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Social-ecological change: insights from the Southern African Program on Ecosystem Change and Society

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ABSTRACT

Social-ecological systems (SES) research has emerged as an important area of sustainability science, informing and supporting pressing issues of transformation towards more sustainable, just and equitable futures. To date, much SES research has been done in or from the Global North, where the challenges and contexts for supporting sustainability transformations are substantially different from the Global South. This paper synthesises emerging insights on SES dynamics that can inform actions and advance research to support sustainability transformations specifically in the southern African context. The paper draws on work linked to members of the Southern African Program on Ecosystem Change and Society (SAPECS), a leading SES research network in the region, synthesizing key insights with respect to the five core themes of SAPECS: (i) transdisciplinary and engaged research, (ii) ecosystem services and human well-being, (iii) governance institutions and management practices, (iv) spatial relationships and cross-scale connections, and (v) regime shifts, traps and transformations. For each theme, we focus on insights that are particularly novel, interesting or important in the southern African context, and reflect on key research gaps and emerging frontiers for SES research in the region going forward. Such place-based insights are important for understanding the variation in SES dynamics around the world, and are crucial for informing a context-sensitive global agenda to foster sustainability transformations at local to global scales.

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1. Introduction

A defining challenge for the coming decades is to effect large-scale societal transformations to tackle global poverty and inequality, and significantly reduce the negative impacts of our economies and other activities on the functioning of ecosystems and the Earth system (Steffen et al. 2015; Raworth 2017; Hickel 2018). This challenge is particularly acute in sub-Saharan Africa, where about half the population lives below the World Bank's poverty line (World Bank 2018). Populations in many African countries are expected to more than double by 2050 (World Bank 2018), the continent is experiencing very rapid urban growth, and extreme climatic events such as

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droughts and floods are projected to increase in magnitude and frequency due to the impacts of climate change (IPCC 2018; Otto et al. 2018; Sousa et al. 2018). These changes are likely to amplify pre-existing stresses caused by poverty, inequality, social tensions, burden of disease and social insecurity (World Bank 2018; UNDP 2020). At the same time, they will substantially increase demand for ecosystem services in the region, especially food, clean water and urban green spaces (IPBES 2018). These demands will increase pressure on the region's rich biodiversity and already-pressed agricultural systems (IPBES 2018; Archer et al. 2021). They will also affect important cultural services that underpin local identities and influence societal cohesion, affecting society's capacity to deal with social and environmental change (Archer et al. 2021). To shift regional development onto a more equitable, sustainable and just trajectory, a better understanding of and engagement with the particular social-ecological dynamics at play in the region are critical.

Sustainability science, which focuses on issues of intertwined social and ecological sustainability using transdisciplinary, problem-driven approaches, has emerged as a key research field to support sustainability transformations (Kates et al. 2001; Clark and Dickson 2003; Burns and Weaver 2008; Clark and Harley 2020). Social-ecological systems (SES) research is an important subfield within sustainability science (Clark and Harley 2020), supported by research networks such as the Resilience Alliance (RA) and the Programme on Ecosystem Change and Society (PECS) (Carpenter et al. 2012; Norström et al. 2017). While a growing body of SES work is being undertaken in the Global South, many theories and insights are still shaped by understanding and frameworks from the Global North (Collyer 2018; Nagendra et al. 2018; Pereira et al. 2020a). These are often not easily transferable to the Global South, given differing ecological, cultural and economic contexts. There is increasing recognition of the importance of understanding the particular SES dynamics of regions to support context-sensitive sustainability transformations at interconnected local to global scales (Pereira et al. 2018a).

