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Using a leverage points perspective to compare social-ecological systems: a case study on rural landscapes

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ABSTRACT
A leverage points perspective recognises different levels of systemic depth, ranging from the relatively shallow levels of parameters and feedbacks to the deeper levels of system design and intent. Analysing a given social-ecological system for its characteristics across these four levels of systemic depth provides a useful diagnostic to better understand sustainability problems, and can complement other types of cause-and-effect systems modelling. Moreover, the structured comparison of multiple systems can highlight whether sustainability challenges in different systems have a similar origin (e.g. similar feedbacks or similar design). We used a leverage points perspective to systematically compare findings from three in-depth social-ecological case studies, which investigated rural landscapes in southeastern Australia, central Romania, and southwestern Ethiopia. Inductive coding of key findings documented in over 60 empirical publications was used to generate synthesis statements of key findings in the three case studies. Despite major socioeconomic and ecological differences, many synthesis statements applied to all three case studies. Major sustainability problems occurred at the design and intent levels. For example, at the intent level, all three rural landscapes were driven by goals and paradigms that mirrored a productivist green revolution discourse. Our paper thus highlights that there are underlying challenges for rural sustainability across the world, which appear to apply similarly across strongly contrasting socioeconomic contexts. Sustainability interventions should be mindful of such deep similarities in system characteristics. We conclude that a leverage points perspective could be used to compare many other types of social-ecological systems around the world.

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Introduction

We live in an era of unprecedented and increasingly rapid global change. Since the Industrial Revolution, exponential increases have been documented in diverse socioeconomic variables such as human population, economic activity or the number of motor vehicles; as well as in many environmental variables such as the amounts of domesticated land, freshwater or fertilizer use (Steffen et al. 2004). Global sustainability challenges thus span both social and ecological dimensions, and include numerous links between these two dimensions (Rockström et al. 2009; Raworth 2012; United Nations 2015). In this paper, we focus on rural landscapes, which provide tangible opportunities to study and address diverse socioeconomic and environmental sustainability challenges. One way to better understand (and subsequently manage) rural landscapes is via conceptualizing them as social-ecological systems; that is, applying systems thinking (Senge 1990; Meadows 2009) to their interlinked human-environment dynamics (Berkes and Folke 1998; Fischer et al. 2015).

The aim of this paper is to use a 'leverage points perspective' to undertake a structured comparison of three rural landscapes – all of which were previously studied in depth by members of the author team as social-ecological systems. The three rural landscapes are located in Australia, Romania and Ethiopia. They cover a broad gradient from large-scale intensive agriculture (in Australia) via small-scale semi-mechanized agriculture (in Romania), to traditional smallholder farming (in Ethiopia). Economic wealth follows a similar gradient from wealthy in Australia, to much less wealthy in Romania, to poor in Ethiopia. Biodiversity is threatened by diverse processes in the three settings, but has been hit particularly heavily by land clearing and land use intensification in the Australian landscape. Our retrospective application of a leverage points perspective to these case studies is intended as a proof of concept; we

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Supplemental data for this article can be accessed here.

sought to establish to what extent a leverage points perspective could be a useful and potentially powerful way to uncover shared sustainability challenges, drivers and opportunities across multiple different systems.

As we explain in the following, just like ‘resilience thinking’ is more than ‘resilience’ (Walker and Salt 2006), a ‘leverage points perspective’ is more than only the analysis of ‘leverage points’ – it is a perspective inspired by thinking about leverage points, but it goes beyond the identification of concrete interventions (Fischer and Riechers 2019). Leverage points are places in a system where relatively minor interventions can lead to substantial changes in certain outcomes (Meadows 1999). In 1999, Donella Meadows proposed a hierarchy of ‘places to intervene’ in complex systems. She distinguished between leverage points at which interventions are easy but have limited transformative potential versus increasingly more influential leverage points, where interventions are more difficult or more costly to carry out, but have great potential to bring about transformative change. More recently, Abson et al. (2017) simplified the 12 leverage points by Meadows into four ‘realms of leverage’, which can be thought of as four levels of ‘systemic depth’ (see also Fischer and Riechers 2019). Increasingly influential levels of systemic depth are hypothesised to relate to parameters, feedbacks, system design, and the intent encapsulated by a system (Table 1) – that is, interventions at the level of parameters are expected to be less influential than interventions at the level of system intent. This is because ‘deeper’ system characteristics constrain possible changes to shallower system characteristics. For example, changes that can be made to system parameters are, at least in part, determined by the feedbacks, design and intent of the system in which such parameter changes are made. Such interlinkages, however, do not exclude the possibility that changes to shallower system characteristics can also influence deeper system characteristics (Manlosa et al. 2018).

