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The politics of adaptiveness in agroecosystems and its role in transformations to sustainable food systems

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ABSTRACT

Food systems are responsible for pushing human resource use past three thresholds of safe planetary operating space, yet the potential of agroecosystems to contribute to sustainability of food systems when managed for multiple benefits is underexplored. This gap has led to a call for food systems transformation. Previous reviews have acknowledged that governance of food systems transformations is not well understood. The aim of this review is to examine the challenges to transformative governance of agroecosystems, and the potential to apply existing paradigms of adaptiveness in agroecosystems for this transformation. Agricultural production landscapes have been found to be a key level of governance for realizing sustainability transformations of food systems and the landscape concept has been a key paradigm for managing multiple social and ecological objectives at a landscape scale. An examination of the landscape concept using five transformative governance characteristics and applying the earth system governance research lenses illustrated two key areas for further investigation and action for transformative governance. The first is landscape design for continuous social and ecological changes and evolving understandings of sustainability, and the second is the allocation of landscape costs, rights and benefits in present and future decision-making and among human and non-human entities. Managing the pluralistic diversities inherent to agroecosystems will be a key dynamic important to governance and policy for food systems transformations.

1. Introduction

1.1. A global decline of agrobiodiversity and the impact of food systems on climate and human well-being

Food and agriculture account for 25% of total greenhouse gas emissions (GHG), although this figure can rise as high as one third depending on the estimates used for deforestation emissions among others (Crippa et al., 2021). Globally, food systems are responsible for pushing human resource use past three thresholds of safe operating space for biodiversity, land use, and nitrogen and phosphorous biogeochemical cycles (Campbell et al. 2017; Gordon et al. 2017). While food production itself has exceeded caloric needs of the human population, globally, there are still 820 million people that are severely hungry or undernourished and up to 2.5 billion people moderately so (Misselhorn et al. 2012; Cooper et al., 2021). Biodiversity for food and agriculture is declining at multiple scales from genetic material to entire ecosystems (FAO 2019).

Global environmental change in food systems has uneven effects on regions and populations. Tropical developing areas are likely to suffer disproportionately the negative impacts of climate change and inequitable access to nutritious and adequate food (Fischer et al. 2005; Jones and Thornton 2003; Lipper et al. 2014; Lobell et al. 2008; Schlenker and Lobell 2010; Wheeler and von Braun 2013). Smallholder farmers in tropical areas, whom are also often comprised of poor and subsistence farmers, are likely to experience higher negative impacts from climate change due to limitations in adaptive capacity (Morton and Easterling 2007).

Dramatic energy sector transformations to low carbon systems will not be enough to stave off severe impacts of climate change on social-

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ecological systems including agroecosystems. Addressing these challenges is creating a call for transformations of food systems.

1.2. A call for transformation of food systems

This avid call for transformation in the agriculture sector to lower sector emissions and adapt to the impacts of climate change is not only to drastically change the way that food is produced, but also to reimagine the aims and objectives of the food and agriculture sector itself (Campbell et al. 2018). Ultimately food is produced for the health and nutrition security of humans. Recently, authors have argued that this question of healthy and environmentally sustainable foods should receive more attention at a collective action level rather than the current research focus on individual behavior change (James et al. 2018). Recent work has mapped out the ideal healthy diets, and the inequities among regions and developed and developing nations (Willett et al. 2019), as well as the metrics of sustainable food systems that would account for food and nutrition security (Gustafson et al. 2016).

Climate change management in the agriculture sector must overcome large challenges to transform to sustainable food systems with different aims, means of production and metrics for evaluation to halt and reverse climate change and its impacts, and for food systems to contribute in a positive way to operating within environmentally safe operating limits. The food and agriculture sector must also transform in tandem with the increased demands from the human population, which is expected to grow to 10 billion by 2050 (Bustamante et al. 2014).

Many pathways have been put forth to enable this transformation, including changes that increase the efficiency of production, use less land under cropping systems, reduce food waste and allow for more plant-based diets (Foley et al. 2011; Lin 2011; Springmann et al. 2018; Stehfest et al. 2009; Thompson 2015). Researchers agree that more than one strategy is needed to meet the 2° target of the Paris Agreement (Foley et al. 2011; Springmann et al. 2018), and thus that we need to take into account trade-offs and synergies in the adoption of different strategies and seek synergies that will maximize outcomes with multiple benefits among food security, adaptation and mitigation (Saj et al. 2017; Springmann et al. 2018).

Financing, planning and implementation of mitigation and adaptation activities in the agriculture sector to date are insufficient and poorly coordinated, and suffer from challenges in translating proven activities into action at scale and turning the growing scientific consensus on the requisite pathways to technical and managerial know-how in governing the transformation to more sustainable food systems.

1.3. The importance of agroecosystems to moving toward transformations to sustainable food systems

Agroecosystems are influenced by domains of social and environmental decision-making for agriculture and land-use (Tomich et al. 2011) and recognized as social-ecological systems (Bretagnolle et al. 2018). Agroecosystems particular importance in sustainable food transformations has been linked to their potential to contribute to multiple sustainabilities in climate, land, water and biodiversity for food and hunger when managed for multiple benefits (DeClerck et al. 2016; Ellis et al. 2019; FAO 2019; Díaz et al. 2019; Mbow et al. 2019; Rockström et al. 2017). Due to this status of agroecosystems and the interest in managing them we focus in this paper on the potential of agroecosystems to contribute to transformations to sustainable food systems through their governance as part of a multi-level governance system.

While several paradigms of adaptiveness in agroecosystems have aimed to integrate multiple objectives and scales, these paradigms have thus far been insufficient in coverage and scope in providing adaptation measures that will transform agroecosystems to sustainable food systems (FAO 2019). One of the reasons that so many promising pathways toward lower emissions and adaptation measures in the agriculture sector remain elusive is that it is difficult to transform scientific knowledge about tradeoffs into management decisions when many stakeholders are involved and there are multiple land-related decisions to be made (Kanter et al. 2018). In addition, the science itself is still underway on how best to manage tradeoffs or to make these decisions (Garnett et al. 2013; Ogle et al. 2014; Saj et al. 2017). These challenges are intimately linked to the politics of agroecosystems, or the ways in which social decisions intersect with and influence, or affect the changes and a wide variety of social and ecological outcomes, in agroecosystems (Berardo et al. 2017).

1.4. Aims and organization of the paper

Multiple paradigms of adaptiveness have governed the use and management of agroecosystems over the past decade. At this critical juncture in earth systems governance research it is valuable to take stock of existing strategies for adaptiveness in agroecosystems and their potential for transformative effects in agroecosystems for moving toward sustainable food systems. One of the authors of this paper is a co-coordinator of the adaptiveness working group of the Earth Systems Governance (ESG) Harvesting Initiative which framed the important research questions for harvesting the lessons from adaptiveness in guiding this shift toward transformation. In this paper, therefore, the aim is to respond to this gap identified by the Harvesting Initiative by examining the challenges to transformative governance of agroecosystems, and we ask what is the potential to apply existing paradigms of adaptiveness in agroecosystems for this transformation toward sustainable food systems? The objectives are twofold: (i) to review the recent paradigm of governing adaptiveness in agroecosystems including a key paradigm the landscape concept, and (ii) to identify the gaps and potential of this paradigm for governing the transformation of agroecosystems towards sustainable food systems.

After detailing the methods used in this chapter in section II, section III, a literature review on governing adaptiveness in agroecosystems, explores the politics of adaptiveness through (a) challenges to governing adaptiveness in agroecosystems, b) current paradigms of adaptiveness, and (c) the landscape concept, a recently adopted umbrella paradigm for adaptiveness in agroecosystems. A fourth section reports the results and explores the politics of how we might move toward transformations for sustainable food systems through (a) governance characteristics and the gaps and the transformative potential of the current agroecosystem paradigm, (b) the landscape concept and transformative governance, and (c) a discussion on moving toward governing transformation to sustainable food systems. Section five gives concluding remarks.

2. Methodologies

To meet our objectives (i) & (ii), we conducted secondary data collection and review and analysis of the transformative governance potential of paradigms of adaptiveness in agroecosystems in four steps. In this review we use a combination of key word searches, selection criteria, and review of key papers through snowballing.

In the first step, papers were selected that sought to review the ambition and potential of a key paradigm of adaptiveness in agroecosystems, the landscape concept, over the period of the first earth system governance science plan from 2009 to 2018. A set of 27 papers on the landscape concept were selected using three criteria (See Annex 1 for list of papers).

The first criteria was to select papers that view the landscape concept from its different constructs as a collaborative multi-stakeholder initiative, a boundary, an integrated management approach, and a governance paradigm. Secondly, the papers were selected for their inclusion of a review of the overall value or role of the landscape concept to science or to meeting one or more aims of sustainability.

Third, this set of papers was selected with additional consideration for their relevance to agroecosystems, or to mosaic land uses in multiple ecosystems in landscapes where cultivated ecosystems are a major land use. In choosing a focus on agroecosystems, we thereby left aside the rich literature on adaptive governance through landscape approaches and landscape governance drawing on the model forest concept and forest landscape restoration paradigms (see for instance Elbakidze et al. 2010; Mansourian et al. 2017; Spathelf et al. 2018; Stanturf et al. 2014).

In the second step, we identified emerging theoretical characteristics deemed important for governance systems that can steer transformative change toward more sustainable systems. We performed a SCOPUS database search using the keywords "transformative governance" and "sustainability transformation and governance" up to April 2018. Papers were excluded that pertained to sustainability transformations within individual universities or cities, or were in non-relevant disciplines such as ecotoxicology. These papers were also complemented with a literature search through keyword internet searches, including in google scholar, and using additional sector relevant keywords such as "agriculture" and "food systems," as well as through mining of the cited works listed in influential and review papers found in these searches.

A total of 23 papers (See Annex 2 for list of papers) were selected for reviewing theory on governance characteristics for sustainability transformations. We used a combination of open and axial coding to determine the emerging governance characteristics in the literature. The articles were screened for governance characteristics and each characteristic was recorded using excel under open coding. Governance characteristics representing similar or related concepts or functions found in more than 3 papers and ranging from 7 to 13 papers were selected for further analysis, totaling 5 groups. Within these 5 groups, we bridged the concepts and functions pertaining to characteristics found in each paper under broader functions. Five governance characteristics are then presented that demonstrate the greatest consensus or interest (by frequency of mention or discussion of similar concepts or properties) among the authors of these papers. For instance, multi-directional coordination, the capacity to bring actors together, and re-connecting citizens with nature were grouped together under connecting actors and practices.