The Southern African Program on Ecosystem Change and Society (SAPECS, sapecs.org) aims to contribute to this need by providing insights and perspectives grounded in the southern African context (Biggs and Reyers 2012; Biggs et al. in review). SAPECS is a leading SES research network in southern Africa and one of the first and largest regional case study networks linked to PECS. The objective of SAPECS is to build on previous and ongoing SES-related research activities in the region to advance stewardship of SES and ecosystem services in southern Africa by producing empirical evidence and theory, synthesising and mainstreaming knowledge, and growing the regional community of practice on SES research (Biggs and Reyers 2012; Biggs et al. in review). Southern Africa provides an important and rich context for research on social-ecological dynamics and the relationships between ecosystems, human well-being, inequality and poverty, given its high diversity of ecosystems, climate, cultures, property regimes and levels of inequality (Burns and Weaver 2008; IPBES 2018; Archer et al. 2021; Du Toit et al. 2021). Given the relatively low levels of socio-economic development in the region, and the potential to leverage existing pockets of wealth and expertise, there is a possibility for both higher-level policy and bottom-up interventions by civil society to influence future development along more sustainable trajectories (Swilling and Annecke 2012; Pereira et al. 2019a; Swilling 2020; Archer et al. 2021). This context has the potential to provide novel insights and approaches to address the substantial sustainability challenges faced in this and other regions.

This paper synthesises key insights on SES dynamics and research that have emerged in relation to five co-created research themes around which SAPECS has been organised (Biggs et al. in review): (i) transdisciplinary and engaged research, (ii) ecosystem services and human well-being, (iii) governance institutions and management practices, (iv) spatial relationships and cross-scale connections, and (v) regime shifts, traps and transformations. (Figure 1). After introducing our synthesis approach, the remainder of the paper focuses on each of these themes in turn. We start by briefly introducing each theme, then discuss key insights giving examples of illustrative work in the region, and conclude with a reflection on future research directions for the theme. The paper concludes with a brief synthesis of what we see as key contributions to SES research from the southern African community, and key areas of future research. We intend this to be a useful synthesis of the contribution and frontier of SES work in southern Africa to inform SES research, policy and practice in the region, the Global South more broadly, and globally.

2. Approach

To identify the insights presented here, we asked the group of approximately 30 SAPECS members to submit references to their work and the work of their students or research teams that relate to the objectives of SAPECS. A smaller team of authors worked through the 149 submitted papers, coding them for their relevance to the five themes. Rather than attempting a comprehensive synthesis of work under each theme, we identified 3–4 key

1
Transdisciplinary and engaged research

- Transdisciplinary initiatives have the potential to shift the *research-implementation gap* into a *research-implementation interface* characterized by active and iterative knowledge exchange over time.
- Transdisciplinary research relies on skilful facilitation by intermediaries, e.g. boundary spanners, bridging agents and knowledge brokers. Intermediaries embedded in implementation agencies can particularly contribute to transformative potential and post-project sustainability.
- Mutual learning in transdisciplinary initiatives is enhanced by careful co-design of co-learning spaces or "third places" conducive to dialogue among diverse actors.
- A focus on knowledge co-production can promote adoption and implementation of the products of transdisciplinary research, and mobilise practice-based and action-oriented knowledge.
- Transdisciplinary research requires long-term commitment. Single projects are typically too limited in scope to allow for the development of relationships and trust, problem co-framing, co-learning and co-production of knowledge among diverse actors.

2
Ecosystem services and human well-being

- Ecosystem services emerge and are mediated through social-ecological interactions and relationships, resulting in well-being and equity implications for different societal groups and geographies.
- Factors such as property rights, skills and access to financial and technical resources, as well as considerations of safety and security, contribute to determining ecosystem service outcomes and their diverse and plural values.
- Ecosystem services are vital for many households and communities on a daily basis for consumption and/or income. In addition, ecosystem services play an important role as a safety net in times of hardship, and as a coping mechanism for dealing with climate change and other interacting stressors, not only for the rural poor, but also for wealthier rural and urban households.
- Cultural services such as religious and ritual use, and sense of place are highly prevalent in the region, as are more nuanced attachments to nature, such as finding solace and comfort in nature, and coping with conflict, disease and migration.
- Assessing bundles of ecosystem services highlights complex people-nature interactions that co-produce services at different scales, which may pose distinct management challenges, particularly in protected areas.

