the changing nature of land governance that has implications for regulations of increasingly telecoupled systems (Sikor et al., 2013; Gentry et al., 2014). Drawing on theoretical advances within political economy, critical political geography and sociology, these scholars suggest that the governance structures for land have been changing from classical place-based, territorial arrangements towards more flow-based arrangements. These have in parts been driven by a global revalorisation of land, by increasing competition for land resources and by a restructuring, and to some extent a concentration, of the global production networks in large multinational agriculture, forestry and mineral exploitation companies (Sikor et al., 2013; Gentry et al., 2014). Land use, it is argued, "is no longer under a single territorial institution […] but is now also the subject of multiple, flow-anchored governance arrangements" (Gentry et al., 2014: 240). This includes not only production, environmental and social standards set by multi-national agro-food companies, but also civil society activism, for example for fair trade. These insights hold important implications for addressing telecouplings, especially when considering the definition put forward by Eakin et al., (2014) that telecoupled systems are two or more systems that are separated in terms of their governance structures. Integrating the awareness that these governance structures themselves are increasingly flow-based thus presents a challenge that future telecoupling research needs to address.

9. Concluding remarks

The aim of this Discussion Paper has been to present, apply and discuss the concept of telecoupling emerging from a decade of theoretical work within Land System Science. The telecoupling framework is framed around the question of drivers and causal relations of change in land systems. Moving from the land transition notion and the framework of proximate and underlying driving forces to the concept of land and urban land teleconnections, the telecoupling framework has emerged to capture two current trends in the LSS scholarship. Firstly, it addresses the growing complexity and increasing influence of globalisation processes in driving land system change. Secondly, it aims at integrating place-based and process-based analytical approaches. Telecouplings thus represent the next logical step in the conceptual development that embraces the possibility of simultaneous and multi-directional streams of change and places great importance on the feedbacks in distantly connected human-environmental systems.

Despite the differences in the analytical focus between the two telecoupling frameworks presented in this paper, both frameworks propose a systematic analytical approach for dealing with distal connections in land system change. Their main strength, especially prominent in the framework proposed by Eakin et al., (2014), is the relative flexibility given to researchers with regard to the analytical entry point. This has implications for two interrelated aspects of analysis. Firstly, the flexibility of the framework makes it possible to start the analysis from a range of different perspectives suitable to the individual research project while maintaining a comprehensive view of the entire telecoupling process. Secondly, in order to address the full complexity of telecouplings, the openness of the framework invites researchers to engage in interdisciplinary research. The strongest analytical aspect of the telecoupling framework is therefore perhaps the development of a heuristic tool and a common language that provide researchers with an "umbrella" under which interdisciplinary work can be pursued in the effort to address interactions, relations and processes working over distances to produce land system change today.

However, as evident from the case of rubber expansion in Laos, the application of the framework presents some challenges. The inherent openness of the framework necessitates a range of analytical choices, which have substantial implications for how telecouplings are analysed and understood. This is especially evident in relation to temporal and spatial scale-choices. Therefore, the challenge remains for LSS researchers working to understand telecouplings to consciously acknowledge the implications of their analytical scale-choices. Looking beyond Land System Science, future telecoupling research could benefit from a critical conceptual engagement with other strands of research on distal relations, actor networks and flows. Such a cross-fertilisation of theoretical and methodological approaches could contribute to deepening the understanding of complex telecoupling processes, and provide a stronger foundation for empirical research on telecouplings.

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Appendix

List of theoretical concepts and analytical methodologies with potential for illuminating telecoupling analysis (Eakin *et al.,* 2014: 155-157).

Table 8.2 Analytical tools and lenses.