In selecting these governance characteristics we have reviewed emerging concepts and properties pertaining to sustainability transformations across six major research streams from among different disciplinary traditions, thereby giving a multidisciplinary viewpoint of theoretical concepts for governing sustainability transformations. These research streams include socio-technical transitions (e.g. Schäpke et al. 2017), resilience of social-ecological systems (e.g. Pichler et al. 2017), shared socio-economic pathways (e.g. Tàbara et al. 2018a), adaptation pathways and development (e.g. Bosomworth et al. 2017), innovation systems (e.g. Schlaile et al. 2017), and urban transformations (e.g. Koch et al. 2017). Some papers bridge theory across several of these research streams, particularly in integrated sectors such as water governance (e.g. Pahl-Wostl 2017; Rijke et al. 2013).

In the third step we used deductive coding using the set of 5 governance characteristics to create 5 transcripts explaining in what ways the landscape concept has contributed to these 5 characteristics using the 27 papers of the landscape concept. The results are summarized in section 4.1.

In the fourth and final step, we analyzed the overall character of the landscape concept for adaptiveness and transformative governance. Nvivo 12 for mac was used for the qualitative analysis. We developed a codebook for the old and new earth system governance research lenses to examine the characterization of the differences between the concepts emphasized in the 2008 and 2018 science plans for moving from governance paradigms of adaptiveness to transformation of social-ecological systems (Biermann et al. 2009, 2010; Burch et al. 2019; Earth System Governance Project 2018). Based on this analysis we identified the potential of the landscape paradigm for transformative governance of agroecosystems to sustainable food systems, and the gaps in our current understanding and needed areas of action and further research for the coming years (Results Sec 4.2).

3. Governing adaptiveness in agroecosystems

3.1. Challenges to governing adaptiveness in agroecosystems

In the case of governing land use for sustainability, it is a complex endeavor. Land provides multiple ecosystem services for human well-being, conservation, protection of biodiversity and the regulation of earth system services. There are increasing demands for these services from more diverse sets of actors at different scales that value differing services; thereby requiring trade-offs among uses across scales and time (Benton et al. 2018). Soils too are increasingly expected to contribute higher outputs of biomass per unit to support more integrated functions at various scales from farm to biome, and an increasing variety of bio-products for multiple purposes (Helming et al. 2018; Juerges and Hansjürgens 2018).The choices that we make about land use have trade-offs in terms of the amount of agricultural goods produced and negative environmental impacts that contribute to climate change, and these decisions are also key for mitigation and adaptation activities in the agriculture sector (Bustamante et al. 2014; Campbell et al. 2017, 2018; DeClerck et al. 2016; Foley et al. 2005; Funabashi 2018; Rockström et al. 2017; Vermeulen et al. 2012).

Drivers of industrialization, overexploitation, urbanization and modern agricultural production methods have led to the adaptation of agroecosystems that sometimes shifts allocation of benefits derived from local provisioning services to stakeholders that are far away, or further exacerbates these economic dynamics in ways that create new paths of marginalization for local farmers from the loss of biodiversity and ecosystem services (Hunt 2015). Early earth system governance challenges identified for adaptiveness in agroecosystems included a reaction to these global environmental changes with a focus on scale mismatches among ecological and social scales, and among governance levels (Biermann et al. 2009; Dewulf et al. 2015); addressing the increased complexity among polycentric nodes of decision-making and fragmentation of actors (Galaz 2014); and the inequalities in resource benefits and decision-making among landscape residents and other actors and within communities of landscape residents (Wu 2013).

The dynamics of the Anthropocene have shaped the politics of social-ecological systems in terms of how the flows of goods and people and their environmental impacts in complex systems cross boundaries and scales, disrupting power structures. Increasingly too, the agency of both human and non-human entities (for instance, ecosystems) and the dynamics of inequality between resource users and those affected by environmental pollution and degradation is shifting (Baskin 2019; Burke and Fishel 2019). In particular, such systems are intertwined in novel ways from local to global scales, with resulting changes in multiple levels of power and agency and shifts in governance challenges of detangling and governing the externalities and telecoupling of these systems spread over space, scales and time, and among multiple nodes of decision-making (Biermann and Lövbrand 2019). The problems related to governance of agroecosystems have continued to become more intertwined among scales through telecoupling of agricultural production chains (Clapp 2015; Munroe et al. 2019), and there is a growing awareness of the impacts of pollution from modern agricultural production methods and the consumption of animal products on the environment, as well as the inequities in the global distribution of calories and nutrients (Aleksandrowicz et al. 2016; Poore and Nemecek 2018; Willett et al. 2019). These complex and inter-related sets of drivers in changing land-use patterns are driving the loss of biodiversity and agrobiodiversity despite the number of paradigms for adaptiveness in agroecosystems.

These dynamics continue to shift groups of winners and losers and power dynamics in governing adaptiveness in agroecosystems, and create new sets of risks, in particular in commodity landscapes where large international firms have a stake in the quality of the ecosystem that supports global value chains such as cacao, oil palm, and rice, and where firms are willing to invest in these environmental services (Opdam and

Steingröver 2018). Thereafter, firms' interests lie in promoting or characterizing a particular narrative about which values of the production landscape have importance and how the agroecosystem is governed to maintain particular services. In the case of agricultural production landscapes, resulting decision-making is decoupled from place-based social-ecological systems where people have a history of cultural connections to land uses, and residents and producers of the landscape sometimes become subject to decisions made by a small group of actors in global commodity chains that are oftentimes not linked to local sustainability understandings or metrics at the scales where food is produced (Gordon et al. 2017; Österblom et al. 2015; van Oosten et al. 2017). These dynamics and the increasing diversity of actors, values and narratives further challenges the just allocation of landscape benefits, and together with changing nodes of decision-making on land use at different scales, challenges the balance of needs in novel ways for the collaborative governance of agroecosystems.

Thereby, in light of these calls for complete transformations of existing agroecosystems and the governance systems themselves, a critical analysis of institutional conditions tells us that it is not just a challenge of creating new governance systems capable of effectively guiding these transformations and of governing in the uncertain conditions of the Anthropocene, but also a deeply political process that concerns the question of how to account for multiple values in deciding what type of transformation is attainable and reflective of different actors' values (Scoones et al. 2015; Smith and Stirling 2010). Indeed, public policy theories also tell us one of the challenges of opening up sustainable pathways that recognize and respect the goals of residents in the landscape is uncovering and connecting the varying and often contested 'frames,' or the narrative or understanding of problems, issues or solutions based on the values held by varying actors engaged in decision-making for sustainability transformations (Dewulf et al. 2011; Van Lieshout et al. 2017). It is often the governance system itself that is responsible for past failures in sustainably managing social-ecological systems rather than the quality of the soils, land, water or ecosystem services (Pahl-Wostl 2017), thus, understanding the properties and characteristics of governance systems effective for sustainability transformations is the challenge.

Before examining these characteristics of transformative governance systems, we first review in more depth the existing paradigms of adaptiveness in agroecosystems that have been applied to address these challenges to governing adaptiveness in agroecosystems.

3.2. Paradigms of adaptiveness in agroecosystems

Adaptive governance, co-adaptation, or adaptive management of agroecosystems have been well-tested concepts to respond to the governance challenges of mismatched scales among administrative levels and agroecosystems, the growing complexity of actor networks engaged in managing agroecosystems at all scales, and their fragmentation among administrative levels and among polycentric networks with varying aims, problem narratives, and influence. These governance responses have primarily sought to first understand and react to the nature of vulnerabilities, adaptiveness and resilience in the face of novel changes to the environment.

Several paradigms have emerged in the past decade for adapting to the expected impacts of climate change to the agriculture sector and to reduce and halt or reverse the contribution of agriculture to climate change, land degradation, and biodiversity loss that is reducing biodiversity and ecosystem services in agroecosystems that underpin human well-being. Some of these paradigms are sustainable land management (SLM) (Cowie et al. 2011, 2018; Kust et al. 2017), sustainable intensification (SI) (Garnett et al. 2013; Pretty and Bharucha 2014; Rockström et al. 2017; Tilman et al. 2011), climate-smart agriculture (CSA) (Lipper et al. 2014; Steenwerth et al. 2014), conservation agriculture (CA) (Kassam et al. 2009; Pittelkow et al. 2015), ecosystem-based adaptation (EbA) (Donatti et al. 2019; Munang et al., 2013; Vignola et al. 2015), and agroecology (AE) (Altieri 2002; Altieri et al. 2012; Wezel et al. 2009, 2014).

These paradigms and approaches are not mutually exclusive and in some cases are considered to contribute to one another or to be interlinked, and to have potential for more mutually beneficial outcomes when adopted synergistically (Campbell et al. 2014; Dumont et al. 2018; Saj et al. 2017; Thierfelder et al. 2017; Wezel et al. 2015). They are variously considered as a set of practices or principles or as an operational framework.

While each of these individual paradigms may be successful in bridging various groups of actors previously working on their own to work collaboratively in more integrated management modes, and to be more inclusive and holistic in engaging stakeholders and setting aims, the agronomic principles and practices of the approaches may require unpacking and further scientific scrutiny. The scientific merits, performance and limitations of these approaches have been challenged, and specific agronomic practices may overlap or be subsets of one another of these various paradigms. For instance, conservation agriculture is largely considered a set of practices that can contribute to sustainable intensification (Giller et al. 2015). Climate-smart agriculture is a unifying paradigm for development, climate change adaptation and the agriculture sector, and programs to address common concerns of poverty, food security and livelihoods of vulnerable smallholders in developing areas through a collaborative narrative that addresses each sector's priorities, yet the agronomic basis of the term is ambiguous and does not indicate a specific set of principles or practices (Martinez-Baron et al. 2018; Neufeldt et al. 2013; Steenwerth et al. 2014).

Further, the prescribed benefits of a paradigm may only be produced under certain agronomic and environmental conditions and with careful attention to particular management practices. However, oftentimes claims of successful win-win synergies and positive environmental outcomes precede the scientific evidence to demonstrate the widespread effectiveness of the practices, especially in the varying plot and farm conditions of smallholder farming systems such as in sub-Saharan Africa and South Asia (Palm et al. 2014). For example, conservation agriculture has been promoted in particular geographic areas (i.e. sub-Saharan Africa and South Asia), but has also failed in a number of local contexts to produce the expected agronomic results (Giller et al. 2015). Existing mechanisms have also been criticized for their complexity and the difficulty to measure their effectiveness for the vulnerable and poor, or to realize the equitable distribution of benefits from such programs (Huang and Wang 2014).

Less attention has been paid to the politics of the narratives of each paradigm, which are not neutral. Rather they reflect the interests, values, and power differentials among different actors and proponents and the international and local policy arenas in which they participate in the promotion and implementation of change in setting the goals, means and benefits of the paradigms (Scoones et al. 2015). For instance, sustainable land management (SLM) has been linked to the UNCCD convention and land degradation neutrality discourse and has formed an important intervention in particular national contexts such as dryland areas in Ethiopia (Nigussie et al. 2018), while Ecosystem-based Approaches (EbA) have been applied in a number of different ecosystems (agroecosystems, forest, in-land water, etc.) and at varying scales, and have been linked to narratives and implementing paradigms of disaster and drought risk reduction (McVittie et al. 2018).