3
Governance institutions and management practices

- Political regime changes can create 'windows of opportunity' that allow for large-scale social-ecological change. In southern Africa, transitions to democracy have created opportunities for experimentation with a diversity of new institutions and governance systems, particularly participatory approaches to natural resource management.
- Progressive, participatory policies and mainstreaming approaches, such as innovative conservancy models in the region, can provide enabling environments for building more equitable and resilient social-ecological systems
- Despite successes, challenges such as ineffective biodiversity conservation, a lack of substantive changes in power relations, societal conflict, and unequal and insufficient benefit sharing continue to feature prominently in the region.
- Several of these challenges result from 'missing capacities' in key stakeholder groups, often linked to the degradation of local institutions, compounded by a lack of bridging institutions and ignorance of the multiple values of nature and traditional institutions in management decisions and policies.
- Sustainable and just landscape-level governance requires intensive engagement at local level, particularly with traditional governance systems and other traditional institutions, but this engagement may be difficult to scale.

4
Spatial relationships cross-scale connections

- Southern African systems, particularly research on protected areas and freshwater systems, offer insights into the implications of cross-scale interactions for ecosystem services and SES.
- Protected areas interact with one another, the landscape in which they are embedded, and a range of broader-scale patterns and processes. Geographic proximity influences their resilience through its effect on both ecological connectivity and socio-economic interactions. At broader scales, protected areas are influenced by shifting global societal preferences, volatile international markets, anthropogenic climate change and uncontrolled movements of species and disease.
- Spatial connectivity of freshwater ecosystems calls for polycentric governance arrangements with cross-scale feedbacks. Work in the region has shown that deterioration of water quality and quantity in water source areas can have a disproportionately large impact ondownstream users. The disconnect between water source and water use means that the full social-ecological impacts of development in water source areas are often not apparent to decision-makers or users.
- The spatial scale at which studies and assessments are done can have significant consequences and needs to be carefully considered. A holistic and nuanced understanding of an SES often requires perspectives and insights from multiple scales.

5
Regime Shifts, Traps and Transformations

- Research on social-ecological regime shifts in the region have highlighted the impacts on ecosystems and human well-being, particularly in poor, rural settings. These shifts have been linked to long-term processes such as persistent poverty and inequality resulting from legacies of colonialism, past policies and systemically unjust processes.
- Southern Africa has been an important context for studying the dynamics of social-ecological traps and how these dynamics link to persistent poverty and a variety of sustainability challenges. Shifts are driven by factors interacting at multiple scales, such as historical policies and erosion of social capital that hamper people's abilities to respond to local vulnerabilities.
- A deeper understanding of the interconnectedness of entrenched poverty, environmental degradation and hunger has provided insight into how to break social-ecological traps through locally appropriate solutions.
- There is increasing work on social-ecological transformations in the region. Building futures literacy in order to guide transformative change equitably through acknowledging the diversity of people, perspectives and place is critical.

Figure 1. Key insights with respect to the five co-created research themes of SAPECS that have emerged from work in the region.

insights where we felt the southern African context provides particularly interesting or unique perspectives that may be of relevance to other regions and inform the future SES research agenda both in southern Africa and more widely. These insights were developed and refined through an iterative process of collective discussion and sense-making among the authors of this paper, a process that has been valuable in fostering learning and further building the SAPECS community (for more detail on the development of the SAPECS network, see Biggs et al. (in review)).

We present the insights in terms of each of the five core SAPECS research themes, supporting or illustrating them with examples from the submitted papers as well as from additional relevant papers that were subsequently identified or appeared in print. The synthesis we present draws primarily on insights from work conducted by researchers linked to SAPECS, but also references other pertinent SES studies in the region, as well as literature that has been particularly influential in shaping our work. We acknowledge that there are a number of researchers not linked to SAPECS that are conducting important SES work in the region; given the focus of this paper, their work may not necessarily be cited here.