Analytical tool	Short description	Relevance for telecoupling
Actor theory-based approaches	Actor models comprise at least three nested components: • action as the dynamic interplay between activity and agency (means and meaning), • strategy of action as a combination of actions, and • institutions in which meanings of action are embedded.	An actor's capacity to influence land-use change can be discerned through his activity but also through the agency he can employ and how he is thereby influenced by external actors. Multiple interactions with other actors can be analyzed through direct influence on other actors (activity) or through shared institutions. This eventually allows indirect effects on land-use change to be identified that an actor exerts through actor networks.
Social network analysis	Allows the networked arrangements among many different actors to be analyzed in terms of various flows (e.g., information, money, material flows). The metrics permit network characteristics (e.g., density, centralization, bridging, and bonding ties) to be identified. Distinction of subgroups within networks is also an important measure.	Allows assemblages and hence system boundaries of telecoupled systems to be delineated, which then permit relevant socioecological systems to be identified and addressed. The identification of "brokers" (i.e., actors who ensure the connection between systems) highlights which actors and flows are decisive for enabling telecoupling, and hence represent leverage points for change and regime shifts
Process tracing	Identifies and decomposes all the detailed steps of the hypothesized causal chains that link some initial independent variables to the observed outcome of the dependent variable. When all steps of the causal chain, as well as their implications, are validated, and the counter-hypotheses are shown to be invalidated, then the causal link between the initial variable and the outcome can be established.	Well-suited to the longitudinal analysis of complex multidimensional cases, such as those which include nonmaterial flows and linkages that may be instrumental in land outcomes.
World city systems analysis	Scholars focus on two different aspects of global hierarchies: • differential attributes of global cities and the quantity, which involves ranking cities by the performance or level of specific traits, and • intensity of flows or linkages between them, which focuses on the interactions among cities within the hierarchy.	Explores partial "telecouplings" between cities in different nations. Theories, methods, and empirical results may be of use to those interested in land-use telecoupling.

Table 8.2 Analytical tools and lenses *(continued)*.

Analytical tool	Short description	Relevance for telecoupling
Assemblages	The concept of "assemblages" suggests the coming together and interaction of multiple things. This is used to theorize and study structural change in social relations and the global political economy. Assemblages do not privilege specific units of analysis or predetermined causal relationships.	May be a useful heuristic device to capture the complexity of analyzing the interaction among fragments of institutional forms, ideas, and actors across historical periods. Can be useful in examining the sets of actors and varieties of agencies across space that are then telecoupled to land uses.
Economic models	A wide variety of economic tools and modeling approaches are potentially applicable: • computable general equilibrium models capture linkages between input and output markets and can thus be used to study how changes in one market affect individuals in a distal market, • models of economic growth and migration capture flows of people, goods, capital, and firms across regions and feedback effects, and • models of social interactions capture the influence of groups and networks on individual choices.	Useful to capture the implications of interregional flows of people, goods, and services in specific places as well as the relative influence of particular flows on observed outcomes.
Diffusion theory	Addresses how innovations spread through space and time. Has been used in fields from communications to marketing to understand how information, knowledge, ideas, lifestyle, and consumer patterns "travel" through society and are adopted over time by an increasing number of people. The mechanisms by which this process of diffusion occurs relate to knowledge and interactions among people.	Can help identify the nature of the force (e.g., idea, policy), the communication channels, the time, and the systems (actors, linkages) that enable an innovation to flow through the system. Uses concepts such as critical mass and tipping points which should be considered when analyzing what makes two systems coupled.
Organization theory	Used to understand how organizations arrange actors and processes to obtain a goal.	Can help us identify the individuals, structures, processes, and motivations that guide the behavior of the key actors.

Table 8.2 *continued*

Analytical tool	Short description	Relevance for telecoupling
Trend analysis	An analytical approach in business (financial management, marketing) is employed to try and predict future behavior. Quantitative and qualitative methods are employed. To conduct marketing research, one tools consists of identifying "trendsetters" and following their actions, decisions, and interactions with others to detect the birth of a new trend.	As urban lifestyles become globally adopted, changes in patterns of consumption or interest of small but influential populations can be the origin of changes in behavior at a large scale and the telecoupling of distal systems.
Multisite studies	These are places of study that are connected by processes rather than comparable units of analysis or systems features. Such a study might involve all sites in which the activities along a commodity chain take place and use different methods for each site.	Is essential for analyzing telecoupling since, by definition, it occurs at multiple sites, with different actors, and activities of interest in each site.
Flow analysis	This general category of analytical tools incorporates commodity/value chain analysis, life cycle analysis, material flow analysis, and other methods that trace systematically the movement of material (energy, goods, capital) through a system.	Accounts for the movement of material and value between systems, and thus the feedbacks and linkages in telecoupled interactions.
Pathway analysis	Focuses on strategies that arise from decisions taken by individual actors, households, and groups of people. It stresses that opportunities and constraints on decision makers are imposed by other actors as well as higher-level institutions.	Is relevant for telecoupling analysis, which pays attention to the role of actors in dynamics and feedback.
Scenario and visioning	Different fields have developed strategies and procedures for scenario construction and analysis as well as participatory visioning activities. These approaches entail facilitating the construction of possible and plausible futures with key social actors, in which the indirect and direct consequences of actions and development trends can be explored.	May enable telecoupled land outcomes to be predicted and anticipated, and adverse outcomes avoided, through anticipatory actions and social learning.

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