A ‘leverage points perspective’, in turn, seeks to understand a system by analysing it across the suite of structural depths described above (Fischer and Riechers 2019). This perspective can help to think about interventions (i.e. actual leverage points), but it can also help to think about how different levels of systemic depth interact or reinforce or constrain one another. For example, the greening of the Common Agricultural Policy (CAP) in Europe has been criticised for not going far enough to halt biodiversity decline (Pe’er et al. 2020; Scown et al. 2020). From a leverage points perspective, parameter-level interventions for biodiversity have been ineffective because they are overshadowed by an institutional design favouring large-scale, industrial agriculture; which, in turn, is rooted in a green revolution paradigm. A leverage points perspective thus offers a tool to draw out what is going on in a given system at different levels of systemic depth – from parameters, through feedbacks and system design, to goals and paradigms underpinning the system.

A leverage points perspective is not an entirely new or different way of looking at systems. Rather, it should be seen as a heuristic that draws attention to particular aspects of systems that can be overlooked in other types of systems analysis. Indeed, Meadows (1999) suggested that some of the most important layers of a given system were not captured by conventional cause-and-effect analyses alone, but rather related to how systems are structured and which goals are pursued through them. Making explicit different levels of depth thus opens new ways of analysing any given system (for details and examples, see Manlosa et al. 2018; Jiren et al. 2021; Riechers et al. 2021).

We hypothesized that despite obvious differences in the three rural landscapes, from a leverage points perspective, some of their sustainability challenges might be very similar. Learning about such similarities, in turn, may highlight ubiquitous systemic problems facing many rural landscapes around the world (see also Nyström et al. 2019). Of course, differences between the landscapes could also be interesting, because they highlight unique challenges that are especially relevant in some settings. The overarching goal of this paper thus is to provide a new, structured approach for the comparison of social-ecological

Table 1. Four levels of systemic depth as defined by Abson et al. (2017), and 12 leverage points as defined by Meadows (1999).

Level of systemic depth	Leverage point	Example (of relevance to rural landscapes)
Parameters	Parameters	Quantity of inorganic fertilizer used
	Size of buffer stocks	Amount of livestock feed stored to cope with a drought
	Structure of material stocks and flows	Run-off dynamics of nutrients from fields into streams
Feedbacks	Length of delays	Extinction debt of forest trees persisting in recently cleared farmland
	Strength of balancing feedbacks	Extent to which a lake can absorb agricultural nutrients and remain clear
	Gain around reinforcing feedbacks	Extent poverty may cause population growth, which may cause poverty
Design	Information flows	How knowledge about various types of agricultural methods is transmitted
	Rules of the system	Policy instruments and regulations in various interacting sectors
	Power to change system structure	Ability of farmers to self-organise to sustainably use a communal pasture
Intent	Goals of the system	Maximising agricultural exports versus improving national food sovereignty
	Paradigm underpinning the system	A green revolution paradigm versus an agroecological paradigm
	Power to transcend paradigms	Conscious shift from a growth-based economy to a steady-state economy

Increasingly deep (i.e. influential) leverage points are listed towards the bottom of the table.

systems. The approach suggested here can complement existing approaches to systems modelling, with its particular strength being the explicit recognition of multiple levels of systemic depth (see also Nguyen and Bosch 2013). Our paper first introduces the three case study landscapes; then provides a methodological overview of how a leverage points perspective was applied to the three landscapes; and lastly discusses the findings and provides an outlook for future research.

Case study landscapes

The three case studies presented here were all designed from the outset as interdisciplinary, social-ecological team research, with transdisciplinary elements. All three broadly addressed ecological, social, and interlinked social-ecological questions. Moreover, all three broadly followed a similar integration approach, which we previously labelled as integration by 'case, place and process' (Sherren et al. 2010a). That is, ecological, social, and social-ecological investigations focused on shared cases (e.g. villages or farms), in a generally pre-defined place or landscape (sensu Selman 2006), and used processes such as interdisciplinary papers, joint workshops, and ways to build a collaborative team atmosphere to facilitate integration within the research team and with stakeholders (for details, see Sherren et al. 2010a; Fischer et al. 2014). There was also substantial overlap in researchers across the case studies, with all authors involved here contributing to papers from two or even three of the three cases. An overview of publications from the three research projects is available in the supplementary material – showing many similarities in scope. For simplicity, the case studies are referred to in this paper by the country they were located in.