Thus, narrative diversity, whether it concerns linking climate change and agriculture or disaster risk reduction with nature, is what drives the creation of multiple and overlapping paradigms in governing agroecosystems, while science plays a supportive role in justifying courses of action, and often the scientific principles and practices are difficult to distinguish among paradigms and difficult to measure. In the current governance system, paradigm development is a political process in which scientists are just one actor, and in some cases the framework or approach comes first from practice, or from a defined societal need, and is tested by environmental or agricultural organizations, and only later science works to operationalize the framework or to find ways to measure its performance against a set of outcomes (see for instance Minelli et al. 2017).

The result is that rather than reflecting a systematic set of science-based agroecological systems for adaptiveness, these paradigms reflect varying actors' narratives of a particular solution that reflects their values, interests, preferences, aims, and agency or capacity to act on the collective whole of their worldview. The degree to which agronomic and ecological sciences underpin the principles and practices of each of these paradigms reflects not only the particular actor constellation and their interests but also their collective commitment or value placed on scientific knowledge (Beunen and Opdam 2011). Multiple paradigms may reflect viable pathways toward sustainability or resilience of agroecosystems as supported by scientific evidence, thus confusing what is 'scientific truth' among multiple and interacting political realities (Hahn and Nykvist 2017). Moreover, these approaches take on the values and interests of actors at other scales than at the scale of implementation, and are changed, reconfigured and re-branded as needed to fit particular narratives of sustainability.

However, this recognition that the worldviews of actors shapes the paradigms and solutions applied is increasingly recognized in the analysis of adaptiveness in agroecosystems (Dumont et al. 2018). Further, science is now recognizing that these varying paradigms of conservation and sustainability should have science-based targets that not only are grounded in agroecologically based principles, but also link actions at multiple scales and can account for food system planetary boundaries (Rockström et al. 2020).

We examine now the politics of one such paradigm and how it has intersected among these varying worldviews, and been substantiated by or has further advanced agroecologically based principles and science-based targets. Table 1 shows the varying paradigms of adaptiveness mentioned and their differences and introduces the landscape paradigm. The landscape paradigm, as discussed in the next section, has brought together other paradigms of adaptiveness, has garnered attention for its unique scale attributes both at an operational level and as part of a multi-level framework, and has demonstrated the far-reaching capabilities of its narrative to generate coalitions of actors across sectors with the aim to manifest multiple benefits from agroecosystems; its characteristics of which make it a good selection to evaluate its potential as a transformative paradigm.

3.3. A landscape approach to adaptiveness in agroecosystems

One emerging paradigm of adaptiveness in agroecosystems that has garnered increased attention in science, policy and practice over the past decade is the landscape concept, referred to varyingly as *sustainable landscapes, landscape approaches, integrated landscape management* or *landscape governance*. The landscape concept has been simultaneously promoted as an umbrella framework for other agroecosystem paradigms (Mann et al. 2018), and as roughly synonymous with other integrated paradigms for adaptiveness in agroecosystems (Freeman et al. 2015). Significant empirical work has been done in constructing how the landscape concept is operationalized as a synonymous approach or a landscape-scale application of other agroecosystem paradigms (Barbut and Alexander 2016; DeFries and Rosenzweig 2010; Garrity et al. 2010; Harvey et al. 2014; Holland et al. 2016; Marques et al. 2016; Mbow et al. 2015; Pretty 2018; Rahman et al. 2017).

As an umbrella paradigm, a landscape concept accommodates other sectoral paradigms such as sustainable forest management and watershed approaches, with the understanding that landscapes exist as mosaics of diverse ecosystems, and thereby considering agroecosystems together with forest, in-land water, and other ecosystems in mosaic land-uses. This provides a basis for the landscape concept to have potential to be an umbrella paradigm that can link to planetary boundaries of land use and biodiversity on varying scales. This appeal has created a powerful narrative over the past decade for defining, operationalizing and evaluating the landscape concept for adaptiveness and sustainability. Table 2 summarizes some of the main research trends in exploring and assessing the landscape concept.

Landscape approaches have also become part of powerful narratives in intergovernmental processes and science-policy forums. The trio of Rio conventions have recognized the role of landscape approaches in reaching political targets such as a land degradation neutral world (UNCCD UNCCD, 2013). The CBD recently held in 2019 a thematic consultation on landscape approaches for the post-2020 biodiversity framework, while the Global Landscapes Forum (GLF), which grew out of the previous joint agriculture and environment day at UNCCCF is now an independent institution with multiple annual learning events and advocacy channels. Landscape approaches were also recognized in the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) Global Assessment (Chan et al. 2019) and the IPCC Special Report on Land (Arneth et al. 2019) as an important approach for integrating multiple benefits from agroecosystems and meeting multiple sustainability goals.

In the case of agroecosystems, there is a growing consensus that the landscape scale is the most optimal scale at which to govern within a multi-level governance structure (Anderson et al. 2019; Ellis et al. 2019; Jiren et al. 2018; Langston et al. 2019; Leventon et al. 2019; McGonigle et al. 2020; Quinn and Allen 2021; van Oosten et al. 2018; Zinngrebe et al. 2020). In particular, agricultural production landscapes, as agroecosystems, have a distinct politics of their own, stemming from the contributions of humans to shaping, selecting, and producing the benefits of the social-ecological system, and this tradition of human management, influence and intricate ties to the resulting system has been known as cultural landscapes in Europe, *Satoyama* in Japan, and social-ecological production landscapes and seascapes (SEPLS), among others (Plieninger et al. 2014; Takeuchi et al. 2016).

The politics that then shape these place-based social-ecological systems are uniquely tied to the attachments formed by local actors to the services produced by the mosaic of land uses and ecosystem services and the resulting character of the landscape, which is shaped over time by the changing preferences and socio-economic drivers affecting the choices of different landscape residents (Görg 2007; van Oosten 2013). In the many forms of place-specific landscapes, landscape residents have traditionally balanced the needs of various ecosystem services in ways that conserve nature's services and provide benefits to people (Díaz et al. 2019). The distribution or capture of these benefits has varied among local power differentials.

However, despite these attachments by landscape actors to a particular place-based character of the landscape, agricultural production landscapes, as agroecosystems or complex social-ecological systems, are increasingly impacted by the changes brought on by the Anthropocene in the global economy. Across forestry and agriculture, climate adaptation and mitigation, oceans and costal management, and disaster risk reduction sectors, and together with biodiversity and environmental conservation organizations, a growing number of intergovernmental organizations and science-policy platforms, and with business coalitions, alliances and networks of actors have come together on landscape approaches. Other paradigms of adaptiveness in agroecosystems have not enjoyed the same broad political appeal and momentum. However, sustainable intensification still remains a powerful paradigm with calls to operationalize it for transformations to sustainable food systems (Pretty et al. 2018; Rockström et al. 2017), as do many of the paradigms for adaptiveness in agroecosystems as they continue to receive funding and build upon successful programs and partnerships in different parts of the world.

However, the landscape concept has not yet been evaluated as to how it can potentially be operationalized for transformative governance of sustainable food systems, nor how its potential as a paradigm for adaptiveness has seeded transformative elements for moving toward sustainable food systems.

Table 1
Paradigms of adaptiveness in agroecosystems.

Paradigm name	Scope	How concerned with adaptiveness	Primary unit of focus	Narrative or interests fulfilled	Proponents
sustainable land management (SLM)	- A set of principles and practices to avert, reduce or reverse land degradation - One of its objectives is to fashion lasting resilience within agroecosystems (Cowie et al. 2011)	- Managing human-environment interactions in land requires adaptive management (Cowie et al. 2011) - An implementation of the land degradation neutrality (LDN) framework utilizes an adaptive management cycle to improve land management (Cowie et al. 2018)	Land area (ha)	- Dryland sector - Land degradation neutrality	- UNCCD[a]
sustainable intensification (SI)	- A policy goal or system to increase yields without increasing the land area under agriculture - Sustainable agroecosystems are those that return energy and nutrients within the system (Pretty and Bharucha 2014)	- Technology adaptation, varietal adaptation - Adaptation to suit local contexts/ local conditions	Plot to farm	- World food production - Food insecurity - Sustainable development	- Scientists
climate-smart agriculture (CSA)	- Increasing food production to meet food security considering the conditions created by climate change - Programs to address common concerns of poverty, food security and livelihoods of vulnerable smallholders in developing areas - Manage trade-offs among production and ecosystem functions and increase resilience and resource use efficiency in agroecosystems (Lipper et al. 2014)	- Aims to increase adaptive capacity of farmers and institutions for variable local solutions - Adaptive management and strategies an essential part of the approach	Plot to farm	- Food security - Climate change - Unifying paradigm for development, climate change adaptation and the agriculture sector	- FAO[b] - World Bank and development agencies - CCAFS[c]
conservation agriculture (CA)	- a set of principles that simultaneously contribute to improvement of soil structure and sustainability and to productivity, primarily no-till - Applied globally across different agroecosystems	- Adaptation of the principles of CA to different agroecosystems	Plot to farm	- Sustainability - Climate change - Vulnerable smallholder farmers	- FAO - Donors - No-till organizations - agriculture companies
ecosystem-based adaptation (EbA)	- Strategies to uphold and enhance ecosystems and to deliver ecosystems services that reduce the risks and impacts of climate change - Making use of biodiversity or ecosystem services for farmers to adapt to climate change and also to maintain the ability of agroecosystems to provide farm and landscape scale ecosystem services (Vignola et al. 2015)	- Robust ecosystems provide more variety in adaptation responses and are better positioned to respond with adaptation measures - Making use of nature's adaptiveness can have multiple benefits for climate, economy, livelihood	Ecosystem	- Climate risk and adaptation - Sustainability - A variety of sectors (food, water, etc.) - Disaster and drought risk reduction	- UNEP[d] - IUCN[e]
agroecology (AE)	- Alternatively a science, a social movement and a practice; a set of principles have been articulated ranging from agroeconomic practices to social, economic, and governance aspects; the combination of agroecological science and indigenous knowledge with emphasis on farmers' participation and empowerment (Altieri et al. 2012; Wezel et al. 2020)	- Views indigenous knowledge as source of adaptive capacity (Altieri et al. 2012)	Plot to farm,	- Poor smallholder farmers	- Small NGOs
	- Agroecology promotes a diverse agroecosystem capable of supporting itself (Altieri 2002)	- Examples of national and locally adapted site-specific systems developed for food sovereignty that are made more resilient to climate change	Agroecosystem	- Indigenous peoples and movements	- Increasingly large institutions – UNFSS (United Nations Food Systems Summit)
Landscape	- A spatial and multi-sectoral land use concept and approach that is scale sensitive and place-based (Arts et al., 2017) - Agricultural production landscapes are multifunctional agroecosystems	- Adaptive management is a pragmatic system for recurring learning (Sayer et al. 2013) - Adaptive management is a means to iterative planning and monitoring for the uncertainties and changing social-ecological dynamics of landscapes	Landscape	- Managing trade-offs between agricultural production and conservation	- Biodiversity and conservation organizations - Rio conventions - IPBES[f], IPCC[g] - Private sector commodity chains - Agricultural research organizations

[a] United Nations Convention to Combat Desertification.
[b] Food and Agriculture Organization of the United Nations.
[c] Research Program on Climate Change, Agriculture and Food Security.
[d] United Nations Environment Programme.

