Telecoupled Landscapes for Nature Inclusive Transitions

Conceptual framing and methods

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The Dutch landscape is highly connected with other (inter)national landscapes, implying that considering telecoupling is foundational for nature inclusive transitions in the Netherlands. Our review demonstrated that there are multiple framings of telecoupling, with a development from structural to actor based and governance approaches. Each of the identified approaches uses different angles, such as systems impact, flow focused or intervention impact. To effectively use the concept of telecoupling, it is important to further develop and connect to scholarship such as power, equity, transformative change and environmental justice, which is currently lacking. This also includes different perspectives and knowledge often overlooked in systems approaches (e.g. local knowledge) and the learning across methodologies (e.g. Social learning, ethnography)

Keywords: Nature inclusive, transition, telecoupling

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Report WCDI-23-232

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Contents

1 Introduction

The research project *Telecoupled Landscapes for Nature Inclusive Transitions* is part of the Wageningen Research KB36 research programme. This overall programme aims to contribute to the transformation of existing social-ecological systems to include more biodiversity, whilst making effective use of nature-based solutions that are socially inclusive and economically sustainable. Its focus is on the transformation of food systems, by emphasising the importance of resilient ecosystems as a fundament for sustainable and inclusive food systems. The programme covers a broad set of research projects focusing on sustainable agriculture (soil ecosystems, climate resilience, zoonoses, impact of alien invasive species); the scaling of nature inclusive agriculture and biodiversity in circular agro-economies; the spatial management of biodiversity in a crowded country; and the use of modelling, remote sensing and artificial intelligence (data driven biodiversity).

The KB 36 programme is interested in nature-inclusive transitions at the field, the farm and the landscape level, mostly within the Netherlands and its overseas territories in the Caribbean. It contributes to the increasing body of knowledge on nature-inclusive transitions in the Netherlands, but so far it has not been explicit on the spatial impact that these transitions in the Netherlands may have on telecoupled countries or landscapes in the global South. This raises a few questions regarding the sustainability of nature-inclusive transitions in the Netherlands at the global scale. Could it be that, while attempting to reduce the ecological *'food' print* of the Netherlands, it indirectly increases the food prints of telecoupled landscapes overseas? Could it be that the shortening of food chains from a Netherlands perspective leads to declining prices in producing countries, with detrimental impact on farm incomes and livelihoods? Or could it be that nature inclusive transitions in the Netherlands result into a reduction of per capita yield, hence to new demands for imported food? How would carbon offsets influence distant land use patterns, and raise new claims on scarcely available nutrients, water, and land? What would due diligence and zero deforestation regulations mean for producers of cocoa, coffee, and tropical timber? Given the Netherlands' commitment to the Paris Agreement, CBD's Post-2020 Biodiversity Framework and the Sustainable Development Goals, such negative impact would certainly not be desirable, and therefore needs to be critically examined. There is a knowledge gab on the potentially negative impacts of Netherlands based nature-inclusive transitions in terms of sustainability and equitability, which is the reason why this new research topic has been added to the KB36 agenda, with the aim to critically assess the impact of nature-inclusive transitions in the Netherlands on landscapes in the Global South.

2 Research objective and deliverables

The aim of this research is intricately connected to the aim of KB 36, yet specifically focused on the impacts of nature-inclusive transitions in the Netherlands as studied under KB36 on telecoupled landscapes elsewhere in the world. It uses telecoupling as a suitable concept to map, understand and analyse such telecoupled transitions, and help to predict and avoid negative impact of nature inclusive transitions in the Netherlands on countries and landscapes in the Global South. With this, the research project aims to strengthen the international dimension of the KB 36 programme, by putting nature-inclusive transitions in an international perspective. This general aim leads to the following research questions:

1. How are nature inclusive transitions in the Netherlands connected to global resource and trade flows, i.e. telecoupling?
2. Which geospatial methodologies can help mapping resource and trade flows, and explore scenarios for telecoupled nature-based transitions?
3. Which socio-economic methodologies can help mapping social relations between telecoupled landscapes, and potentially establish a process of social learning between distant stakeholders involved?
4. Can the combination of these methodologies lead to an interdisciplinary framework for analysing telecoupled food systems, and contribute to nature-inclusive transitions that are beneficial to both the Netherlands and the Global South?

As there is hardly any work on telecoupling in the context of nature-inclusive transitions, the nature of this research is explorative, and methodologies will have to be developed along the line. The outcomes of the research will be novel, and highly relevant to KB36, as well as to the Netherlands policy agenda on nature-inclusive transitions. In addition to the above mentioned aims, this research strengthens the WUR vision on food systems and nature-inclusive transitions by adding an international perspective, highlighting WUR's critical thinking and its social responsibility towards the Global South. It highlights the embeddedness of the Netherlands within global supply chains and examines the positive and negative consequences of its nature-inclusive transition on those countries and landscapes it is related to. It allows for closer collaboration between Wageningen Economic Research (WEcR) which has experience with the analysis of global resource and trade flows, and the experience of Wageningen Environmental Research (WenR) in geospatial modelling and scenario development. It builds on Wageningen Centre for Development Innovation's (WCDI) work on social learning, multi-stakeholder collaboration and food systems and landscape transitions in the Global South. It allows for collaboration with Wageningen Science Groups, including the Laboratory of Geo-information Science and Remote Sensing, the Marketing and Consumer Behaviour Group, and the Forest and Nature Conservation Policy Group, each of which are engaged in related work. Itt connects to the Wageningen Biodiversity Initiative, particularly its first theme of *sustainable sourcing of raw materials, protecting and restoring landscape level agrobiodiversity*. And finally, it builds a conceptual framework on telecoupled landscapes, as a basis for the new HORIZON 2020 research programme called *Transformative Change for Biodiversity and Equity (TC4BE),* which is joint proposal of Wageningen University (lead), the Natural Resources Institute (University of Greenwich), IDDRI & CIRAD (France), and overseas partners in Colombia, Cameroon, and Kenya. This project uses telecoupling as an important entry point for transformative change, thus offering an opportunity for the results to be integrated in an ongoing research endeavour having a much wider scape and outreach.