In Australia, we worked in the southeast, around the towns of Boorowa and Cowra, in the country's sheep-wheat belt. The landscape was used for commercial cattle and sheep grazing, as well as for wheat cropping. Ecologically, the landscape is highly modified, and > 85% of grassy *Eucalyptus* woodland cover has been cleared (Prober and Thiele 1995; Fischer et al. 2010a). Among other topics, our research covered ecological issues such as tree decline (Fischer et al. 2009b) and its consequences for wildlife, including birds (Fischer et al. 2010b; Hanspach et al. 2011) and bats (Fischer et al. 2010b; Hanspach et al. 2012). With colleagues, we also covered social issues such as farmers' perceptions of trees and landscape change (Sherren et al. 2010b), management paradigms and their rationales (Abson et al. 2019; Sherren et al. 2012) and policy preferences (Schirmer et al. 2012) – which, in turn, shaped their land management decisions, causing social-ecological flow-on effects on tree regeneration and hence the ecology of farms. The farms we studied spanned a gradient from conventional (continuous grazing) to holistic grazing management (Savory and Butterfield 1999); thereby representing contrasting paradigms of optimal resource exploitation versus systems thinking (Fischer et al. 2009a; Mann et al. 2019).

In Romania, we studied the region around the town of Sighisoara, in the centre of the country. The landscape is a notable biocultural hotspot in Europe (Barthel et al. 2013), with exceptionally high biodiversity stemming from the continuation of traditional land-use practices. Approximately a third of the landscape is forested, a third is pastures, and a third is small-scale agricultural fields; most settlements are small villages. The study focused on 30 villages and the farmland around these. Ecological aspects addressed included landscape ecological questions on plants, birds, butterflies, and forest mammals (e.g. Dorresteijn et al. 2013, 2015a, 2015b; Loos et al. 2014, 2015a, 2015b; Roellig et al. 2014). Social aspects included the analysis of formal (European Union) institutions in relation to local realities (Mikulcak et al. 2013, 2015), as well as the divergent landscape aspirations of different local stakeholder groups (Milcu et al. 2014; Horcea-Milcu et al. 2016) and changing social norms (Horcea-Milcu et al. 2017). Social-ecological linkages were investigated in numerous ways, including via assessments of ecosystem services (Hartel et al. 2014; Horcea-Milcu et al. 2016) and participatory scenario planning (Hanspach et al. 2014).

In Ethiopia, we investigated the southwest of the country, focusing especially on food security and biodiversity conservation. Southwestern Ethiopia is part of a globally recognized biodiversity hotspot (Mittermeier et al. 2011); it is the origin of coffee (*Coffea arabica*), and the landscape is a mosaic of extensive forested areas (approximately 50%) and mixed farmland, densely inhabited by subsistence farmers. Ecologically, we examined the distribution patterns of trees, birds and mammals in relation to historical and current human land use (Rodrigues et al. 2018, 2019, 2021; Shumi et al. 2018, 2019). In terms of social issues, we studied the governance structures and processes influencing food security and biodiversity (Jiren et al. 2018a; Bergsten et al. 2019), as well as household-level livelihood strategies and food security (Manlosa et al. 2019a, 2019b). Our work also addressed the different preferences for how to address food security by diverse stakeholders within the study area (Jiren et al. 2018b), and examined how social norms shaped access to critical livelihood assets and thereby constrained the well-being of some community groups (e.g. women, landless people; (Manlosa 2019)).

Methods

In order to provide a basic overview of key findings in the different case study systems, we initially summarised our main empirical findings in short abstract-like paragraphs for each case study. We then undertook a structured comparison of the findings from the three case studies, following four steps.

First, we drew on the set of publications for each case study (i.e. > 60 publications in total; see supplementary material) to distil specific one-sentence synthesis statements. Each such synthesis statement briefly captured one key social, ecological, or social-ecological finding that had been obtained through our empirical work in a given case study. For example, one synthesis statement from Australia was 'Specialised species of woodland birds require large patches of trees'. All these initial synthesis statements were then sorted by systemic depth – i.e. a specific statement was classified as pertaining to one of the levels of parameters, feedbacks, design or intent (see Table 1 for examples). We note that although these synthesis statements were primarily based on our peer-reviewed publications, we cannot rule out that there was a certain degree of subjectivity involved as to which particular findings were deemed worthy of inclusion in this synthesis exercise. Because all authors were involved in this process, and because we all had expertise on multiple case studies, we believe that this subjectivity does not undermine the ability to meaningfully compare the case studies – the author team agreed that the synthesis statements generated accurately reflect the key findings resulting from the case studies.

Second, we compared the synthesis statements across the three case studies. Here, we paid attention to emerging themes, analogous to inductive coding in content analysis. We assessed if specific synthesis statements from multiple case studies could be re-written as a single shared statement. As examples, we had found that large patches of native vegetation were used by specialist species in all three landscapes; income diversification was important for local livelihoods in at least two landscapes; and remote settlements experienced emigration in at least two landscapes.