[e] International Union for Conservation of Nature.
[f] Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services.
[g] Intergovernmental Panel on Climate Change.

Table 2
A brief history of the research trends related to the landscape concept 2009–2018.

Year(s)	Research trends	Drawing on
2009–10	Bridging conservation, agriculture and development; Landscape-scale	(DeFries and Rosenzweig 2010; Pfund 2010)
2011–13	Science of landscape approaches and governance; Survey	(Beunen and Opdam 2011; Colfer and Pfund 2011; Sayer et al. 2013; Wu 2013)
2014	Assessment; Survey	(Estrada-Carmona et al. 2014; Milder et al. 2014; Reed et al. 2014; Ros-Tonen et al. 2014; Sayer et al. 2014)
2015–16	Operationalizing the concept; Pathways; Effectiveness?	(Bohnet and Beilin 2015; Freeman et al. 2015; Mbow et al. 2015; Reed et al. 2016; Ros-Tonen et al. 2015; Sayer et al. 2016; Sunderland et al. 2015; Torquebiau 2015)
2017	Review of approach and methods	(Arts et al. 2017; Bürgi et al. 2017; Reed et al. 2017; Sunderland et al. 2017; Westerink et al. 2017)
2018	Collaborative design and governance; Solution-oriented approaches	(Campellone et al. 2018; Opdam 2018; Ros-Tonen et al. 2018)

4. Results and discussion: Governance of transformations to sustainable food systems

A recent review of environmental governance modes found that adaptiveness is likely to be insufficient in keeping social-ecological systems from exceeding planetary limits and that transformative governance should transcend adaptive governance in ways that will allow for systemic change, or transformation, of social-ecological systems themselves (Chaffin et al. 2016). In order to transcend adaptiveness in social-ecological systems, governance characteristics should then be able to support fundamental value or paradigm shifts or solutions that foster the emergence of transformative or radical governance system design for normative goals of sustainability (Chaffin et al. 2016; Koch et al. 2017; Schlaile et al. 2017; Tàbara et al. 2018a, 2018b; Weiland et al. 2017). In addition, networks, either on their own as innovation or experimentation spaces (Pereira et al. 2015, 2019, 2018), as self-governance or informal governance structures (Folke et al. 2005; Olsson et al. 2004), or as part of multi-level or polycentric governance arrangements (Galaz et al. 2012; Smith et al. 2005, 2010), are considered key institutional structures for sustainability transformations and for governing transformations.

4.1. Governance characteristics for sustainability transformations in agroecosystem paradigms

Table 3 presents five emergent characteristics of governance for sustainability transformations, which may be system properties, agent capacities, structures, or other conditions that are theorized to be important for bringing about sustainability transformations (for details on how they were derived see the methodology section). The five characteristics presented are (i) greater horizontal and vertical coordination and collective goals; (ii) new power configurations and balances; (iii) imaginaries of new systems and swift action; (iv) the connection of actors and practices; and, (v) experiments for reevaluation of existing governance systems. Insights on their relation to governing transformations in paradigms of adaptiveness for agroecosystems and for the governance of sustainable food systems are articulated.

In the following sections we analyze each of these five governance characteristics in turn in relation to the landscape concept and how it has been treated or enacted for sustainability transformations.

4.1.1. Supports greater horizontal and vertical coordination and collective goals

All 27 papers reviewed on the landscape concept (Table 2) understand it to be differentiated from prior concepts, approaches and environmental governance regimes. The main difference is its aim to set multiple objectives for sustainability and negotiate the trade-offs among them, thereby creating collective goals for landscape management. The most comprehensive review to date of scientific evidence of the benefits gained from the implementation of a landscape concept found no credible evidence across the scientific literature that the landscape concept does in fact achieve multi-functionality of land use, while recognizing that there is some indication in the literature that the landscape concept can contribute to a range of different social and environmental objectives (Reed et al. 2017).

There is evidence that the landscape concept has successfully bridged forest and agricultural sectors and land uses and that a range of tree cover, from mixed farming systems to mosaic land uses, including forested patches and bordering forested areas, provide important synergies in maintaining multiple benefits in agricultural landscapes (Sunderland et al. 2017). The landscape concept is also envisioned to achieve greater horizontal coordination by bridging the sectors of science, policy and practice, and to be able to enable collective goals through joint visions and pathways for meeting multiple objectives (Mbow et al. 2015). Other studies have suggested that the landscape concept differs in that it conducts analysis of options at different scales (Bürgi et al. 2017). Indeed, landscape principles also include addressing multiple scales, including linking to higher levels of governance (Sayer et al. 2013; Wu 2013).

The idea of non-state actors having larger roles in landscape governance has been a feature of the landscape concept as it has been applied in agroecosystems, and the idea of self-governance or hybrid governance forms has been broadly advocated by non-state actors and conservation organizations. Less attention has often been given to integration with existing and formal higher levels of administration, and the linkages between hybrid or self-governance arrangements with government or institutional issues have been less explored dimensions of the landscape concept (Westerink et al. 2017). In part this is due to the tendency to adopt an institutional architecture that supports landscape scale coordination in informal self-governed multi-stakeholder networks (Kusters et al. 2017; Ros-Tonen et al. 2018).

The potential of various tree-based agroecosystem practices at a farm scale, e.g. agroforestry, and bottom-up and farmer-led practices such as farmer-managed natural regeneration (FMNR), have been studied for their potential for sustainability at a landscape scale (Garrity et al. 2010; Rahman et al. 2017). According to one review of the outcomes of the landscape concept, the researchers could not find details about the governance structures in most of the reported literature, but where determined, they found that multi-level governance structures whereby traditional or customary governance arrangements were combined with policy at multiple administrative levels was most correlated with successful social and environmental outcomes (Reed et al. 2017). This is consistent with other findings that coordination at higher vertical levels is necessary for effective governance structures and does not necessarily indicate that a platform at landscape scale is needed for effective landscape governance, depending on how strongly vertical levels from farmer to region can be coordinated. Another factor to consider is whether there are existing structures at some level that allow for inclusion of other stakeholders, such as policy arenas attached to local or reginal level government that include private sector actors.

Table 3
Presentation of characteristics pertaining to governance of and for sustainability transformations.

Characteristics for governance of sustainability transformations	Specific examples	Relevance to landscapes (examples)	Drawing on
Supports greater horizontal and vertical coordination and collective goals	Greater horizontal and vertical coordination of visions, options, pathways; Coordination that exists across boundaries, spheres, sectors, levels, or system elements at multiple spatial and temporal scales; Selection of sustainable pathways and disbandment of unsustainable ones	Governing land at a landscape scale or a scale that allows for coordination across jurisdictions and at ecological scales	(Hahn and Nykvist 2017; Hebinck et al. 2018; Hölscher et al. 2018; Langle-Flores et al. 2017; Rijke et al. 2013; Schäpke et al. 2017; Schlaile et al. 2017; Tàbara et al. 2018a; Weiser et al. 2017)
Unblocks new power configurations and balances	Hold 'integrity,' or the harmony of ecosystems and societies' requirements and values; Balance needs between social and ecological systems; Recognize and maintain a balance of needs among actors; Change entrenched interests, institutional holds and obstruction by actors	Priorities and values of different actors for varying land-use purposes and functions; Livelihood and ecosystem diversity in mosaic landscapes	(Colloff et al. 2017a, 2017b; Gordon et al. 2017; Hahn and Nykvist 2017; Hölscher et al. 2018; Schlaile et al. 2017; Wiek and Larson 2012)
Permits imaginaries of new systems and swift action	Cooperative anticipation and prediction of yet unimagined futures; Not based on existing dependent paths nor a future based on the metrics of today; 'Novelty creation'; Speedy design of governance architecture and solutions for fast-changing problems	New food and nutrition system metrics; Novel production practices and management systems for agricultural production landscapes	(Colloff et al. 2017a, 2017b; Gerhardinger et al. 2018; Hölscher et al. 2018; Pahl-Wostl 2017; Pichler et al. 2017; Rijke et al. 2013; Sarkki et al. 2017; Schäpke et al. 2017; Schlaile et al. 2017; Tàbara et al. 2018b, 2018a; Weiland et al. 2017)
'Connects' actors and practices	Steer networks of actors toward agreeing on and implementing collective agendas; Coordinate multi-actor processes; Coordinate knowledge integration across knowledge systems and among multiple networks; Create 'opportunity contexts' among actors to align values and actions to goals	Revitalizing livelihoods in 'cultural landscapes' and social-ecological production landscapes, including re-imagining traditional agricultural systems and cultural practices in ways that deliver needed services; Connecting new types of actors with different values and interests at different scales, including producers and consumers in new governance of food systems	(Colloff et al. 2017a; Gerhardinger et al. 2018; Gordon et al. 2017; Hahn and Nykvist 2017; Hölscher et al. 2018; Langle-Flores et al. 2017; Rijke et al. 2013; Tàbara et al. 2018a)
Experiments for reevaluation of existing governance systems	Collective experimentation led by different types of actors; Experimentation that is open to novel imaginaries and challenges assumptions and paradigms; Adopt varying characteristics at different stages	Challenging existing paradigms of adaptiveness in agroecosystems; Compositions of landscapes coalitions, alliances and networks and their demands will change as land use changes and food systems evolve to current and future markets	(Colloff et al., 2017a, 2017b; Hahn and Nykvist 2017; Hebinck et al. 2018; Hölscher et al. 2018; Pahl-Wostl 2017; Patterson et al. 2017; Rijke et al. 2013; Schäpke et al. 2017; Schlaile et al. 2017; Weiland et al. 2017; Weiser et al. 2017)

With regards to horizontal and vertical integration and collective goals, the paradigm has clearly evolved from one of a bi-modal relationship between government and local communities to one of multi-stakeholder and multi-objective interactions among scales. However, there is a wide variety in how the landscape concept is applied, and differences as to the meaning and degree of what constitutes greater horizontal coordination via the inclusion of multiple sectors, stakeholders, functions, objectives, and benefits in agroecosystems. In some cases, sectoral programs operate in the same place, while in others a degree of multi-functionality is achieved in trade-offs among land-use and coordination among sectors, versus in others some degree of collaborative landscape governance exists.

In sum, the limitations of the landscape concept in practice often stop at truly connecting multiple scales, at linking the landscape scale to higher policy levels, in linking hybrid and informal governance decision-making with formal structures, and at crossing jurisdictional boundaries in ways that policy makers can enact within and respond to at existing administrative levels. In one study of recent cases from a sustainability science perspective, there is a greater emphasis on the idea of a variety of architectures that combine vertical levels of governance with polycentric networks made up of diverse actors, and that confirm the importance of science in knowledge and design of self-governance networks to help overcome the current limitations of practice (Opdam 2018).