3. Transdisciplinary and engaged research

Effectively addressing sustainability challenges requires integration of knowledge across disciplines, scales, sectors (e.g. conservation, agriculture and water) and the realms of science, policy and practice (van Kerkhoff 2014). Furthermore, it requires consideration of contextually relevant and place-based societal values, policies and management practices, including those based on indigenous and local knowledge (Lutz and Neis 2008; Tengö et al. 2014; Wyborn et al. 2019). Transdisciplinary research processes aim to address these needs by drawing on and integrating perspectives and approaches from a variety of disciplines, as well as actively working with stakeholders and practitioners in the co-design, conduct, communication and application of research (Max-Neef 2005; Hirsch Hadorn et al. 2008). Through collaborative and action-oriented engagement, researchers and societal stakeholders are afforded the opportunity for their understanding of a common social-ecological issue to co-evolve, and their often diverse perspectives to be reinterpreted and reconciled (Pereira et al. 2018a). Such integrative and collaborative modes of knowledge co-production can potentially help inform and shape sustainable outcomes (Lang et al. 2012; Reyers et al. 2015; Roux et al. 2017; Sitas et al. 2019).

There has been a strong tradition of transdisciplinary research in southern Africa (Reyers et al. 2010a; Roux et al. 2010, 2017; Cundill et al. 2015; Cockburn and Cundill 2018; Holden et al. 2019; Wolff et al. 2019; Taylor et al. 2021). Here we highlight four valuable lessons of broader significance. First, work in the region has demonstrated that transdisciplinary initiatives have the potential to shift the so-called *research-implementation gap* (see e.g. Knight et al. 2008) into a *research-implementation interface* characterised by active and iterative knowledge exchange over time (Cockburn et al. 2018a). When actors from different academic disciplines and from policy, management and/or communities work together, the researcher-practitioner dichotomy becomes less relevant (Reyers et al. 2010a; 2015; Sitas et al. 2016; Cockburn et al. 2018a; Buschke et al. 2019). This was evident, for example, in a transdisciplinary project on conserving freshwater ecosystems, for which diverse actors from academia, government and NGOs worked as a "transdisciplinary community of practice" (Cundill et al. 2015) to effect significant policy change (Nel et al. 2016, 2017). Similarly, in a transdisciplinary partnership between a local municipality and a university in Durban, South Africa, city officials worked with scientists to co-design an implementation-oriented research agenda to inform urban environmental planning and management (Cockburn et al. 2016). Transdisciplinary engagement also supported the facilitation of a complexity-based approach for integrating ecosystem services into disaster risk reduction in the Garden Route in the Western Cape province of South Africa, resulting in a sense of shared risk and responsibility in a place-based project between the private sector (short-term insurers and a major brewery), researchers, municipal officials and civil society (Nel et al. 2014; O'Farrell et al. 2015; Reyers et al. 2015).

Second, transdisciplinary research relies on skilful facilitation by "intermediaries" (i.e. boundary spanners, bridging agents and knowledge brokers). Intermediaries are skilled at creating conditions where the "weaving" of diverse social networks can emerge, building trust and creating specialised interfaces between participating actors and different sources of knowledge (Harris and Lyon 2013; Westley et al. 2013; Maag et al. 2018). Whereas it is common for academic researchers to fulfil the role of intermediaries (even during postgraduate studies (Holden et al. 2019)), work in the region has also highlighted that it is beneficial to have intermediaries embedded in implementation agencies, from where they contribute to the transformative potential and post-project sustainability (Roux et al. 2017; Taylor et al. 2021). Providing embedded researchers with appropriate financial, institutional and emotional support is critical to their effectiveness as intermediaries, and connecting them to a cohort of peers can be particularly beneficial (Taylor et al. 2021). Nourishing competencies for intermediaries in engaged,

transdisciplinary research requires "making the path by walking it" (Esler et al. 2016; Holden et al. 2019; Sellberg et al. 2021), and different people play and embody a multiplicity of roles when working in this space (Temper et al. 2019; O'Connor et al. 2021).