3 Building a Conceptual framework

Telecoupling is based on the idea that most landscapes are directly or indirectly shaped by development trends in distant landscapes, influencing the flows of ecosystem goods and services across the globe (Hull and Liu, 2018). Telecoupling contrasts with more locally driven or territorial approaches which tend to underestimate the importance of such distant trends, and falsely assume that local stakeholders are in control (ibid.). There is a small but growing body of literature on telecoupling, emphasising that the costs and benefits of ecosystem goods and services are often spatially distant, in which nature-inclusive transitions in one place may be a driver of agricultural intensification and environmental deterioration in another, leading to new inequalities and interdependencies (Llopiz et al., 2019). Some telecoupling scholars focus on geo-spatial modelling and remote sensing as instruments to map and assess telecoupled processes (McCord et al., 2018). Other scholars examine how interactions between distant stakeholders under telecoupling can engage in a process of social learning, herewith becoming part of innovative biodiversity governance schemes (Martin-Lopez et al., 2019).

'*Landscape governance*[1]' in telecoupled landscapes considers the translocal relations between landscapes where (ecosystem) products and services originate, and landscapes where these same products and services are consumed. It analyses the translocal nature of these products and services, and how these translocal relations are reflected in governance arrangements. This approach includes individual systems such as ecosystems, farms, urban areas, watersheds to look at larger regions where these different elements interact – see Figure 1. In the **'telecoupling'** literature the described single system (which is telecoupled to another one) is often referred to as coupled human and natural systems (CHANS). A unique factor in CHANS approach is the consideration of the connection between the human and natural systems and spaces at multiple scales. This connection is similarly included in the landscape approach.

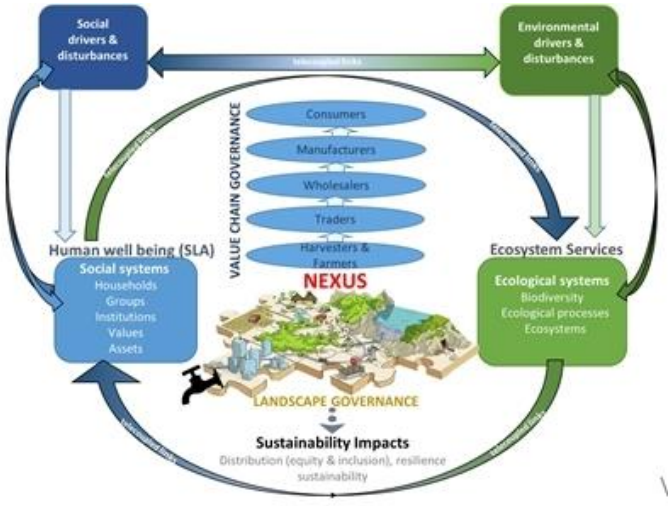

Figure 1 *Nexus of landscape and value chain governance- though the lens of telecoupling and Social-Ecological Systems. Source: (Ingram 2022).*

[1] **Landscape governance** in the domain of geo-politics and political geography builds on the notion of environmental governance that refers to "the set of regulatory processes, mechanisms and organizations through which political actors influence environmental actions and outcomes; it includes the actions of the state and, in addition, encompasses actors such as communities, businesses, and NGOs" and includes spatial dimensions that (*a*) thematize the role of space, scale, and place in governance processes; (*b*) rescales statehood vocabulary in its analyses of the transformation of the nation state; and (*c*) links social (including governance) processes to their biophysical and material conditions. It incorporates multiscalar, global-local processes in the analysis of landscape formation; shows how politics and authority are (re)shifting among various administrative and spatial levels (eg globalisaiton and localisaiton); and it biophysical and material conditions to social analysis often using a social-ecological systems and actor-network theory lens. (Arts et al., 2017)

There is ample literature on landscape governance stressing the interaction of human and natural systems and different stakeholders within a landscape (Arts et al., 2017). In this project the concept of 'telecoupling' introduces another factor, namely the teleconnection and globalization process which connect landscapes across the world. Whereas **globalisation** refers to the connection between human systems and **teleconnection** refers to the connection between natural systems, **telecoupling** approaches human and natural systems as interconnected within each space (as implied within the landscape framing) and refers to the connection between interconnected human-nature systems within one landscape to another distant landscape.

The relations between human and natural systems over variating distances have been referred to with different terms. The human-nature interactions within a system are called **intracoupling**, between distant systems: **telecoupling**, between adjacent systems: **pericoupling**, the interaction of different scales and distances is called **metacoupling** (Figure 2). Telecoupled landscapes thus refers to the relation between distant landscapes consisting out of human and natural systems.

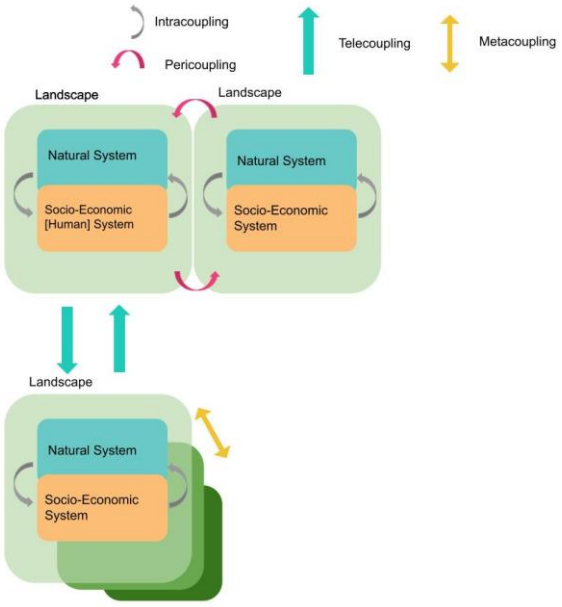

Figure 2 *Framing of telecoupling and related terms 'intracoupling', 'pericoupling', 'telecoupling', and 'metacoupling'.*