However, such governance architectures may yet largely be the potential of the landscape concept as there is not yet strong evidence that the landscape concept applied in its current various forms is a multi-level, multi-scale paradigm.

4.1.2. *Unblocks new power configurations and balances*

Principles of a landscape concept also include balancing the needs and values of multiple stakeholders (Sayer et al. 2013, 2016). The landscape concept is viewed as sustainable when it balances the desired values of a set of landscape actors and is a normative concept (Opdam 2018; Reed et al. 2014). Therefore, it is defined by the societal actors engaged, and will shift over time as values and needs shift, but also as the biophysical and natural conditions of the landscapes change over time as well.

However, shifting power configurations and achieving new balances that respect the different values of multiple actors is difficult to achieve in practice (Sunderland et al. 2015), and the issue of who decides which values are reflected and who benefits are yet relatively underexplored in applications of the landscape concept. No credible evidence across the scientific literature demonstrates that the landscape concept does in fact balance the needs of local stakeholders with others for multiple landscape services for production and conservation (Reed et al. 2017). One of the reasons the landscape concept has not reached its potential in this regard is due to the typical landscape architecture, which does not, in and of itself, provide an operational framework for multi-level governance.

One of the more important governance challenges in facilitating new power configurations is the ability to hold the increasing number of private companies accountable for their decisions that affect landscapes, and to bring them to the table for negotiations and keep them engaged in multi-stakeholder decision-making processes rather than acting on their own (Sayer et al. 2014). Earlier reviews of the application of a landscape concept found that the private sector is not as engaged and is able to circumvent local decision-making and democratic processes, for example, via land grabs (Estrada-Carmona et al. 2014; Milder et al. 2014). More recent reviews have considered applications of a landscape concept where the private sector is strongly engaged and often takes an organizing role, with similar and additional risks to democratic decision-making such as the unequal financial capacity of local actors. Their findings that although greater attention is placed on strategies to address these power asymmetries in theory, there is yet limited evidence that they can be consistently overcome or that any meaningful new balance of power in multi-level governance is regularly achieved (Ros-Tonen et al. 2018).

4.1.3. *Permits imaginaries of new systems and swift action*

There is an increasing interest in the use of the landscape concept as a nonmaterialistic or non-physical conception that can create spaces for co-creating knowledge, options and action that can lead to collective goals and greater horizontal and vertical coordination (Arts et al. 2017; Ros-Tonen et al. 2015; Westerink et al. 2017). Use of the landscape concept in these spaces can give rise to novel definitions of sustainability through creation of place-specific meaning in landscapes (Bohnet and Beilin 2015; Ros-Tonen et al. 2015; Westerink et al. 2017). This process, however, entails permitting the evolution of the landscape concept as it is implemented, and developing as yet undefined practices of measuring the services from production landscapes and their benefits to various stakeholders (Sayer et al. 2013, 2016; Torquebiau 2015; Westerink et al. 2017). To operationalize the novelty of the landscape concept as it is implemented, researchers have posited a process of design, or a process of imagining new landscape services together with other elements of coordination and knowledge integration based on environmental and land use changes (Bürgi et al. 2017; Opdam 2018).

While the landscape concept offers potential to help local actors create new imaginaries, there is a low capacity of knowledge on the dynamics of interactions in landscapes of multiple uses, and this requires new conceptions in visions and ways of working (Opdam 2018; Pfund 2010; Sayer et al. 2013; Watts and Colfer 2011). This low capacity is in part due to the challenge to generate new imaginaries based on non-specific scientific knowledge lacking local knowledge about the landscape, and its acceptance by local actors (Beunen and Opdam 2011). There is not yet an operational mechanism for the quick generation of governance architecture for design, and whether such a design process would support the quick response to changing problems is not yet well tested.

4.1.4. *'Connects' actors and practices*

As one of the principles of the landscape concept is multi-stakeholder negotiation for multiple objectives, there is a good deal of practical evidence supporting the potential of the landscape concept to connect actors and practices. While the emphasis has been on architecture at a landscape scale that consists of a self-governed network of actors with one or more actors playing the connecting role (Ros-Tonen et al. 2014, 2018; Sayer et al. 2016), the type of actor taking the bridging and connecting role and their emphasis varies. This can range from scientists that present information, improve awareness and understanding of complex landscapes, and facilitate knowledge processes (Opdam 2018), to NGOs or Governments that initiate, sustain, oversee, and drive the coalitions of landscape actors and landscape architecture (Ros-Tonen et al. 2018), to individuals acting as 'boundary workers' that manage the evolving manifestations of landscape sustainability across scales and time (Westerink et al. 2017).

There is also evidence the landscape concept has helped create new spaces for connecting actors and practices for novel options and actions for landscape sustainability through the strengthening of social institutions, networks and fiscal terms, and use of learning and feedback mechanisms (Bürgi et al. 2017; Ros-Tonen et al. 2014, 2015). Much attention has been given to the importance of the landscape concept for connecting actors through the integration of knowledge systems across scientific and local, traditional and place-based landscape knowledge, and across landscape components and domains. There is less evidence of the particular effectiveness of connecting actors' roles, particularly scientists, in achieving this in practice across different actors' needs, and the needs of less powerful local landscape actors in particular, and across temporal scales of landscape sustainability and multiple networks and nodes of decision-making processes (Beunen and Opdam 2011; Bürgi et al. 2017; Ros-Tonen et al. 2015).

There is mixed evidence of the success of the landscape concept in connecting actors and practices across spatial scales. In one example, the landscape concept served effectively to bring together a landscape coalition in overcoming power imbalances and effecting collective goals, while other efforts have struggled in practice to use facilitation to overcome common obstacles to scaling vertical integration and balancing the needs of different actors (Arts et al. 2017; Colfer et al. 2011). Other evidence supports that connecting actors can effectively be the facilitating agent across scales where they have knowledge of multiple sectors and capacity to operate across governance levels, particularly where they are able to apply landscape as a boundary concept in organizing learning and action for landscape sustainability (Ros-Tonen et al. 2018; Westerink et al. 2017). Additionally, the landscape concept has strong potential when it pays attention to connecting actors together with the place-specific aspects of landscapes for defining sustainability (Bürgi et al. 2017).

4.1.5. *Experiments for reevaluation of existing governance systems*

Continuous learning and adaptive management are identified as means for iterative monitoring and adaptation to the uncertainty and surprises of changing economic, ecological and biophysical dynamics in landscapes (Pfund 2010; Reed et al. 2016; Sayer et al. 2013). Recent emphasis on landscape design through science-based multi-stakeholder processes in landscapes envision this iterative learning process can help create novel understandings and practices for landscape sustainability that may be experimental in one phase and multiply and proliferate in the next stage (Bürgi et al. 2017; Wu 2013).

In a relatively small number of large multi-site landscape research programs the emphasis in these arenas has been on learning through action research. Two prominent programs have been the CGIAR's Forest, Trees and Agroforestry Sentinel Landscapes (Dewi et al. 2017) and the Long-Term Socio-Ecological Research (LTSER) platforms (Bretagnolle et al. 2018). There are, however, some unique large-scale practical experiments that exemplify the potential of the landscape concept in re-evaluating governance. A Dutch initiative 'Farming for Nature' to provide state support for farmers implementing specific production practices was allowed to proceed as a landscape governance experiment with EU approval (Arts et al. 2017). The extent to which these action research efforts in learning landscapes have contributed beyond landscape services options to experimentation and imagination for new governance paradigms in agroecosystems has not been yet systematically questioned.

In addition, some proposed sustainability science-based frameworks for operationalizing the landscape concept lay out specific processes for re-evaluating governance. For instance, the iCASS platform's landscape conservation design, which aims to coordinate visions of sustainability transformation pathways for landscape mosaics and emphasizes the role of scientific actors as bridging organizations, envisions playing an important role in re-examining the governance paradigm and connecting actors in participatory, multi-sector, cross-jurisdictional systems (Campellone et al. 2018). Such frameworks for operationalizing the landscape concept should be dynamic, and have integral structures for reevaluation to reflect the uncertainty of fluctuating factors and elements in landscapes (Reed et al. 2016; Wu 2013).

Attention to the operationalization of the landscape concept has focused most on developing metrics to assess whether the concept fulfills its promise of meeting multiple objectives for social and environmental sustainability. More recent assessments have tried to address these gaps in measuring tangible social and environmental benefits of the implementation of the landscape concept by using more rigorous assessments, but these are long-term longitudinal studies with multiple qualitative, quantitative and biophysical methods in large-scale multi-country research projects (Sunderland et al. 2017). They are not yet applied with particular concern for re-evaluating governance in and of itself, and for experimenting with governance and institutions in ways that challenge the human and institutional assumptions and paradigms of management at landscape-scale (Sayer et al. 2013).

4.1.6. Inter-connections among governance characteristics for transformation

Despite that there is agreement among the 27 papers that the landscape concept has the potential to serve as a model that can support higher horizontal coordination and collective goals across multiple land uses, there is divergent evidence as to the degree to which such characteristics are manifested, dependent on how the landscape concept has been applied in scope and aim. Studies that have examined the question of whether the landscape concept has potential as a governance model have found that it can create a common understanding for negotiating among stakeholders the multiple objectives, benefits and potential synergies and trade-offs but does not inherently deal with power differentials directly (Ros-Tonen et al. 2014; Sayer et al. 2014).

The landscape concept is thought to contribute to creating knowledge spaces for re-negotiating and re-interpreting landscape sustainability, and for these spaces to be practical arenas for collective experimentation where different actors will discuss and test different landscape options (Arts et al. 2017; Bohnet and Beilin 2015). Recent emphasis on landscape design and governance through science-based multi-stakeholder processes envision an examination of desirable and sustainable futures that can overcome governance challenges in social-ecological systems such as lack of inclusion, fragmentation and inequities. Landscape governance or landscape capability frameworks (Arts et al. 2017), and a framework to integrate long-term collaboration and continuous learning among scientists and stakeholders (Bürgi et al. 2017) have been put forth that would help integrate landscape scale coordination in multi-level governance, whether to achieve the SDGs (Mbow et al. 2015), or to integrate governance of production landscapes among higher level value chains and policy (Ros-Tonen et al. 2014). However, these frameworks have not been widely applied to date.

While the landscape concept has had some success in connecting actors and practices through facilitation of self-organized governance networks, learning processes, and spaces for creating collective options and novelties, there are significant hindrances to successful connections in practice, including the legitimacy and competency of the connecting actor, and the capacities and transaction costs across scales in less developed countries (Pfund 2010; Ros-Tonen et al. 2014, 2018; Sayer et al. 2013, 2014, 2016). Nevertheless, there is future merit in using the landscape concept as a way of reconciling broad mismatch of scales in sustainability between global economic drivers and place-based land use decision-making (Bohnet and Beilin 2015; Wu 2013).