Third, we (i) generated a table of all synthesis statements (in the rows) by case study areas (in the columns); (ii) noted for each statement the level of systemic depth it pertained to (parameters, feedbacks, design, intent); and (iii) indicated for each statement to what extent it applied to a given case study area (not at all, somewhat, strongly, or very strongly). We also (iv) noted whether the particular statement constituted a potential problem for sustainability of the local social-ecological system, or a potential opportunity, or whether it was ambiguous. As examples, 'topography shapes land use' would be considered ambiguous for sustainability; 'land use is being intensified' would be considered a potential problem; and 'some actors are seeking change towards agroecological land management' would be considered a potential opportunity for sustainability. As with the first step of our analysis, we freely admit that there is a degree of subjectivity involved in the extent to which each statement was deemed to apply to a particular case study; as well as to the extent to which a given statement was deemed to constitute a problem for sustainability. However, here, too, we note that as authors of the previous empirical studies, we were well-positioned to interpret our own, prior findings. Moreover, the vast majority of decisions were not difficult – for example, food insecurity or conventional intensification of agriculture are widely agreed upon to be sustainability problems. Therefore, as for the first step of analysis, we do not believe that a certain level of subjectivity undermined the overall objective of our paper; namely to provide a proof of concept for a new type of structured comparison of multiple social-ecological systems.

Finally, then, we separated the data by systemic depth (parameters, feedbacks, design, intent), and screened the resulting four tables for notable patterns. Here, we paid attention to commonalities and differences across the case studies, as well as to problems and opportunities for sustainability across the different levels of systemic depth.

Results

To provide sufficient context for our structured comparison, we initially present a short narrative summary of the main findings in each study area; details can be found in the empirical studies listed in the supplementary material. After this initial overview, we use the leverage points framework to compare the case studies.

Summary of findings in each case study

In Australia, a key focus was on patterns of tree regeneration under different livestock grazing regimes, on large, privately owned farms. Tree regeneration generally was very poor across the study area because of grazing pressure and fertilizer inputs to which the native tree species were ill adapted, such that ecological models predicted major losses of the remaining tree cover over the next few decades. This, in turn, would have negative consequences for many ecological functions and services – including the diversity of birds and bats, as well as most likely ecosystem services such water infiltration or the provision of shade cover for livestock. Farmers had noticed and were concerned about this tree decline, but many were unsure what to do about it. However, we also uncovered major differences in tree regeneration among different types of farms, managed according to different paradigms. 'Holistic' grazing managers thought differently about their environment, and managed farms differently. They employed rotational grazing, with careful attention to their farm as a system, and used few inputs; this was found to benefit tree recruitment. 'Conventional' farmers, in contrast, generally placed somewhat lower importance on the dynamics of the natural environment or, alternatively, protected trees in fenced areas or strips, but grazed livestock continuously elsewhere; tree regeneration levels on conventionally managed farms were typically lower. Looking into the future we found that planting regimes, whether concentrated or distributed, would not have a significant impact on tree cover under conventional grazing. Moreover, we learned that climate adaptation was an apparent co-benefit of holistic management, based on outcomes during the 2000–2010 'Big Dry' drought, during which the research was done. Yet transition from conventional to holistic management had financial, technical and social barriers, which were exacerbated by government funding norms, including that drought support was not coupled to environmental performance.

In Romania, we investigated how traditional smallholder farming landscapes were changing, in both social and ecological ways. Especially following Romania's accession to the EU in 2007, traditional farming livelihoods had become increasingly unviable – farmers typically own relatively small parcels of land, and for this and other reasons have difficulties accessing agricultural subsidies by the European Union. This, in combination with multiple types of political and institutional uncertainty and low levels of finance and other types of capital, put pressure on local residents to either intensify farmland use, or abandon farming altogether (and emigrate from their villages). Such impending changes to land use in turn, would have likely consequences for biodiversity, ecosystem services, and the social fabric of villages. Farmland heterogeneity, for example, was found to be a key driver of the biodiversity of birds, butterflies and plants – but such heterogeneity may be lost if traditional practices are discontinued. Moreover, land use change went hand in hand with changes in the local population structure and changes in people's perceptions of the natural environment, indicating a gradual erosion of traditional landscape values. Attitudes towards the natural environment related not only to farmland but also to the forest. A key challenge found was living side by side with the European brown bear (*Ursus arctos*), which led to occasional human-wildlife conflicts. Looking into the future, we found that different stakeholders held different desires for how the landscape should be used in the future – many, however, preferred a scenario of sustainable rural livelihoods.