Landscapes can be telecoupled based on different flows (Figure 3). Their connections and relations might be via material products and markets, energy, finance, governance, technology, information and knowledge, movement of goods or products, movement of people and their wellbeing (Challinor & Benton, 2021). This means that measuring or evaluating telecoupling can be done in diverse ways with various units (e.g., species, trade value, ecosystem services value, people moving, capitals or assets etc.). In addition, some scholars focus on the flows whereas others focus on the impact on a system, such as the land use change in a landscape. The conceptual basis of telecoupling is therefore applied in different disciplines and literatures and relating to flows that are both material (physical products), immaterial (including services and finance), energy, matter and information or knowledge (i.e., social capital). Some examples are: international trade (Silva et al., 2017), food trade (Garrett et al., 2013), forest products trade (Liu, 2014), energy and virtual water trade (B. Fang et al., 2016; Luetkemeier et al., 2021), water transfer (Deines et al., 2016; W. Yang et al., 2016), land use/land cover change (Liu et al., 2013; Sun et al., 2017), ecosystem services (Liu & Yang, 2013; López-Hoffman, Chester, et al., 2017), tourism (Liu et al., 2015), species invasion (Liu et al., 2014), migration (Hulina et al., 2017), investment (Liu et al., 2015; D. Yang et al., 2016), urbanization (C. Fang & Ren, 2017) and conservation (Carter et al., 2014; Gasparri et al., 2016; Gasparri & de Waroux, 2015; Wang & Liu, 2017).

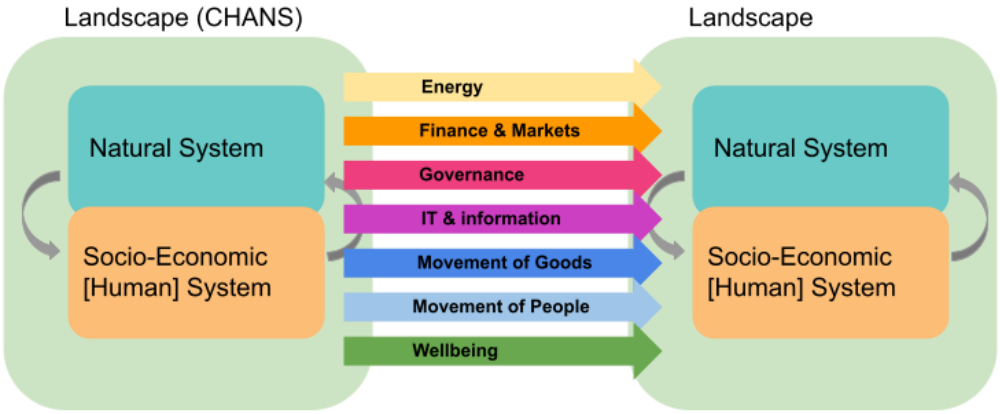

Figure 3 *Conceptual framework for telecoupled landscapes with material and immaterial flows.*

Whereas the origin of the telecoupling concept is based in the land use science (Liu et al., 2013), telecoupling as an implementation framework has developed in several ways. To this end, some have operationalized this concept, whereas others just use the word to refer to distant systems and flows. Therefore, telecoupling offers various things - referring to a phenomenon, a conceptual framework and methodological approaches.

This review is part of a wider research objective to understand the methodologies which can be used in telecoupling and the role of telecoupling in nature inclusive transitions in the Netherlands. As part of the overall goal of the KB36 programme to contribute to the transformation of existing social-ecological systems to include more biodiversity, whilst making effective use of nature-based solutions that are socially inclusive and economically sustainable.

4 The Design of the Literature Review

4.1 Methodology: Scanning the literature

A realist systematic literature review was conducted on the current literature on telecoupling. This was done by using the keyword 'Telecoupl*' in the SCOPUS database, which resulted in 243 articles. Articles were first screened based on title and abstract. In 2018 a review paper was published recapping the last 5 years on telecoupling literature (2013 was the first major article on conceptualizing telecoupling as a framework). The reviewed literature was therefore from 2018 onwards, which resulted in 104 articles. After reading the articles based on the selection criteria in Table 1, 94 articles were included.

Table 1 *Inclusion and exclusion criteria of the reviewed literature.*

Inclusion	Exclusion
English language peer reviewed articles	Telecoupling suggested as a result or recommendation.
Telecoulping as one landscape (human x nature) connected to another	
Use of telecoupling as an approach	
Articles reviewed from 2018 since literature review was published in 2018 and discussed above	

4.2 Interviews

Semi-structured interviews (6) were conducted with WUR researchers from different departments (economics, environment, political ecology, marketing, information technology, geo-information) regarding their conceptual interpretations of telecoupling, and the methodological approaches they employ. It was hard to find the right respondents, as not all of them interpret their work as 'telecoupling', yet their work may be relevant. With the interviewees, the above described concepts were discussed, and their takes on methodological approaches were reflected upon.

4.3 A visualization to inspire

After the literature review, a visualization was developed to capture the different conceptual insights into an attractive graph. This graph was then used during the interviews, to help interviewees to imagine the concept of telecoupling, and brainstorm freely of what this means to them, and how it can best be framed in terms of concepts and methodologies.

Figure 4 *Imaging telecoupled landscapes with human-nature relations within each landscapes connected to other human-nature system. The impacts of telecoupled landscapes can be viewed and experienced at multiple scales global to local.*

5 The Results of the literature review

In 2013 (Liu et al., 2013) telecoupling was first introduced as a framework in the context of land use/change sciences. Whereas the framework of telecoupling was more widely published from 2013 onwards, it is highly likely that more literature is relevant and could fall under the idea of 'telecoupling', but using other terms. This is especially likely when considering the studies focusing on the flows as identified in Figure 2. Some relevant work could for example be found under: 'interregional flows [for ecosystem services or trade]', 'spatial coupling and decoupling', 'transmission pathways', 'cascading effects' and 'trade flows'.