Third, mutual learning in transdisciplinary initiatives in the region has been enhanced by careful co-design of co-learning spaces or "third places" conducive to dialogue among diverse actors (Oldenburg 1989). In transdisciplinary research, third places are physical spaces that create an interface for learning between academia and practice, where researchers and practitioners have an equal voice when they engage to find common ground regarding a particular social-ecological issue (Roux et al. 2017, 2020a). The importance of physical considerations such as accessibility (e.g. a local school hall) and attractiveness (e.g. a meeting venue in a botanical garden), as well as seating arrangements that encourage interactions (e.g. the World Café method (Schieffer et al. 2004)) should not be underestimated. Furthermore, work in the region has highlighted that an effective transdisciplinary third place is characterised by a culture of mutual understanding and respect, explicit identification of values and ethical considerations (Wolff et al. 2019) and careful use of language to allow for more inclusive engagement between and across disciplines, cultures and social inequalities (Roux et al. 2017; Burt 2019). Work in the region has further demonstrated that engaged and action-oriented research that pays attention to the careful co-design of transdisciplinary third places, and use of methodological processes which take into account ethics, power and participants' values, can encourage more equitable participation and agency for participants from marginalised positionalities (Cockburn et al. 2018a; Masterson et al. 2018; Wolff et al. 2019; Pereira et al. 2020a).

Finally, work in the region has shown that a focus on knowledge co-production (Norström et al. 2020; Chambers et al. 2021) can promote adoption and implementation of the products of transdisciplinary research, and can mobilise practice-based and action-oriented knowledge (Reyers et al. 2015; Sitas et al. 2016, 2019; Cockburn et al. 2020; Preiser et al. 2021). Whereas mutual learning has long been a necessary condition of transdisciplinary research (Lang et al. 2012), co-production of knowledge has largely developed as a separate strand of literature (West et al. 2019; Wyborn et al. 2019). Knowledge co-production and mutual learning are often highly complementary processes, where knowledge co-production aims to translate the shared understanding created through the mutual learning into tangible products (Armitage et al. 2011). Similar to experience elsewhere, we have found that co-produced products such as visions, maps, shared strategies and conceptual models have not only helped to capture collective knowledge but also promote broad ownership and practical utility of transdisciplinary research products (Nel et al. 2016; Sitas et al. 2016; Turner et al. 2016; Roux et al. 2017, 2021; Cockburn et al. 2020).

An important caveat is that transdisciplinary research requires long-term commitment. Single projects (one to three years in duration) are typically too limited in scope to allow for the development of relationships and trust, problem co-framing and achieving co-learning and co-production of knowledge among diverse transdisciplinary actors (Esler et al. 2016; Turner et al. 2016; Wolff et al. 2019). A programmatic approach with assurance of long-term (>10 years) continuity, where a number of interdependent projects or studies address a specific social-ecological issue (Ommer 2007; Roux et al. 2010; Pollard et al. 2020), is probably required to realise the transdisciplinary ideals of system-wide learning and transformative change (see Pennington et al. 2013).

Looking ahead, research in the region continues to contribute to the ongoing development of transdisciplinary modes of research, potentially moving towards more transgressive approaches (Kulundu-Bolus et al. 2020) and an activist-scholar perspective (Temper et al. 2018, 2019). A specific focus is to investigate how transdisciplinary work can be conducted with integrity in the context of large societal inequalities (Wolff et al. 2019), while acknowledging the need to care for the well-being of societal partners and researchers (Sellberg et al. 2021). Such contexts pose substantial challenges, including the need for deep engagement with the ethics of working with vulnerable and marginalised groups, as expectations are set whenever research is undertaken (Tengö et al. 2017; Pereira et al. 2019a, 2020a; Wolff et al. 2019).

A further focus for the future is to offer prospective students who are pursuing transdisciplinary research institutional support and mentorship to develop competencies beyond those conventionally expected of traditional disciplinary researchers (Lotz-Sisitka et al. 2015; Cockburn and Cundill 2018; Holden et al. 2019; Biggs et al. 2021). Capacities such as epistemic flexibility and balancing the "moral burden" of responsible and ethical stakeholder engagement with that of achieving scientific excellence have been suggested as key competencies that should be nourished in young researchers both in the region and elsewhere (Sitas 2014; Cockburn and Cundill 2018; Haider et al. 2018; Sellberg 2018; Sellberg et al. 2021; Chambers et al. 2022). These capacities can be further developed and institutionalised when incorporated in learning structures outside of higher education (e.g. Duggan et al. 2021).