In Ethiopia, the intersection of rural livelihoods with biodiversity was a central interest of our research. All land was government-owned, but most households had traditional use rights to small parcels of land, both for agricultural use and to harvest products such as coffee and honey from the otherwise strictly protected forest. Most rural residents pursued diversified livelihoods, and households growing a combination of multiple food crops and cash crops were most food secure. Equity dimensions emerged in several aspects of the work. For example, some residents had trouble with accessing forest resources but suffered crop raiding by forest wildlife; poor residents were often involved in unequal labour relationships with wealthier residents; and women, due to cultural norms around decision-making roles, had substantially lower agency than men. Land use was highly heterogeneous, and farmland supported many different species of both birds and trees. Trees, in turn, were widely used for many different purposes, and thus were central to people's well-being. The forest, too, offered a large variety of different benefits, including the provision of the culturally and economically important cash crop, coffee. Despite the importance of natural resources, their degradation and overuse were identified as key challenges for the future – be it through the use of agrochemicals in the farmland or the intensification of coffee cultivation in the forest. Governance was found to be strongly hierarchical and sometimes highly sectoral. In terms of future trends, population growth and climate change pose major underlying challenges. How these challenges play out will depend to a high degree on uncertainties in land use decisions.

Structured comparison among case studies

System characteristics at the parameter level

Approximately half of the synthesis statements, across the three case studies, were at the parameter level. They denoted a mixture of positive, negative and ambiguous effects on sustainability. All three case studies exhibited at least some areas of high biodiversity, all three exhibited agricultural intensification; and all three were subject to similar external drivers such as climate change or agricultural input prices. Despite numerous similarities, there were also obvious differences stemming from differences in socioeconomic context. For example, Australia did not suffer in major ways from problems related to poverty or inequity, while Ethiopia experienced these issues particularly strongly (Table 2).

Table 2. Social-ecological synthesis statements at the parameter level identified in at least one case study.

Synthesis statement	Effect on sustainability	AU	RO	ETH
* Biodiversity is high.	positive	++	+++	+++
* Specialist species can survive in large patches.	positive	+++	+++	+++
* Generalist species can survive where the matrix is hospitable.	positive	+++	+++	+++
* Farmland biodiversity benefits from landscape heterogeneity.	positive	+++	+++	+++
Cultural and ecological tourism brings new options.	positive	0	++	0
Traditional institutions have social-ecological benefits, and there is evidence of social-ecological co-evolution.	positive	0	+++	+++
* Some social changes towards sustainability are underway.	positive	+	+	+
* Tree cover is being lost.	negative	+++	+	++
* Agricultural intensification is taking place.	negative	++	++	++
* Intensification harms ecological processes.	negative	+++	++	++
There is substantial human-wildlife conflict.	negative	0	+	+++
Food insecurity is a problem.	negative	0	0	++
Land scarcity is a widely agreed problem coupled with population growth.	negative	0	0	+++
Human, financial and social capital stocks are generally low.	negative	0	+++	+++
Access to ecosystem services is inequitable.	negative	0	++	+++
* Economic profitability of farming is a key feature shaping the system.	negative	+++	+++	++
Rural decline is taking place (abandonment of farming, discontinuation of practices).	negative	++	++	0
* Topography is shaping land use.	ambiguous	+++	+++	+++
* Landscape heterogeneity has historical roots.	ambiguous	++	+++	+++
Land holdings are large.	ambiguous	+++	0	0
Land holdings are small.	ambiguous	0	++	+++
* Climate shocks are a challenge.	ambiguous	+++	+	+++
* Agricultural inputs are costly.	ambiguous	+++	+	+++
Infrastructure is improving.	ambiguous	0	0	+
* Demographic change is a key part of current dynamics.	ambiguous	+	++	+++
Most rural residents (not only farmers) depend on local ecosystem services.	ambiguous	0	++	+++

Statements were classified as likely to have a positive, negative, or ambiguous effect on sustainability. Statements applicable to at least some extent to all three study areas are marked with an asterisk (*). (Legend: + denotes weakly present; ++ moderately present; +++ strongly present; 0 denotes not present; AU = Australia, RO = Romania, ETH = Ethiopia).

System characteristics at the level of feedbacks

Relatively few synthesis statements were identified at the feedback level. Only two types of feedbacks were found to have positive effects on sustainability, relating to the benefits of agroecological farming and good information flows enabling adaptation. A reinforcing feedback with negative sustainability consequences in all three systems related to path dependency caused by conventional agricultural intensification (Table 3).

System characteristics at the level of design

At the design level, many more design features were found to have negative effects on sustainability than positive ones. For example, across all study systems, government policies were found to be sectoral and supporting conventional agricultural intensification; and in all systems, local land use was influenced by global forces (e.g. markets, donors, or international discourses). At least some features of system design supporting sustainability were present in every case study – including, for example, strong social networks in Australia, innovative bottom-up initiatives in Romania, or co-evolved and partly sustainable social-ecological system dynamics in Ethiopia (Table 4).