Here we focus on the literature explicitly using the term 'telecoupling', of which some approaches have been summarized in (Hull et al., 2019). These include 1) spatial subsidies approach, where ecosystem services are maps over spatial pathways, 2) Adapted social network analysis to understand the role of distant land use (e.g. grabbing) actors by following their connections, 3) qualitative analysis through ethnography of the system components (sending, receiving, spill over systems), 4) supply chain analysis such as life cycle analysis, footprints and input-output analysis and associated spillover effects, 5) decision-support tools such as the telecoupling Toolbox Geoapp as a tool to identify the telecoupling systems and their flows across different spaces. This shows there is a wide variety in telecoupling approaches covering qualitative and quantitative methods including spatial dimensions.

The first telecoupling paper in 2013 (Liu et al., 2013) provides a rather structural framework for analysis. Since 2013 more attention has been given to the role of actors (incl. institutes) and governance (e.g., influence of policies and treaties). In these latter papers, the framing (i.e., not structural but actor network or governance based) has led to different methodologies and analytical approaches. A quarter (24%) of the literature reviewed only uses telecoupling as a concept to refer to or to acknowledge the distant connections between systems, without using it as a framework or operationalizing it (Table 3). A 2019 literature review (Kapsar et al., 2019) on telecoupling suggests that out of 89 papers, 11 classified telecoupling as a phenomenon, 24 as a concept and 54 as framework. 'Phenomenon' indicates the mentioning but not applying of telecoupling, 'concept' indicates telecoupling as a word is used at least once in the conducted research and 'framework' refers to the operationalisation of the components. This is supported by our analysis showing that 24% of the papers refer to telecoupling with the meaning of distant relations instead of a conceptual framework (Table 2). Another review paper on the causal attribution in telecoupling shows a similar trend, namely that a fifth of the assessed papers did not actually use the telecoupling components (Carlson, Zaehringer, et al., 2018). The telecoupling components are based in their original systems framing from the land use sciences, acknowledging systems, flows, agents, causes and effects (Figure 3).

Table 2 *Overview of framing of reviewed literature using 'telecoupling'.*

Framing	Number of papers	% of total papers n= 94
Structural	28	30%
Incomplete structural (only use one or few elements)	15	16%
Only as concept to refer to distant connection	23	24%
Actor network - governance	17	18%
Just reference to support new framework	11	12%
Other	1	1%

Note: The number of papers do not add up to the total reviewed papers, because some papers were theoretical or reviews and did not apply the framework.

Here we will further unpack the part of the literature which uses 'telecoupling' as a framework approach.

5.1 Structural approach

The structured approach presented by (Liu et al., 2013, 2014) provides a comprehensive place-based conceptualization emphasizing the systematic nature of landscapes and the connections between components and distant interactions. The literature using this approach focuses on analysis based on five components: Sending/receiving/spill over systems, flows, causes, agents, and effects (Figure 4). However, only a few papers used within framework to pay special attention to 'causes' (Carlson, Zaehringer, et al., 2018) or 'spill over systems' (Liu et al., 2018), and others focus on the ability to model systems and understanding the impact of system changes (Carlson, Taylor, et al., 2018; Paitan & Verburg, 2019).

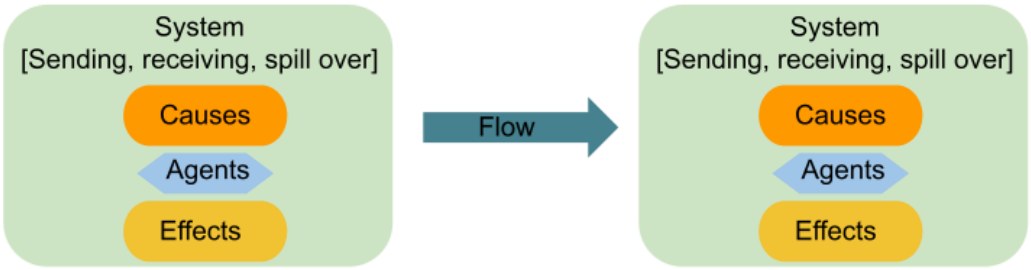

Figure 5 *Telecoupling framework as proposed in Lui et al. 2013.*

Some of the challenges based on this structured telecoupling framework (Friis et al., 2015) have been identified as: 1) Reduction of the complexity of processes and mechanisms, 2) Identifying the distinction between the sending, receiving and spill-over systems, which have many relations which are multi-directional and include feedbacks, 3) Defining spatially and functionally separated systems (prerequisite for telecoupling), 4) Connecting scales since telecoupling operates on a higher spatial scale than the human-nature system relations, but causes and effects are within the human-nature system, 5) Importance of temporal scales for flows and feedbacks, 6) Role of spatial and temporal scale in determining if a system is sending, receiving or/and spill-over.

5.2 Actor network based approach & governance

The initial telecoupling framing (i.e., structural framework) included little on institutions and governance processes. To fill this gap various scholars have taken inspiration from Elinor Ostrom's and colleagues work (Boillat et al., 2018; Oberlack et al., 2018; Ostrom, 2009, 2010), conceptualizing telecoupling governance as polycentric. This places telecoupling governance in a network of action situations, where the interactions between actors of different social distances result in different outcomes. Action situations refer to "*social spaces where individuals interact, exchange goods and services, solve problems, dominate one another, or fight (among the many things that individuals do in action situations)*" (Ostrom, 2011, p. 11). To this end, action situations are social spaces which are part of a landscape and can be telecoupled to other landscapes.