4.2. The landscape concept and transformative governance

Having assessed the strengths and shortcomings of the landscape concept as a paradigm of adaptiveness of agroecosystems using the five identified transformative governance characteristics, we summarize the overall character of the landscape concept for adaptiveness and transformative governance using the research lenses of the Earth System Governance (ESG) science plans. The dimensions of the old and new earth system governance research lenses show the changing needs of governance systems to shift from adaptiveness to transformation, and as identified in earlier reviews, the dimensions of adaptiveness remain important elements of governance systems. Governance of and for transformations extends beyond adaptiveness through an overall paradigm shift valuing reactive to proactive dimensions that support transformative governance design. Adaptiveness already gained in agroecosystems can support the beginnings of transformations toward sustainable food systems. These transformations should allow for systemic change of agroecosystems and novel definitions of landscape sustainability.

This transformative paradigm, and its accompanying change in values, is proactive in responding to the challenges of the Anthropocene. It addresses uncertainty through anticipation of needs, decreases complexity through greater understanding of systems and novel imaginaries, and manages fragmentation of sectors, domains, decision-making nodes and actors through inclusion. The transformative governance paradigm also begins to look not just more closely at how to bridge ecological and social scales but how to allocate trade-offs and benefits among scales and to ensure not only equity among different stakeholders but justice according to land and resource rights and temporal dimensions. It also looks at how to move beyond adaptation and resilience of social-ecological systems to purposeful change and transformation of systems in ways that will alter the driving forces of environmental change. The capacity to measure and reflect shifts from reactive learning processes or circles to more active reflexivity or critical analysis, including experimentation to inform novel actions and options in transformation pathways.

The findings from the 27 papers reviewed on the landscape concept are summarized in Table 4 (blue shaded areas) according to these adaptiveness and transformative dimensions of the ESG research lenses (green shaded areas) and scored as high, moderate and low based on the strength of the evidence (orange shaded areas). Each dimension is then evaluated for its contribution to the potential of the landscape concept as a transformative governance paradigm and found to range from low to moderate-high. No dimensions were found to be evaluated as high, which required demonstrated evidence to support a claim about the use or performance of the landscape concept across aspects of the dimension. Having a moderate-high evaluation then indicates the dimension may have scored high on some regards while scoring moderate in others. A moderate score reflects the recognition of some aspect of the dimension in the literature of either a theoretical nature, or a hypothesis about how the landscape concept may be working in practice. A low score found reported evidence of the gaps in the landscape concept, or represents no mention or a lack of serious attention in the literature to support the potential of the landscape concept on the dimension. Thereby, a moderate-low or a low-moderate score suggests a mix of such scores on varying aspects of the dimension.

Complexity, learning and inequity are found to have a moderate-high evaluation. Adaptiveness, fragmentation, inclusion, purposeful change/ transform and social and ecological scales are evaluated at a moderate

Table 4

Summary of the potential of the landscape concept as a transformative governance paradigm (Biermann et al. 2009, 2010; Burch et al. 2019; Earth System Governance Project 2018)[1]. (High = demonstrated evidence of the landscape concept is reported; Moderate = theory or evidence that supports the potential of the landscape concept is discussed; Low = demonstrated evidence of the gaps in the landscape concept is reported, or no mention or a lack of serious attention that supports the potential of the landscape concept). Reference numbers refer to Annex I. List of 27 papers reviewed on the landscape concept.

Governance system	Adaptiveness of agroecosystems			Transformation toward sustainable food systems		
	Governance of social-ecological systems	Evidence of the adaptiveness of agroecosystems	Evaluation	Governance of / for transformation	Seeds for transformation toward sustainable food systems	Evaluation
Outlook	Uncertainty	Evolution of landscape concept as it is implemented, including mechanisms to respond to fluctuating factors and elements in landscapes that are open-ended (15, 20, 22, 25, 26) (Moderate) Flexibility to create quick and changing new landscape architectures to respond to social and environmental changes while maintaining the stability of landscape resilience (27) (Low) Calculating the distribution of risks or benefits with regards to applying new solutions and technologies (2, 17, 23) (Low)	Low-Moderate	Anticipation	Process of imagining future strategies containing new landscape services (4, 12) (Moderate) Low capacity of shared knowledge on the dynamics of interactions in multi-functional landscapes shapes anticipation processes and limits acceptance by local actors (2, 6, 13) (Low) Identified mechanisms in learning landscapes for determining how future roles and responsibilities and associated risk and liability will be determined based on the future landscape services options identified (4, 17) (Low)	Low-Moderate
System boundaries	Complexity	Reconciling multiple social and environmental objectives for landscape management (14; 1-27) (High) Horizontal coordination among multiple sectors, ecosystems, actors, functions, & benefits of landscapes (8, 11, 14, 21, 23) (Moderate) Science-policy interactions in landscape governance processes (visioning, pathways) (10) (knowledge, design) (12, 27) (Moderate) and (cross-scale/cross-sector) (17, 26) (High) Cross-scale interdependence among vertical levels of landscape governance (22, 26, 27) (Moderate)	Moderate-High	Imagination	The landscape concept can be used in co-creating knowledge, options and action that can lead to collective goals (1, 18, 26) (Moderate) Non-landscape specific scientific knowledge inhibits more engaged and effective discourse processes for communities to generate new imaginaries that transcend existing limits (2) (Low) Mechanisms of co-production of knowledge and visualizations of future landscape services give little attention to determining who wins and loses over time in new imaginaries for collective aims (4) (Low)	Low-Moderate
Actors & Institutions	Fragmentation	Common landscape architecture creates new partnerships for managing governance systems across environmental and non-environmental domains (17, 19, 20) (High)	Moderate	Inclusion	Non-state actors' roles increase in self-governed landscape networks (17, 26) (High) Sustainable landscapes include deliberation and consensus among diverse actors, and including the values of future actors and present and future needs of non-human	Moderate

		Legitimacy of self-governed landscape networks and connecting actors, and accountability of state authorities to polycentric and decentralized landscape institutions (17, 20-22) (Low) Legitimacy of private sector actors' engagement in multi-stakeholder and democratic decision-making processes in self-governed landscape networks (8,11) (Low)			entities such as ecosystems (12, 16, 27) (Moderate) Bridging actors play connecting roles in bringing together diverse actors in landscape alliances, including underrepresented groups, in inclusive deliberation, scenario-building and science-based knowledge processes (12, 17, 26) (Moderate) Effectiveness of the role of connecting actors, particularly scientists, in achieving the integration of knowledges systems inclusive of the needs of less powerful landscape actors (2, 4, 18) (Low) Efforts to integrate top-down governance of production landscapes among higher level value chains and policy with bottom-up processes (19) (Moderate)	
Components	Social and ecological scales	Incorporating interconnected social systems and ecosystems at each spatial scale (7) (Moderate) Multi-level landscape governance that links customary governance to overcome inequalities that are embedded in interactions across all scales (14) (Moderate)	Moderate - Low	Allocation	Despite promotion of new arenas and social processes no evidence of more just or equitable distribution of environmental costs and benefits in landscape concept and landscape architecture (14) (Low) Low attention/exploration of who decides which values are represented in the decision-making processes for environmental costs and benefits (24) (Low) Allocation of costs and benefits of social cooperation in private sector organized	Low
		Creation of place-specific meaning for landscape sustainability options and reconciling mismatches of multiple scales with place-based land use decision-making (3, 18, 26, 27) (Moderate) New concepts and ways of working on the social and ecological dynamics that will bridge multi-level forms of landscape governance systems (9, 12, 13, 19) (Low)			landscape alliances in poor and middle-income countries (13, 17, 19) (Low)	
Goal	Inequity	Landscape concept and principles aim to deal with multi-faceted and intersectional structural inequalities and power imbalances among multiple landscape actors (20, 22) (High) Landscape architecture has potential to challenge inequalities depending on the construction, facilitation, and distribution of risks and costs, but also has the potential to lock in inequalities (2, 19) (Moderate) Ability to negotiate trade-offs	Moderate-High	Justice	The landscape concept helps integrate landscape scale coordination in multi-level governance to achieve goals and targets such as the SDGs (10) (Moderate) The investigation of the landscape concept in determining a fair distribution of environmental and social goods (i) across present and future generations, (ii) among landscape actors, domains, ecosystems and land uses, and (iii) across administrative jurisdictions and ecological scales such as upper and lower watersheds or transnational boundaries, is missing in more rigorous multi-country assessments (23) (Low)	Low-Moderate

		among stakeholders in the case of unpredictable shifts in actor coalitions, interests, sectors, and needs (13, 22) (Moderate)				
Means	Adaptiveness / Resilience	When implemented with continuous and rigorous multi-stakeholder negotiation, the landscape concept can offer adaptive management processes that respond to changing social and economic conditions (17, 20) (Moderate) There is mixed evidence of the success of connecting actors in helping arrange decision-making processes that address the role of power to achieve collective landscape aims (1, 6) (Low) The ability of connecting actors to effectively facilitate the trade-offs among distribution of risk, resources and power across different actors' needs and temporal scales is not yet evident (2, 4, 18) (Low) Considers the needs of future landscape services when incorporating scientific knowledge in effective governance processes for anticipatory adaptive action (2, 4) (Moderate)	Moderate-Low	Purposeful change / Transform	Use of the landscape concept to novelly define place-specific sustainability meaning can aid in efforts to purposefully pursue desirable futures (3, 18, 26) (Moderate) Efforts beyond local and central governments providing a supportive role to authenticate landscape management that aim to effect incremental or radical change in networks, policies, or institutions and that legitimize land and resource rights (1, 20, 21) (Low) Efforts to understand who is determining and benefiting from social and ecological changes are hampered by the messiness of real landscape processes of multi-stakeholder negotiation (6, 24) (Low) Examination of desirable and sustainable futures that can overcome governance challenges in social-ecological systems such as lack of inclusion, fragmentation and inequities (1, 4) (Moderate)	Moderate-Low
Measure	Learning	Creates new spaces that connects actors and practices through social learning for novel options and actions for landscape sustainability (4, 18, 19) (Moderate) Iterative monitoring and adaptation for changing economic, ecological and biophysical dynamics in landscapes through continuous learning and adaptive management (13, 15, 22) (High) Provides a decision-making mechanism to integrate long-term collaboration and continuous learning among different knowledge systems (4) (Moderate)	Moderate-High	Reflexivity	Orients positive values toward ecology for rapid responses to ecological shifts when connecting actors with place-specific elements of landscape sustainability (4) (Moderate) Opens up new knowledge spaces for re-negotiating and re-interpreting landscape sustainability and experimenting with landscape options (1, 3, 27) (Moderate) Holding private sector actors accountable to collective decisions in multi-stakeholder negotiations when other actors threaten existing resource allocation and power configurations (21) (Low) Efforts to measure outcomes in ways that challenge existing governance systems as social and environmental conditions change (1, 5, 22) (Low) Science in governance processes support evolving management of landscape sustainability definitions over space and time but lack evidence of institutional capacities to reincorporate needed changes in governance characteristics over time (26) (Low)	Low-Moderate

level.