System characteristics at the level of intent

At the level of system intent, most of the identified synthesis statements applied to all three study systems. Of these, most were associated with negative effects on sustainability. Specifically, all three landscapes were dominated in their trajectories by goals and paradigms related to conventional agricultural

Table 3. Social-ecological synthesis statements at the level of feedbacks identified in at least one case study.

Synthesis statement	Effect on sustainability	AU	RO	ETH
* Despite some trade-offs, there are social-ecological co-benefits of using the environment for agroecological ways or holistic ways of farming.	positive	++	++	++
* Good information flows and social relations enable adaptation.	positive	++	++	++
Agricultural abandonment and poor governance cause path dependency.	negative	0	++	0
* Conventional agricultural intensification causes path dependency.	negative	++	+	++
Intensification is caused by traditional practices being not viable.	negative	0	++	+
Lack of knowledge about the past is starting to cause a shifting baseline syndrome.	negative	+	+	0
Patterns of inequity are self-reinforcing.	negative	0	+	++

Statements were classified as likely to have a positive, negative, or ambiguous effect on sustainability. Statements applicable to at least some extent to all three study areas are marked with an asterisk (*). (Legend: + denotes weakly present; ++ moderately present; +++ strongly present; 0 denotes not present; AU = Australia, RO = Romania, ETH = Ethiopia).

Table 4. Social-ecological synthesis statements at the level of design identified in at least one case study.

Synthesis statement	Effect on sustainability	AU	RO	ETH
The social-ecological system has co-evolved.	positive	0	+++	+++
Pro-sustainability social networks facilitate innovation.	positive	+++	+	0
There are bottom-up socio-cultural initiatives seeking transformative change.	positive	+	+++	0
Local positive examples of pluralistic leadership exist.	positive	++	++	0
* Some ecological monitoring programs are in place.	positive	++	++	++
* External inputs in agriculture are encouraged by the government (directly or indirectly).	negative	++	++	+++
Locally evolved institutions are disappearing.	negative	0	+++	+
* Policy programs are short-term and can shift abruptly.	negative	+++	+++	+++
There is a mismatch between higher-level governance structures and goals vis-a-vis local realities.	negative	0	+++	+++
* There are siloed higher-level governance approaches to conservation management and rural development, ignoring interdependencies.	negative	+++	+++	+++
* Local governance is shaped by outside forces.	negative	+	+++	+++
There are power abuses by government	negative	0	++	++
Governance is strongly hierarchical (top-down), limiting individual agency.	negative	0	++	+++
Inequalities are maintained through formal and informal rules.	negative	0	++	+++
Market access is uneven within the landscape.	negative	0	++	+++
Accessing government support is limited by low levels of human capital.	negative	0	+++	0
Information flow between municipalities is poor.	negative	0	0	+++
Initiatives seeking transformative change are poorly coordinated.	negative	0	+++	+++
There are financial barriers to using more sustainable land use practices.	negative	+++	+++	0
Dominant (status quo) land uses receive institutional support.	ambiguous	+++	0	+
* There are differing approaches to using capital stocks to provide livelihoods.	ambiguous	+++	+++	+++

Statements were classified as likely to have a positive, negative, or ambiguous effect on sustainability. Statements applicable to at least some extent to all three study areas are marked with an asterisk (*). (Legend: + denotes weakly present; ++ moderately present; +++ strongly present; 0 denotes not present; AU = Australia, RO = Romania, ETH = Ethiopia).

intensification and a lack of appreciation of system complexity. Moreover, in all three systems, positive visions for sustainability were held by a minority of actors, yet were generally suppressed by more dominant forces (including non-local actors) (Table 5).

Discussion

There are relatively few nuanced approaches to qualitative synthesis across case studies to date. With this paper, we set out to provide a proof of concept, namely to demonstrate how a leverage points perspective can help to facilitate the structured comparison of social-ecological systems. Understanding enabling and constraining factors across multiple levels of depth that influence the sustainability of social-ecological systems provides three critical innovations.

First, a leverage points perspective encourages new ways of thinking about system dynamics. Many conventional representations of social-ecological systems – e.g. causal loop diagrams – focus primarily on causal relationships, leaving relatively little room for human agency about how to design systems or which goals to pursue through a given system. A leverage points perspective has the advantage that it acknowledges both causal and teleological explanations of system change (Fischer and Riechers 2019). That is, human agency is ascribed explicit importance

Table 5. Social-ecological synthesis statements at the level of intent identified in at least one case study.