Following from this approach, Eakin et al. (2014) presented an 'heuristic' approach for studying telecoupling. The emphasis was placed on the spatial distance (e.g., spatial mapping) and the social distance (e.g., actor networks, perception based, stakeholder mapping) of processes and networks. Eakin et al.'s (2014) suggestion that telecouplings are the result of networks of interactions at different scales, contrasting therefore with (Liu et al., 2013) structural approach where telecouplings are a structured spatial hierarchy. Instead of the analytical checklist provided in the structural approach, this heuristic approach provides more open analytical entry points with a focus on actors, processes, and networks (Friis et al., 2015). This

analytical approach enables the analysis of existing and potential system changes and connections. Five triggers for telecoupling can be considered within this framework: *"triggers that produce telecouplings, direct impacts that results in systems changes, indirect impacts to distant (but coupled systems), feedback dynamics in the coupled systems relationships, and social and institutional change resulting from feedbacks"* (Newman et al., 2022, p. 345).

The governance approach is based on the actor networks underpinning of telecoupling as a result of interactions on different scales. The governance approach provides a different set of challenges in terms of global environmental governance, namely: knowledge deficits, divergent interests, high transaction costs of cooperation, the weak legitimacy base of current governance arrangements, and policy incoherence and fragmentation (Newig et al., 2019). These challenges are, however, representative of different perspectives on the role of governance in telecoupling. Some scholars refer to governance as making the rules and as drivers of telecoupling challenges and solutions (e.g., institutional analysis perspective – (Oberlack et al., 2018). Governance scholars can thus consider telecoupling as part of facilitating interregional networks, or coordinated flows organized by value or supply chain actors. On the other hand, other scholars have approached telecoupling as an 'ungoverned' process (Eakin et al., 2017) due to negative telecoupling externalities being outside reach of governing institutions (Eakin et al., 2014; Newig et al., 2019).

In operationalizing the governance approach, scholars have used the actor network-based approach to develop analytical frameworks for power analysis (e.g. (Martín-López et al., 2019). For example, in the case of the cross-scale influence dependence framework, the distribution of ecosystem services among stakeholders is analysed through: *"1) identification of social actors related with a set of ecosystem services at different scales, 2) assessment of dependence level on ecosystem service, 3) assessment of the influence level in decision-making, 4) identification of within and cross-scale interactions between social actors in decision-making"* (Martín-López et al., 2019, p. 241). Munroe et al. (2019) propose an actor network based framework inspired by Newig et al. (2019, 2020), with producers, consumers, intermediate actors and spill over actors' categories within a collective decision arena. The institutional fields would then be comprised by civil society, public-private sector interactions, firms (as commodity flows) and firms (as information flows).

Instead of actor-based networks, there has also been some work centered around commodity networks and chains. Ingram et al. (2020) operationalized telecoupling to investigate the outcomes of consumption and trade of commodities in the Netherlands, to direct and indirect deforestation across the globe using a value chain concept for agro-commodities such as cocoa, beef and palm oil, to assess the traceability to deforestation caused by commodity production, noting and impacts such as greenhouse gas emissions, biodiversity loss, human rights violations, financial impacts due to corporate reputational and operational sourcing risks.

Taking a governance approach brings together different literature strands from the different governance scholarship, as summarized, and categorized by (Newig et al., 2020) (Table 3).

Table 3 *Governance literature strands informing the governance approach to telecoupling, including the identified governance challenges and limitations. From (Newig et al., 2020).*

Scholarship	Focus	Limitations
Global Environmental Governance	Governance arrangements across state borders. Focus on institutional interconnections and challenges. Idea of international regimes	Focus on international institutional settings with cognitive distance and little focus on the role of local context.
Transnational Private governance	Private sector influence on product movements (e.g., certification, standards). Private governance which crosses scales and jurisdictions.	Little on public-private relations and cross-sectoral connections.
Global Commodity chains	Focus on production to consumption chains and the role of economic chain actors over distant areas. Commodity chain governance with diverse actors, mainly private and market based.	Emphasis within chain actors without the wider institutional and environmental impact context.
Environmental flows	Sociological point of view on the flow governance (e.g. connecting different interests from actors)	Remains rather conceptual on governance approaches.
Critical political economy of the global environment	Exact descriptions of value chains and environmental impacts. Pays attention to power relations, such as moving environmental impact from the Global North to the Global South. Approaches include radial systemic change.	Little mentioning of governance response subtleties. Focus is often on the limitations of global capitalist economy over the telecoupling as places and flows.
Scalar governance	Encompasses the spatial connection between the governance and institutions with the challenges that needs to be addressed.	Limited on disconnections between spaces, such scalar mismatches between drivers and effects.
Telecoupling and land system science	Combines place-based and flow-based activities and examines the interaction in multiscale governance	'would benefit from more nuanced treatment of governance'

Telecoupling continues to be used in many disciplines, in part because of the wide diversity of flows connecting different landscapes as shown in Figure 3. One more recent addition to already existing governance and actor network telecoupling frameworks is 'environmental justice' (Boillat et al., 2020). This strand focuses on *"1) the distribution of social-ecological burdens and benefits across distances [distributive justice], 2) power and justice issues in governing distantly tied systems [procedural justice], and 3) recognition issues in information flows, framings and discourses across distances [recognition justice]."* (Boillat et al., 2020, p. 1). The importance of equity has been emphasized in telecoupling literature, which acknowledges the complexity of agro-food systems due to their diverse geographical scales, the opacity of value chains, and highly inequitable power relations. This complexity increasingly displaces decision making far from communities and nation states and externalizes negative socio-environmental impacts (Liu et al., 2013). Whereas this has increased the importance of the concept of telecoupling, there is still a focus on systemic and model approaches to telecoupling with little attention to the role of intangible concepts such as power, equity and environmental justice.

5.3 Flow & System types

In terms of flow or system types, a literature review up till 2018 ((Kapsar et al., 2019) – total of 89 papers) identified 40 papers covering flows of trade (45%), 27 knowledge transfer (30%), 9 species dispersal (10%), tourism (>10%), water transfer, human migration, waste transfer, biophysical, technology transfer, investment, animal migration, ecosystem services. Within the papers which actually applied the telecoupling framework, 14 referred to telecoupling in international scale, 13 referred to regional or national scale, and 6 on local scale.