One of the main areas of weakness limiting the application of the landscape concept as a governance paradigm has been the lack of representation of multiple values and the just distribution of landscape costs and benefits among multiple entities. Justice and reflexivity are evaluated low-moderate, and allocation low.

The landscape concept is viewed as sustainable when it includes deliberation and consensus among diverse actors, and including the values of future actors and present and future needs of non-human entities such as ecosystems, but is challenged by the need for more legitimacy in self-governed processes with strong power imbalances among communities and private sector and state actors, and a lack of democratic norms that consider future generations and non-human entities such as ecosystems (Wu 2013). A critical analysis of the values of different landscape actors and challenges to existing landscape alliances as social and environmental conditions change have been less considered. In particular, the landscape concept gives little attention to aspects that pertain to distributive justice or allocation within governance dimensions it otherwise moderately addresses such as inclusion, adaptiveness and purposeful change. Allocation is the dimension of the landscape concept with the lowest evaluation, and presents little evidence or exploration of who decides which values are represented in decisions about landscape costs and benefits, particularly in settings with unequal power or agency among actors.

A second weak area limiting the potential of the landscape concept is addressing changing social and ecological conditions and future landscape needs and sustainability. Uncertainty, anticipation and imagination are each evaluated low-moderate.

Factors of uncertainty related to flexible institutions that also maintain stability (Burch et al. 2019), and calculating the risks and benefits associated with the uncertainties of changing needs in technologies demonstrate gaps in related aspects of allocation. Anticipating how future roles and responsibilities and associated risk and liability will be determined based on the future landscape services options identified, and determining who wins and loses over time in new imaginaries for collective aims are also weaknesses in this area related to allocation.

An examination of this paradigm using the earth system governance research lenses illustrated two key areas for further investigation and action for transformative governance. These two areas were identified by grouping together the 6 dimensions found as low or low-moderate in two main challenges to further developing the landscape concept as a paradigm for transformative governance of sustainable food systems. In addition to these two weak areas, when going beyond the five characteristics of transformative governance to examine the landscape concept from the perspective of ESG lenses, we find weak aspects in distributive justice across all of the ESG dimensions. Much more work will need to be done to determine how a landscape concept can contribute to sustainable food systems through transformative governance.

4.3. Discussion: moving toward governing sustainability transformations of food systems

The existing paradigm of adaptiveness in agroecosystems has been insufficient for governance of the needed sustainability transformation. In this section we discuss the challenges to governing agroecosystems for the transformation towards sustainable food systems in relation to the two identified areas for further action. The first is landscape design for continuous social and ecological changes and evolving understandings of sustainability (uncertainty, anticipation, imagination), and the second is the allocation of landscape costs, rights and benefits in present and future decision-making and among human and non-human entities (justice, reflexivity, allocation).

4.3.1. Landscape design

The gap in landscape design is hampered by a continuously evolving array of actors, changing problem and adaptation contexts, narratives of change, and solution frames, including how to anticipate these evolving configurations of landscape compositions and needs and to reconcile diverse visions and new imaginaries among shifting power dynamics. Many of the low-scored aspects of the dimensions to do with landscape design, e.g. uncertainty, anticipation and imagination of new landscape sustainabilities and pathways to realizing them, have to do with the plurality of demands for ecosystems services at different scales and by different actors as well as the increasing demand for food systems to account for many services and outcomes.

Pluralistic diversities in agroecosystems of an agrobiological (Bioversity International 2017; IPES-Food 2016), farming system (Therond et al. 2017), ecological (Díaz et al. 2019), diet (Allen et al. 2014), institutional (Brondizio et al., 2009), actor (Grêt-Regamey et al., 2019), normative (knowledges, values, narratives, etc.) (Burch et al., 2019), innovation (Leach et al., 2012), livelihood (Cleaver and De Koning 2015), and place-based (Folke et al., 2016) nature shape the governance challenges of sustainability transformations of food systems. We define pluralistic diversities of agroecosystems as multiple occurrences of multiple types of diversity in biophysical, spatial, scaled and governance aspects of land use management, and are interested in the difficulties in managing these diversities in effective land use decisions for multiple benefits among different actors across space and time. Managing pluralistic diversities should be a proactive feature of new transformation governance for overcoming the current limitations in the adaptiveness paradigm and moving toward sustainability transformations of food systems.

The landscape concept tries to fill this gap by providing an operational framework that can accommodate pluralistic diversities in land use from the scale of genetic material up to mosaic ecosystems of interconnecting landscapes, and through the narratives, values, knowledges, and actors that shape the decisions on these multiple uses and functions. Indeed, the advantage of a landscape collective framework among multiple actors has been posited as its potential for managing the diversity of multiple land functions (Torquebiau 2015). Further, the landscape concept incorporates the scale at which mismatches between social and ecological scales can be addressed together through active management of biological and cultural diversities (Agnoletti and Rotherham 2015; Morand and Lajaunie 2017; Oosten and Hijweege 2012).

In addition, the low scores in uncertainty, anticipation and imagination leading to the gap in landscape design has also to do with the multiple narratives of landscape sustainability. We must also recognize the science of planetary limits is itself a paradigm that is still debated and contested, and in fact there are alternate paradigms, such as that of 'planetary opportunities,' which may indeed offer novel pathways for re-imagining sustainable food systems and connecting new and different interests of consumers and producers at different scales (DeFries et al., 2012; Leach 2015). Research on pluralistic diversities in agroecosystems should give more attention to processes that explore the diversities among sustainability narratives and the underlying knowledges (including knowledge embedded in the use of language, see for instance McNamara 2017), and values that define what are sustainable food systems at different scales. Indeed, countries and individual landscapes need to be free and to have the agency to imagine and to enact values and adopt actions in such alternative pathways that reflect their visions of a good life and build on traditional agricultural systems and cultural practices, and that promote equality and justice among resources users and residents whether or not that falls outside of the dominant paradigm.

This gap in design and the uncertainties, anticipation and imagination of future landscape sustainability is apparent in the current challenges in transforming aims and objectives, means of production and metrics for sustainable food systems. Transformations to sustainable food systems must include healthy diets in the aims and objectives of a new paradigm that can provide food and nutrition security while keeping food systems within planetary scale environmental limits. Thereby, healthy diets must be part of the landscape concept if it is to be a viable paradigm for transformative change at the level of collective action on food choices and food supply. Reframing the concept of food security in a revolutionary way, as nutrition security, or food security that provides a healthy diet, is a way of shifting the paradigm of sustainable food systems to truly transformative change through system-wide end goals (Ingram 2020).

It also subsequently re-shapes the important research questions for governance of transformations to sustainable food systems to include questions of the politics of healthy diets reflective of the values of landscape residents. For instance, who and what defines a healthy diet and what type of regenerative production practices will provide multiple landscape benefits to whom, and how do we produce food in diverse multi-scale systems to meet these definitions and targets. Indeed, reviews of the importance of biodiversity across the landscape for nutritional outcomes have encouraged landscape approaches for integrating conservation, agriculture, and forests with nutrition and food security (Powell et al., 2015). Yet such nutrition-sensitive paradigms are yet to be widely operationalized in sustainable food systems, although recent considerations recognize the growing list of system components sustainable food systems must grapple with, including nutrition-friendly, business-friendly, and climate-friendly practices (Willett et al., 2019).

Transformations to sustainable food systems will also have to incorporate governance of soils in the paradigm, as it is not only the outcome of the paradigm that needs to shift, but also the inputs at all scales and the means of production. While there is a rich set of research on farmers' decision-making regarding soil management at plot and farm scale, we still know little about how the drivers at other scales, such as the inherent trade-offs and synergies across private and public plots of land at a landscape scale, affect these decisions (Juerges and Hansjürgens 2018), or how the trade-offs in short-term decision-making affect the long-term impacts that farmers face when considering the adoption of more agroecologically diverse farming systems (see for instance Rahman et al. 2016). Another question becomes what type of governance systems may help steer transformations at a landscape scale toward more agroecologically diverse systems while improving food production diversity in ways that will anticipate and imagine multiple landscape benefits given the uncertain shifts in actors, narratives and problem contexts. Some work has been done in anticipating new means of production using climate-smart crops such as drought tolerant varieties in places where agroecological zones will shift, however these imaginaries tend to interact less with a critical analysis of who would most benefit from such changes and how it might re-shape power dynamics or the agency of actors in future agroecosystems.

The metrics for landscape sustainability will need to anticipate and imagine different framings of sustainability, which often shapes how different actors define problems in the landscape and what would be an indicator of success (Kudo and Mino 2020). Recent scholars have demonstrated that sustainability is a contested narrative at the local level between those that depend on the landscape for their livelihoods, and stakeholders in other places or at higher levels of governance, and among landscape residents who have diverse meanings of landscape and place (Beilin and Bohnet 2015; Bremer and Funtowicz 2015; Masterson et al., 2017; McNamara 2017). The use of the landscape concept in defining key values for sustainability has the potential to mask narrowly defined interests from actors at one scale as inclusive or multi-objective in the absence of neither a sufficient nor shared understanding of the narrative diversity of sustainability among landscape residents. In the course of such, the adoption of the landscape concept is as or more likely to create pathways to sustainable food systems that discount or ignore the needs of one or more marginalized groups.

Knowledge co-production and integration has become one process by which diverse framings of sustainability are meant to be negotiated among a diversity of stakeholders (Chapman and Schott 2020; Tengö et al., 2017). However, tools for moving from a diversity of values to shared values in the landscape are in nascent form, (see for instance Cerreta et al., 2017), and are also subject to the same possibility that a shared values framework may discount or ignore the short-term income trade-offs of farmers with the long-term benefits gained in the landscape.

4.3.2. Allocation of landscape costs, rights and benefits

The decisions regarding the prioritization of some landscape services over others in agroecosystems are key aspects of the governance of transformations of food and agricultural systems due to the potential unequal or positive or negative effects on different actors across scales and time (Leach et al. 2018). Few positive and locally relevant and accepted pathways that show how landscape residents can demonstrate agency in creating pathways to sustainable food systems that reflect their values have been developed (Raudsepp-Hearne et al. 2020). In the context of pluralistic diversities, a key question then is whose narratives and imaginaries of sustainable food systems count, and who has the agency, or the power in enacting, principles and actions for allocating the benefits of landscapes across different political and administrative contexts, including in landscapes steered by powerful actors with means to create and set paradigms at higher levels of governance; and secondly, how diverse multi-level governance architectures include or exclude actors and affect their agency in deciding the allocations of landscape roles, rights, costs and benefits.