4. Ecosystem services and human well-being

An SES approach to ecosystem services aims to identify not only the biophysical production functions that underlie their supply but also the social factors and social-ecological interactions that are necessary for the co-production and realisation of ecosystem services for different groups of beneficiaries (Cowling et al. 2008; Reyers et al. 2013; Wessels et al. 2021a, 2021b). Mirroring developments globally (Wangai et al. 2016; IPBES 2018; Chan et al. 2020), and strengthened by a conducive decision-making environment that references ecosystem services in a number of policies (Reyers et al. 2015; Cumming et al. 2017), southern African ecosystem service research now encompasses a wide variety of ecosystem services and non-monetary valuation methods. It also focuses on the complex ways in which ecosystem services emerge and are mediated through social-ecological interactions and relationships, and the well-being and equity implications for different societal groups and geographies.

Studies from the southern African region have particularly highlighted the role of factors such as property rights, skills and access to financial and technical resources in determining ecosystem service outcomes (e.g. Henriksson Malinga et al. 2018; Sowman and Sunde 2018). These examples reveal legacies of unjust and racially discriminatory land or resource ownership and governance systems, as well as ongoing underinvestment in addressing these injustices (Venter et al. 2020; Sowman and Sunde 2021). Also key are safety and security, in that vulnerable members of society (e.g. women and children) often fear for their personal safety while harvesting natural resources, since wooded or "wild" areas are sometimes perceived to be associated with crime (de Neergaard et al. 2005; Shackleton et al. 2015, 2019a; Manyani et al. 2021). These concerns limit access to ecosystem services for the many female-headed households in the southern African region, and are often an additional driver of inequity and vulnerability in already highly unequal communities (Shackleton et al. 2014). Redressing inequalities needs careful consideration of the heterogeneity of both landscapes and people, and must account for the diverse and multi-functional ways in which ecosystem services are co-produced in the southern African region, as well as their diverse and plural values (Masterson et al. 2019a; Clements et al. 2021).

Additional insights come from research into the role of ecosystem services as a safety net in times of hardship, and as a coping mechanism for dealing with climate change and other interacting stressors (Shackleton and Shackleton 2012; Masunungure and Shackleton 2018). The safety net function of ecosystem services in poor rural areas is widely documented; however, research in the southern African region extends these insights to wealthier rural and urban households (Shackleton and Shackleton 2004; Paumgarten and Shackleton 2009; Shackleton et al. 2015; Cilliers et al. 2018). For instance, studies in urban areas across the region (including small and medium-sized towns) show a strong reliance by urban households on public land for a range of provisioning services (such as fuelwood, medicinal plants, wild foods and grazing, among others), which make significant contributions to poverty mitigation and, at times, alleviation (Davenport et al. 2012; Kaoma and Shackleton 2015; Shackleton et al. 2018a). In addition, urban green spaces can provide situation-specific, irreplaceable regulating and cultural services to urban residents across the socio-economic spectrum (O'Farrell et al. 2012; Shackleton et al. 2015; Cocks and Shackleton 2021). These findings underscore the important role of ecosystem services to beneficiaries beyond the rural poor, especially in times of hardship or crisis, while highlighting the diversity of users and of perspectives on these ecosystem services and disservices (Thondhlana et al. 2022).

In exploring the multi-faceted linkages between ecosystem services and human well-being, research in southern Africa has spanned many spatial scales and contributed to the development of novel research methods. Innovative systems-based approaches have been useful at the local scale to explore the links between climate change, food and water security, as well as health (Pollard and De Villiers 2020). Value assessments have shown the prevalence of cultural services such as religious and ritual use, and sense of place (Cocks et al. 2008; Thondhlana and Shackleton 2015; Cundill et al. 2017; Masterson et al. 2017; 2019a; Smit et al. 2017; Henriksson Malinga et al. 2018). New assessment techniques are beginning to uncover the significance of more nuanced attachments to nature that are especially important in poverty contexts, such as finding solace and comfort in nature, and coping with conflict, disease and migration (Mandondo 1997; Lynam et al. 2003; Cocks et al. 2012; Masterson et al. 2018; Njwambe et al. 2019; Cocks and Shackleton 2021). Work in the region also highlights that if use of local provisioning services decreases (due to interventions such as social grants), the value of cultural services becomes more prominent and a driving force in linking communities to nature (Chinyimba 2012; Shackleton and Blair 2013).