In this review from 2018 onwards not all telecoupling scholarship focuses on the flows. Some only focus on impacts (e.g. land use change, urbanization). From the papers which did explicitly consider flows, the following distribution was found:

Table 4 *Overview and count of the flow types in the reviewed telecoupling literature.*

Flow or connection type	Number	% n
Trade products	32	34%
Monetary & financial	10	11%
Knowledge & information	14	15%
People movement	13	13%
Environmental assets/ services	6	6%
Governance (also as drivers, institutions, decision-making)	18	19%
Species migration	8	9%
Biophysical flows (soil, water, air)	9	10%
Environmental justice & wellbeing	2	2%
Cultural service	1	1%

This shows that both before 2018 and after 2018, trade flows remain the most studied telecoupled connection. The study of a commodity flows creates clear boundaries, which is one of the challenges when studying telecoupled systems. Therefore, it provides a more tangible and traceable connection.

5.4 Telecoupling Landscapes Research in the Netherlands and within WUR

Based on the literature review only two papers (Ibarrola-Rivas et al., 2020; Schröter et al., 2020) included the Netherlands explicitly as a receiving or sending system. In addition, one mentioned the Netherlands as a major soybean importer and another paper referred to the Netherlands as a cocoa importer, but did not explicitly include the Netherlands in the analysis.

Based on interviews with WUR researchers, however, there are multiple ongoing projects with are connected to telecoupling but which are not using 'telecoupling' framing. It is therefore likely that many projects have some telecoupling elements but do not use it as a focus or the framing.

In the field of economics, quantitative approaches to understand policy impacts were found to be most common. Economic focused interviewees commented that main mechanisms are trade (loss through coupling), people movements such as tourism, and financial streams. WUR project examples are price development based on fishery management, or the influence of controlling a landscape (e.g. the natural resources in a landscape) such as illegal fishing or production levels. The management of a landscape or natural resource can lead to less export and increase export in other landscapes. For example, the successful handling of illegal fishing in Indonesia has increased illegal fishing in other landscapes. In this field, statistical methods such as regressions and structural equation models were used but these are not framed as proving causality. Another economic model with spatial analysis is MAGNET (MAGNET (magnet-model.eu), or MRIO tables (life cycle assessment). The MAGNET model can work with scenario pathways (socio-economic) to generate land use, prices and trade outputs implying trade streams including labour, materials and energy can be modelled in future scenarios. In contrast, MRIOs are not good for future projections but are detailed on tracing the origins of products and value chains. Scenarios can include, for example, the impact of a subsidy, tax cut on commodities such as bio ethanol trade. It was mentioned that in this field a move towards 'economic wellbeing' as output is gaining popularity in relation to the SDGs. This means instead of solely looking at prices, the objective is to translate outputs to 'poverty' and 'food security' impacts. For example, safe and just operating spaces are becoming more important, considering social foundations (doughnut economics) and planetary boundaries.

From the field of information technology, agent based modelling has been used the see patterns and understanding what causes these patterns. This type of modelling can understand the impact of behavioural connections and highlight negative externalities.

***From a marketing & consumers perspective**,* telecoupling is relevant in decision-making connected landscapes. Prices connect consumers and producers in different landscapes, and reflect flows of communication and decision-making. The pressure on prices by consumer choices have negative implications for producers, whose challenges are not seen by consumers due to distant connections. Questions in this field in the context of telecoupling address questions on how to create more awareness of producer pressures in terms of social and environmental issues. Flows often go from consumer to producer but not the other way around. Methods often used in these research projects are qualitative to understand the farmer connection to the market or psychology based qualitative methods (e.g. stakeholder interviews) for market innovation and shaping. For example, providing choice experiments for producers and consumers between different market options.

From the field of political ecology discourse, there are some critical perspective on telecoupling. Namely, the lack of attention to power, politics and equity. Especially considering the influence of international conservation and development programs such as REDD+ or carbon trade bring together power dynamics at different scales. A discussion on Biodiversity Impact Chains (Büscher et al., 2022) focuses on the role of global political economy in our current governance systems sustaining current environmental and development challenges.

6 Methodological approaches to 'Telecoupling'

The review on causality in telecoupling by Carlson et al. (2018) reported that 62.9% (n=56) of the reviewed papers provided only descriptive statements (i.e. qualitative). Of these, a majority used qualitative secondary data and only two papers used both qualitative and quantitative analysis (e.g. network analysis, simulation modeling, statistics) (López-Hoffman, Diffendorfer, et al., 2017; Schaffartzik et al., 2015).

Based on this literature review a methodology overview was created (Table 5). As shown in the previous section 3.1 the diversity in telecoupling approaches and subjects results in different methodologies aimed at different objectives within telecoupling (e.g. focus on flows vs system impact, product or policy/programme focus).

Table 5 *Overview of methodologies to investigate telecoupling from literature review.*

Type	Spatial Yes/no	Methodology	Additional Description	No. of papers
Qualitative (Descriptive)		Description per structural framework component based on secondary data *		7
		Description structural framework based on surveys, interviews, workshops *		2
		Description of actors, events/factors or networks – social network analysis /social and power relations analysis *	based on interviews, focus groups survey, ethnography or secondary data. examine the level of dependencies and influences of contemporary key actors on the ecosystem services and interrelations	16
		New framework development (using concepts of telecoupling) or literature review on sub topic *		13
		'Cross-scale influence-dependence framework'	Stage1: semi structured interviews; questionnaires; focus groups; expert panel-based approaches. Stage 2 and 3: assessment of cognitive mapping and mental models; rainbow diagrams; interest influence matrix; participatory and deliberative mapping; scenario planning. for Stage 4: type and strength of actor linkage matrices; net map; social network analysis; institutional ethnography	1
		Historical trajectory analysis / archival research*		2
		Network of Adjacent Action Situations (NAS), Combined IAD-SES (CIS) framework		1
Quantitative		Multiregional input-output (MRIO) tables/ models	Quantify net flows and spill over flows	4
		General equilibrium model (GTA) – and recent modified GTAP-BIOP	identification of the changes in each drivers and impact on growth in soybean trade and land use change/CO2 emission (quantitative)	1