There is still very little understanding about how agency and norms of accountability and democratic governance may be employed in governance for and of transformations (Patterson et al. 2017). Further, while agency is a familiar concept at an individual scale, little has been studied in the way of agency in the context of multi-level networks (Olsson et al. 2014), nor the manner in which agency is utilized by varying networks in transformative processes to pursue one set of values over another, including which organizations or networks decide upon the problem frames, scope of issues or processes that will regulate change, and how this influences the outcome of which pathways are selected or do not materialize (Scoones et al. 2015).

The legitimacy and accountability of multi-level governance arrangements that include self-organized forms of governance for just land and resource rights is a key gap of the landscape concept in allocation for transformative governance. Both the optimal governance architecture at the landscape scale and how the landscape scale is related to multi-level governance at other scales, including new landscape governance architecture, or the institutional frameworks that will allow for the coordination at higher vertical levels while also relating to and supporting the horizontal coordination of stakeholders at a landscape and others scales is still a question for transformative governance. As we move from paradigms of adaptiveness to climate change in agroecosystems to transformation to sustainable food systems, how do the current paradigms and the dominant governance architecture need to change to embrace the gaps in the landscape concept? Are there archetypes of pathways for transformative change to more diverse agroecosystems, and who has the agency to reflect their values and interests in alternative pathways and to affect the change needed? In particular, how can these pathways reflect the knowledges, frames, and values (normative diversity) of local landscape actors, especially indigenous communities with often unique languages, knowledge and values of the landscape?

In this study we selected key review papers of the potential of the landscape concept as a governance paradigm, yet there is a rich set of empirical cases of the landscape concept that is continuing to grow and may offer additional insights on its promise. This research for the earth system governance harvesting initiative was completed in 2018. One of the limitations of our study is that the research on sustainability transformations and governance is a rapidly evolving topic and the number of papers on this subject have increased at a greater pace since the time of the initial research. Further analysis of how adaptiveness will be important in food system transformation narratives and the importance of varying governance characteristics in transformations will be warranted.

5. Conclusions

In this chapter we analyze the potential of the current paradigm of adaptiveness in agroecosystems, the landscape concept, using characteristics of governance drawn from sustainability transformations literature and earth systems governance research lenses. At this turning point in the governance paradigm from adaptiveness to transformation, examining the landscape concept from the point of view of earth system governance research lenses demonstrates important gaps in researching seeds of transformation in food systems and defines two action areas for advancing the transformative nature of the landscape concept for redefining food systems. The landscape concept can serve as a bridge from adaptiveness in agroecosystems to governance modes that support transformations to sustainable food systems.

Yet, the use of the landscape concept itself is not sufficient as a transformative governance paradigm. Using earth systems governance research lenses highlights the areas of landscape design in anticipating and imagining landscape services and sustainability, and of allocation and justice in who determines and benefits from these services. This creates the challenge of defining alternative and transformative pathways that can address these gaps in the landscape concept in ways that will be more just in allocation of landscape costs and benefits and transcend sustainability imaginaries through design in uncertain social and ecological changes. Utilizing the transformative governance paradigm may offer an opportunity for stakeholders to address the major shortcomings of the implementation of the landscape concept by developing landscape governance architecture for higher level vertical coordination, and balancing multiple needs through more proactive governance of pluralistic diversities.

Pluralistic diversities in an important dimension to be studied in transformations of agroecosystems as these factors of diversity in actors, ecosystems, production systems, nutrients, values, knowledges, narratives, livelihoods, scales, and institutions shape the politics of agroecosystems. One of the first challenges will be in mapping the forms of pluralistic diversities in agroecosystems, and is an important research gap in governance for transformations toward sustainable food systems for the next five years. Research should examine how managing pluralistic diversities could proactively enact the needed changes in architecture, agency, and allocation to transform agroecosystems for sustainable food systems.

Finally, earth systems governance research helps bridge characteristics of governance for transformations with agronomic principles for the science for sustainable food systems including science-based targets, relevant scales for land use and biodiversity in food systems, together with the politics and narratives of diversity. To improve our understanding of collective agency and its role in transformations toward sustainable food systems we will need to utilize interdisciplinary sciences such as earth systems governance and sustainability science. To conduct such investigations in a manner that will ensure that such transformations account for multiple values, we will need to use transdisciplinary methods that engage multiple stakeholders and that include residents whose livelihoods are dependent upon the production landscape.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Annex I. List of 27 papers reviewed for landscape concept

No.	Author (First)	Title	Year	Journal/Publisher
1.	Arts	Landscape Approaches: A State-of-the-Art Review	2017	Annual Review of Environment and Resources
2.	Beunen	When landscape planning becomes landscape governance, what happens to the science?	2011	Landscape and Urban Planning
3.	Bohnet	Editorial: Pathways towards sustainable landscapes	2015	Sustainability Science
4.	Bürgi	Integrated Landscape Approach: Closing the Gap between Theory and Application	2017	Sustainability
5.	Campellone	The iCASS Platform: Nine principles for landscape conservation design	2018	Landscape and Urban Planning
6.	Colfer	Collaborative governance of tropical landscapes	2011	Routledge
7.	DeFries	Toward a whole-landscape approach for sustainable land use in the tropics	2010	PNAS
8.	Estrada-Carmona	Integrated landscape management for agriculture, rural livelihoods, and ecosystem conservation: An assessment of experience from Latin America and the Caribbean	2014	Landscape and Urban Planning
9.	Freeman	Operationalizing the integrated landscape approach in practice	2015	Ecology and Society
10.	Mbow	How can an integrated landscape approach contribute to the implementation of the Sustainable Development Goals (SDGs) and advance climate-smart objectives?	2015	World Agroforestry Centre (ICRAF)
11.	Milder	Integrated Landscape Initiatives for African Agriculture, Development, and Conservation: A Region-Wide Assessment	2014	World Development
12.	Opdam	Exploring the Role of Science in Sustainable Landscape Management. An Introduction to the Special Issue	2018	Sustainability
13.	Pfund	Landscape-scale research for conservation and development in the tropics: fighting persisting challenges	2010	Current Opinion in Environmental Sustainability
14.	Reed	Have integrated landscape approaches reconciled societal and environmental issues in the tropics?	2017	Land Use Policy
15.	Reed	Integrated landscape approaches to managing social and environmental issues in the tropics: learning from the past to guide the future	2016	Global Change Biology
16.	Reed	What are “Integrated Landscape Approaches” and how effectively have they been implemented in the tropics: a systematic map protocol	2014	Environmental Evidence
17.	Ros-Tonen	From Synergy to Complexity: The Trend Toward Integrated Value Chain and Landscape Governance	2018	Environmental Management
18.	Ros-Tonen	Landscapes of Social Inclusion: Inclusive Value-Chain Collaboration Through the Lenses of Food Sovereignty and Landscape Governance	2015	The European Journal of Development Research
19.	Ros-Tonen	From Co-Management to Landscape Governance: Whither Ghana’s Modified Taungya System?	2014	Forests
20.	Sayer	Measuring the effectiveness of landscape approaches to conservation and development	2016	Sustainability Science
21.	Sayer	Landscape approaches; what are the pre-conditions for success?	2014	Sustainability Science
22.	Sayer	Ten principles for a landscape approach to reconciling agriculture, conservation, and other competing land uses	2013	PNAS

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No.	Author (First)	Title	Year	Journal/Publisher
23.	Sunderland	A methodological approach for assessing cross-site landscape change: Understanding socio-ecological systems	2017	Forest Policy and Economics
24.	Sunderland	Response Options Across the Landscape	2015	Cambridge
25.	Torquebiau	Whither landscapes? Compiling requirements of the landscape approach	2015	World Agroforestry Centre (ICRAF)
26.	Westerink	Landscape services as boundary concept in landscape governance: Building social capital in collaboration and adapting the landscape	2017	Land Use Policy
27.	Wu	Landscape sustainability science: Ecosystem services and human well-being in changing landscapes	2013	Landscape Ecology

Annex II. List of 23 papers reviewed for properties or characteristics relevant to governance for sustainability transformations

No.	Author (First)	Title	Year	Journal
1.	Bosomworth	What's the problem in adaptation pathways planning? The potential of a diagnostic problem structuring approach	2017	Environmental Science and Policy
2.	Chaffin	Transformative Environmental Governance	2016	Annual Review of Environment and Resources
3.	Colloff	An integrative research framework for enabling transformative adaptation	2017	Environmental Science and Policy
4.	Colloff	Transforming conservation science and practice for a postnormal world	2017	Conservation Biology
5.	Gerhardinger	Healing Brazil's Blue Amazon: The role of knowledge networks in nurturing cross-scale transformations at the frontlines of ocean sustainability	2018	Frontiers in Marine Science
6.	Gordon	Rewiring food systems to enhance human health and biosphere stewardship	2017	Environmental Research Letters
7.	Hahn	Are adaptations self-organized, autonomous, and harmonious? Assessing the social–ecological resilience literature	2017	Ecology and Society
8.	Hebinck	Capturing change in European food assistance practices: a transformative social innovation perspective	2018	Local Environment
9.	Hölscher	Steering transformations under climate change: capacities for transformative climate governance and the case of Rotterdam, the Netherlands	2018	Regional Environmental Change
10.	Koch	A transformative turn towards sustainability in the context of urban related studies? A systematic review from 1957 to 2016	2017	Sustainability (Switzerland)
11.	Langle-Flores	The Role of Social Networks in the Sustainability Transformation of Cabo Pulmo: A Multiplex Perspective	2017	Journal of Coastal Research
12.	Pahl-Wostl	An Evolutionary Perspective on Water Governance: From Understanding to Transformation	2017	Water Resources Management
13.	Patterson	Exploring the governance and politics of transformations towards sustainability	2017	Environmental Innovation and Societal Transitions
14.	Pichler	Drivers of society-nature relations in the Anthropocene and their implications for sustainability transformations	2017	Current Opinion in Environmental Sustainability
15.	Rijke	Configuring transformative governance to enhance resilient urban water systems	2013	Environmental Science and Policy
16.	Sarkki	How pragmatism in environmental science and policy can undermine sustainability transformations: the case of marginalized mountain areas under climate and landuse change	2017	Sustainability Science
17.	Schäpke	Linking transitions to sustainability: A study of the societal effects of transition management	2017	Sustainability (Switzerland)
18.	Schlaile	Innovation systems for transformations towards sustainability? Taking the normative dimension seriously	2017	Sustainability (Switzerland)
19.	Tàbara	Exploring institutional transformations to address high-end climate change in Iberia	2018	Sustainability (Switzerland)
20.	Tàbara	Positive tipping points in a rapidly warming world	2018	Current Opinion in Environmental Sustainability
21.	Weiland	The nature of experiments for sustainability transformations: A search for common ground	2017	Journal of Cleaner Production
22.	Weiser	Acknowledging temporal diversity in sustainability transformations at the nexus of interconnected systems	2017	Journal of Cleaner Production
23.	Wiek	Water, People, and Sustainability: A Systems Framework for Analyzing and Assessing Water Governance Regimes	2012	Water Resources Management

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