Synthesis statement	Effect on sustainability	AU	RO	ETH
* Sustainability considerations are starting to be picked up in policy.	positive	++	++	++
* Some actors promote alternative approaches to land management, embracing diverse methods and land covers.	positive	+++	+++	+
* Immaterial values are ascribed to ecological features.	positive	++	+++	+
Current values represent co-evolved history of the social-ecological system.	positive	0	+++	+
* Aspirations for the landscape are diverse, differ between local and non-local stakeholders, and resulting clashes pose an obstacle for sustainability.	negative	+++	+++	+++
* Dominant narratives for agriculture follow a green revolution logic.	negative	+++	++	+++
* Instrumental (financial) benefits dominate farmers values.	negative	+++	+	+
Cultural values of the majority of rural residents overshadow concern for the environment (ETH = desire for many children; AU = taming wild nature).	negative	++	0	+++
* There are clashing paradigms around capital stock substitutability versus capital stock complementarity.	negative	+++	++	++
* There is a clash between cultural and ecological conservation goals and profit-driven agriculture.	negative	+++	+++	+++
* Biodiversity is secondary as a policy goal relative to food and fibre production.	negative	+++	+++	+++
* Sustainability discourses are clashing.	negative	+++	++	+++
* Higher-level governance is unaware of some key system features (e.g. wood pastures, scattered trees).	negative	+++	+++	+++
* Short-term benefits prioritized over long-term sustainability.	negative	+++	++	+++
* Formal conservation prioritizes large, pristine patches.	negative	+++	++	+++

Statements were classified as likely to have a positive, negative, or ambiguous effect on sustainability. Statements applicable to at least some extent to all three study areas are marked with an asterisk (*). (Legend: + denotes weakly present; ++ moderately present; +++ strongly present; 0 denotes not present; AU = Australia, RO = Romania, ETH = Ethiopia).

in this perspective, and diverse characteristics of a system are differentiated from the outset in terms of their depth (e.g. see Nguyen and Bosch 2013; Manlosa et al. 2018). A change in the direction of sustainability, arguably, will be most likely to occur where there is alignment across the system characteristics – or put differently, contradictory features across the four levels of systemic depth are unlikely to lead to a stable or sustainable system state. Especially for unsustainable systems, a leverage points perspective thus offers a new way to think about why the system is not behaving in the (sustainable) way one might like: contradictory forces may be pulling the system in different directions. Notably, although the distinction of different levels of systemic depth is a possible advantage of a leverage points perspective, this does not imply that other approaches are not also useful – rather, different ways of analysing systems have different, complementary strengths. For example, a causal-loop approach is especially useful for identifying feedbacks; a resilience lens is particularly useful for analysing surprises and alternative stable states; while arguably, a leverage points perspective is particularly useful to uncover otherwise hidden challenges pertaining to system design or intent.

Second, a leverage points perspective by its very nature offers an entry point for thinking about how to intervene in a given system. Evaluating a system's characteristics across multiple levels of depth reveals what might need to change. For example, if design characteristics prevent sustainability, then these need to change; if it is only parameter-level characteristics that stand in the way of sustainability, those need to be altered. Especially for deeper level characteristics, it may not be possible to directly intervene at the level of depth where the problem has been found. For example, it is not possible (nor necessarily appropriate) to 'engineer' different value systems or paradigms into an existing social-ecological system (Manfredo et al. 2017). Yet, if current paradigms underpin sustainability problems, then change at the level of paradigms is ultimately required (Ives and Fischer 2017). In such instances, it may be necessary to take an 'intervention detour' by considering possible interactions among system characteristics, and by carefully weighing the costs and feasibility of alternative plausible interventions. For example, Manlosa et al. (2018) demonstrated that attitudes towards women in southwestern Ethiopia (a deep system characteristic) had changed not through direct interventions but rather through system changes at the levels of system design (rules and institutions) and parameters (women being more present in public life) – which ultimately changed the gender-related social fabric at deeper levels.

Third, and as we showed here, the specific focus on four levels of systemic depth may help to uncover common challenges that apply to many social-ecological systems, even if the systems examined appear to be very different on the surface. Our case studies were all rural social-ecological systems, but in vastly different settings in terms of wealth, population density and agricultural methods. Still, we found many similar system characteristics. At the parameter level, certain ecological principles held in all three systems, sometimes with positive implications for sustainability – for example, heterogeneous farmland provided habitat for many species in all three systems. Similarly, certain types of landscape change with negative repercussions for sustainability were similar – for example, all landscapes experienced a trend towards conventional intensification of agriculture (Table 2). Feedbacks were found to be quite case-specific, but here, too, some similarities emerged – most notably, all three systems experienced path dependency driven by conventional agricultural intensification (Table 3).