Type	Spatial Yes/no	Methodology	Additional Description	No. of papers
	+/-	Stated choice model*	to relate the attributes of scenarios(i.e., crop damage intensity, payment level, and social norm)presented in the stated choice questions to households' willingness to participate in future programs	1
	+	Telecoupling GeoApp*	to relate the attributes of scenarios (i.e., crop damage intensity, payment level, and social norm) presented in the stated choice questions to households' willingness to participate in future	2
		Surveys and interviews to quantify telecoupling structural framework flows		1
	+	Statistical analysis – to construct networks (igraph), nodes, flow paths, trend analysis		3
	+	Statistical analysis - Agents - Descriptive statistics; Flows - Radial flow analysis; Causes - ES supply quantification and principal components analysis/linear panel regression analysis/correlation; Effects - Effect analysis*		2
		Statistical analysis – descriptive statistics		6
	+	Statistical analysis- logistic regressions with robust standard errors clustered by state.		1
	+	Geospatial analysis – satellite remote sensing*	Tang et al. 2021 DDS: local and telecoupling coordination degree model (LTCCDM) is proposed to quantify the local and teleoupling coordination	8
	+	Statistical - Spatial cluster analysis*		1
	+/-	Citizen science*		1
		Life cycle assessment		1(part of review paper)
		Environmental footprints and indicators (e.g. based on food frequency questionnaire)*		1 (part of review paper) +1
	+/-	Agent-based models (rule and process based) – Tele ABM		1 (part of review paper) + 3
	+/-	System dynamics models (rule and process based)		1 (part of review paper)
		Equilibrium models (incl. computable general equilibrium models (CGE), partial equilibrium models (PE)and input-output analysis (IO))		1 (part of review paper)
	+	Land use models		1 (part of review paper)
		time series autoregressive integrated moving average (ARIMA) models		1
	+/-	Ecosystem services analysis (e.g. tiered approach)*		5

Type	Spatial Yes/no	Methodology	Additional Description	No. of papers
		Value chain analysis (e.g. physical consumption-based accounting approach with national statistics and process chain modelling or Total Material Requirement)*		3
		Integrated risk assessment		1
		Particle tracking models		1
	+/-	Telemetry*		1
		Social Network Analysis		2
	+	Machine learning and GIS to model-predict the at-sea distribution of seabirds Relative index of occurence (RIO)		1
	+	Structural equation model – Second-order spatial autoregressive model (SO-SAR)		1
	+/-	Water Scarcity Index		1
		Scenario simulation		2
		FAO Aquacrop model		1
	+	InVEST model	Spatially explicit models which use and produce maps. Results return in either biophysical or economic units.	1
	+	CRAFTY-BRasil – Land use cover model	Agency-based model which simulates land uses based on land actors decisions.	1
		Water transfer model	Constructs the input and output indicators of the model. The input indicators are mainly based on Water Transfer, while the output indicators emphasize the economic, social and ecological benefits of water used by provinces and cities, which facilitates the measurement of the metacoupling. Secondly, the evaluation framework for the parallel data envelopment analysis (DEA) model of metacoupling of water transfer was built from the perspective of efficiency. This framework divides the metacoupling of the water transfer project into intracoupling, pericoupling and telecoupling, and opens the internal structure of the traditional DEA system.	1
	+/-	Biophysical temporal data – historical change analysis	If based on NDVI (satellite based) it is spatial. Vegetation indices concerning biophysics.	1
	+	Spatial Durbin Error Model (SDEM)		1
		Vector autoregressive model		1
		Phospurus model equations	Virtual P use	1
		Metric Telecoupling intensity		1
	+/-	Tourism Satellite Account and input–output model		1

* indicates methodologies potentially useful for nature inclusiveness, suggestions and not limited to these methods.

\+ means this is a spatial method.

+/- indicates this method can be spatial if based on spatial data, e.g. satellite data.

The overview shows a plethora of quantitative methodologies of which many can be spatial. Especially, geospatial methodologies using GIS and/or remote sensing, descriptive or basic statistical analysis of inputs and ecosystem services analysis are popular. Various methodologies are connected to specific flows types, such as ecosystem services analysis to the movement of goods, or qualitative methods/social network analysis for the governance flow. In terms of decisions on methodologies there are distinct difference in what

is studied. If the flow is the focus (e.g. life cycle assessment, Multiregional input-output (MRIO) tables/ models) or the impact on a system (e.g. land use models, remote sensing), or the influence of a certain program/policy (e.g. interviews). As indicated in the table some methodologies can be used specifically for spatial analysis, often depending on the input. If the input is spatial, the outputs can be as well. Based on the reviewed literature there few papers using mixed methodologies such as quantitative and qualitative methodologies.

7 Discussion and conclusion

The new Dutch Global Climate Strategy identifies that 40% of the Dutch GHG footprint is sourced outside the Netherlands due to many services and goods being imported (Hickel et al., 2022; Sustainable development Solutions Network & Institute European Environmental Policy, 2021). Therefore, telecoupling approaches are foundational in discussions about nature inclusive transitions in the Netherlands. The wide variety of telecoupling flows shows that there are plenty of connections from Dutch landscapes to other landscapes (Figure 4). These couplings can be identified as Energy, Finance & Markets, Governance, IT & Information, Goods, People and Wellbeing, thereby more diverse than the initial concept of telecoupling referred to. Especially the Dutch global agenda in terms of trade and resources implies that nature inclusive transitions in the Netherlands cannot be decoupled from impacts on other landscapes. Dutch telecoupled landscapes can be multiple, where one transition can affect multiple landscapes (Figure 4). Within the WUR, multiple researchers and projects contribute to understanding telecoupling flows and landscapes. These examples include (but not limited to) economics, information technology, marketing & consumption, political ecology, logistics, information management. While progress is being made there are some challenges to address; 1) clear understanding of what telecoupling is across disciplines, 2) the connection of different disciplines and approaches to telecoupled landscapes which includes human and nature systems, 3) telecoupling as a focus point in transformative change instead of solely a side or sub part of Dutch landscape focused work.

The literature review pointed out that there are various ways of operationalizing and framing telecoupling from a structural approach (embedded in land use sciences) to actor based and governance focused approaches. Through identification of the types of flows between landscapes (Figure 1) the diverse disciplinary strands of literature are influenced. In addition, the angle used to observe and examine plays an important role; most land use based literature focus on the impact on a system (e.g. landscape), whereas economic approaches are often concerned with flows, and governance often examine the role of an intervention (e.g. policy, subsidy) on the flows and system. Whereas telecoupling as a concept started in the land use and environmental science, recent literature focuses increasingly on governance and actor based networks. This highlights a need and slow move to focus on wellbeing, equity and (environmental justice).

The diverse approaches towards telecoupling analysis (e.g. flows, system impacts, governance, policy impact etc.) and topics (e.g. trade, ecosystem services, governance) result in a wide variety of methodologies that can be used. In most case, telecoupling was found to be used in a descriptive or conceptual manner. To this end, telecoupling is mostly used to indicate the 'challenge' of connections between distant landscapes. Building on this descriptive approach, is the need for more in-depth understanding in quantitative and qualitative analysis (incl. spatial). For this in-depth understanding quantitative analysis (frequently with spatial data) are popular, which can be explained by the concept's origin in land use science. Various identified qualitative, quantitative and spatial methodologies are suitable for understanding telecoupling in relation to nature inclusive transitions (e.g. ecosystem products and services, biodiversity and social inclusiveness), although the use of mixed methods is uncommon. This represents perhaps a more common challenge in mixing methodologies in the context of food system transformation, namely how to connect models on large scales with the nuances in local contexts which are better represented by qualitative and narrative approaches.

Only few of the reviewed papers have included products (produced in or consumed in) as part of nature inclusive transitions in the Netherlands. This justifies the knowledge gap identified in the role of telecoupling for nature inclusive transitions in the Netherlands. At the WUR, however, there are various ongoing projects which are connected to telecoupling. Many of these projects do not use telecoupling as a concept or framework since their own disciplinary fields have different concepts. Additionally, telecoupled landscapes are often a sub part of project and not the sole focus. The concept as telecoupling as it currently stands with its main associated quantitative approaches are found to be limited in terms of attention to power, equity, and environmental justice.

The need for mixed methods to form an interdisciplinary approach for telecoupling is important, and crucial to address the conceptual meaning of telecoupling. Spatial approaches provide an opportunity, where both qualitative and quantitative methods from different disciplines can come together. Spatial can then be interpreted not only in a sense of ecology and land use but also as a social distance between institutions and actor which influence between landscapes (e.g. actor networks, perception based, stakeholder mapping).

The role of governance and actors highlights a major development in the field of telecoupling, which started with a rather systematic and model approach. Whereas telecoupling highlights a shift in control of resources and land from nation, regions and communities towards international players (e.g. investors and corporations), the role of power dynamics, equity, and environmental justice is still under highlighted in the concept of telecoupling. To effectively use the concept of telecoupling as a framework and approach, it is important to continue the development and connection to environmental justice and associated methodologies. This also includes different perspectives and knowledge often overlooked in systems approaches (e.g. local knowledge) and the learning across methodologies (e.g. modelling and ethnography).

Telecoupling as a framing concept does provide the conceptual space to combine methodologies which highlight the different flows and associated dimensions. To this end, it provides the opportunity for nature inclusive assessments to combine methods such as quantitative models, with spatial analysis and qualitative approaches to governance and environmental justice. Most importantly, the landscape interconnectedness is often an under highlighted aspect of current research efforts focusing on one landscape or system.

Concluding remarks

The Dutch landscape is highly connected with other (inter)national landscapes, implying that considering telecoupling is foundational for nature inclusive transitions in the Netherlands. Our review demonstrated that there are multiple framings of telecoupling, with a development from structural to actor based and governance approaches. Each of the identified approaches uses different angles, such as systems impact, flow focused or intervention impact. To effectively use the concept of telecoupling, it is important to further develop and connect to scholarship such as power, equity, transformative change and environmental justice, which is currently lacking. This also includes different perspectives and knowledge often overlooked in systems approaches (e.g. local knowledge) and the learning across methodologies (e.g. Social learning, ethnography).

Methodologies for studying telecoupling were often descriptive only, although quantitative analysis is popular for the structural approach (e.g. land use science origin). The use of mixed methodologies is uncommon, but the use of spatial approaches could support more mixed methodological and interdisciplinary design. For example, by reflecting on physical, natural and social spaces. The telecoupling scholarship would highly benefit of such interdisciplinarity to fulfill its conceptual space, which reflects on the multiple flows (i.e. connections) between landscapes as human-nature systems.

Identified challenges that remain to be tackled are:

- The terminology of telecoupling not used consistently across disciplines, especially with the focus on human-nature interactions. Clear terminology as a framework that can bring together different disciplines can enhance an interdisciplinary approach.
- There is often focus on mechanisms and systems, but this is rarely placed in practice. Here qualitative methodologies and mixed methodologies can be supportive.
- There are only few methods on understanding the decision-making on price and market impact on ecosystems. Therefore, various connections between human-nature system are not yet understood.
- The connection of different disciplines and approaches to telecoupled landscapes which includes human and nature systems.
- Telecoupling is often a side or sub part in the research on transformative change and nature inclusive Dutch landscape.
- There is a lack of a political lens to telecoupling: how do knowledge, power, social learning, and equity play a role.

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