In terms of common challenges, the most interesting findings probably emerged at the levels of system design and intent. At the level of intent, all three systems were fundamentally underpinned in their dynamics by paradigms and goals related to a green revolution logic – with agriculture being increasingly short-term profit-driven, capital-intensive and artificially separated from the local social and environmental context (Table 5) (see also Nyström et al. 2019). At the design level, many institutional challenges were identified. While these were often highly-place specific, the findings here showed that institutional design remains fundamentally challenging for the sustainable governance of rural landscapes (Table 4). Although this is widely recognized in scholarship on social-ecological systems (Anderies et al. 2004; Ostrom 2009), a leverage points perspective puts governance challenges into a context of other levels of system dynamics. A close connection very likely exists between the design and intent levels of social-ecological systems. For example, fundamentally underpinned by a paradigm of producing more food, the European Common Agricultural Policy fails to deliver good outcomes for biodiversity conservation (Otero et al. 2020; Pe'er et al. 2020). The dominant paradigm, in this instance, is simply not sustainability but agricultural productivism: the system is delivering rather well what it was intended and designed to do. Systematically uncovering such issues helps to focus interventions – at least in terms of the ultimate change that is being sought (see example on gender above) – at the level where change is actually needed. Put differently, countless well-intentioned parameter-level interventions for sustainability are likely to continue to fall short of expectations if they are not backed up by a system design and intent that actually prioritises sustainability goals and paradigms.

Finally, the approach outlined here not only highlighted commonalities across systems, but also locally unique differences. For example, Romania with its post-communist history has a very different social history from Australia, with its history of European colonisation causing cultural and environmental destruction; or Ethiopia, with its dynamic of rapid and ongoing human population growth. Even in the presence of some unifying, shared paradigms across systems, unique differences between landscapes may arise from differing ecosystems or actors being involved. The power dynamics between actors, in particular, vary in the different settings we studied. Australia has a relatively well-functioning representative democracy, highly skilled and educated farmers, and highly professional government agencies and non-government organisations. Romania has a much higher level of social heterogeneity, with power being far less evenly distributed among actors; in fact, corruption continues to be a major problem to this day. Ethiopia faces a different situation yet again, with highly powerful international donors (e.g. the World Bank or Bill and Melinda Gates Foundation) substantially influencing the directions pursued through government policy (e.g. a green revolution trajectory of agriculture) (Jiren et al. 2020); while local people are largely powerless recipients of the rules developed and enforced from the top down. Local differences such as these highlight the importance of deeply understanding the governance and power dynamics in different locations – purely science-driven recommendations for particular governance interventions may be unrealistic in many if not most landscapes of the world. What then, can social-ecological research in complex adaptive systems contribute? Arguably, engagement of stakeholders and co-learning is usually a good start; particular methods of engagement, in turn, need to be adjusted based on the local context (Reed 2008; see, e.g. Capitani et al. 2016; Freeth and Drimie 2016; Newig et al. 2018; Leta et al. 2020).

Conclusion

We set out to compare three case studies in order to provide a proof of concept for how a leverage points perspective can be used to compare multiple social-ecological systems. Through our comparison of case studies, we showed that a leverage points perspective is more than just hunting for the most effective interventions. When Meadows (1999) proposed a possible hierarchy of twelve leverage points, she sketched out increasingly deep levels at which the dynamics of a given system can be shaped. A central argument for taking a leverage points perspective is that such a lens helps to more comprehensively examine a given system's dynamics across varying depths from parameters to intent. This, in turn, provides vital information about the level at which change is most urgently needed. Moreover, such a perspective may help better understand how interventions at different systemic depths are likely to constrain or interact with each other.

In many cases, it is likely to be the deepest levels underpinning a system's dynamics – its intent, goals and paradigms – that ultimately need to change for the system's trajectory to become sustainable. As we showed here, agricultural landscapes from very rich to very poor are still deeply rooted in a green revolution paradigm pursuing capital – and input-intensive industrial agriculture. This paradigm, in many cases, is quite fundamentally at odds with key sustainability dimensions, such as biodiversity conservation or social equity. While the jury is out on how best to tackle the change of paradigms, a leverage points perspective provides new ways of thinking about these challenges. For example, which realistic institutional changes could help to promote different social norms (Everard et al. 2016; Nyborg et al. 2016)? Will decision-makers and other stakeholders think differently about their landscapes when guided to reflect on social-ecological complexity, including from a leverage points perspective? Which changes to current practice are needed to better align interventions across all four system levels, from parameters to paradigms? – This paper was not written to answer these questions, but rather to demonstrate that further pursuing a leverage points perspective when studying social-ecological systems holds substantial promise to uncover new ways to work towards sustainability. We acknowledge that this might be best achieved by designing new research projects explicitly taking a leverage points perspective from the outset. However, the analysis presented in this paper also suggests there is value in the post-hoc application of such a perspective, particularly as a means to compare and synthesize findings across the wide range of cases and contexts over which sustainability focused social-ecological systems research occurs.

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