At the national scale, research has shifted from mapping the supply of single ecosystem services to

a systems-inspired approach of mapping bundles of services and investigating how they are co-produced. In South Africa, for example, bundles of provisioning services were used to identify distinct SES and relate to human well-being across multiple dimensions (Hamann et al. 2015, 2016). In protected areas, Ament et al. (2017) showed that visitor preferences strongly determined the bundle of cultural services provided by South Africa's national parks, and Roux et al. (2020b) demonstrated that cultural services are outcomes of complex people-nature interactions, thus posing distinct management challenges. Zoeller et al. (2020) have shown that South African birds can be grouped into "cultural functional groups" based on the cultural services they provide, suggesting a way of simplifying the evaluation of cultural services and their integration with ecological data.

Looking to the future, more dynamic explorations of the flows, relationships and feedbacks between ecosystems and people are required to address questions about how these interactions change over time and in response to different kinds of stressors (Shackleton and Shackleton 2012; Shackleton and Luckert 2015; Mausungure and Shackleton 2018; Falyai et al. 2019; Masterson et al. 2019b; Reyers and Selig 2020; Selomane et al. in press). Emerging research areas include equity and social justice implications of changes in ecosystem service bundles due to changes in climate (particularly in relation to water availability), property rights, land use and development (Thondhlana et al. 2022) and access to natural resources (e.g. Krüger et al. 2016; Thondlana et al. 2016), as well as the role of multiple ecosystem services in reducing the impacts of climate change and supporting adaptation (Rebelo et al. 2021). These are key research priorities, not just in rural areas but also in areas where urban growth is rapidly changing the social-ecological landscape, and in the context of formal vs informal development (Du Toit et al. 2018; Venter et al. 2020; Cocks and Shackleton 2021; Thondhlana et al. 2022). Innovative approaches must not only improve fine-scale spatial understanding of ecosystem services and human well-being, but also clarify the diversity of values and dimensions of well-being associated with nature across different groups, regions and time (Masterson et al. 2019b; Thondhlana et al. 2022).

A further frontier for research and policy is in the application of SES approaches to ecosystem and natural capital assessment and accounting frameworks, e.g. in the development of evidence-based policies on sustainable diets and food systems (Sobratee et al. 2022), innovations in relational approaches to sustainable development indicators (Selomane et al. in Press), and in the first generation of ecosystem accounts produced to move Systems of National Accounts beyond GDP to better account for the role of ecosystem services (Nel and Driver 2015). In many of these advances, southern Africa not only offers some of the first examples of such approaches, but also does so in a context of complex socio-political legacies and in ways that bridge local-global, terrestrial-freshwater, and urban-rural divides, which have hampered ecosystem service research and practice.

5. Governance institutions and management practices

Governance strategies and practices influence how individuals and groups make decisions, share power and access resources (Bevir 2013). Such influence can be either formally recognised in the form of policies and accepted decision-making processes, or it can be subtler in the form of norms of behaviour that shape the ways in which power is shared and decisions are contested (Folke et al. 2005). How governance shapes decisions and resource use in a particular context depends on structural considerations (Ostrom 2010) as well as the roles of key individuals (Bodin and Crona 2011), shadow networks (Folke et al. 2011), social movements (Ernstson et al. 2008), traditional institutions and values (Mosimane and Silva 2015; Masterson et al. 2017) and history (Cundill and Fabricius 2010; Cockburn et al. 2019).

The interplay between structure, power and agency, particularly in the context of governance transitions, has been at the heart of work on the governance of ecosystem services in the region. In southern Africa, transitions to democracy in the last 30 years created "windows of opportunity" (Olsson et al. 2006) that opened the region to large-scale social-ecological change (Fabricius et al. 2001; Biggs et al. 2015), resulting in experimentation with a diversity of new institutions and governance systems (Campbell and Shackleton 2001; Shackleton et al. 2001). Particularly notable have been experiments in participatory approaches to natural resource management, involving many examples of devolved decision-making about natural resources. Examples include the ground-breaking work in the Campfire programme in Zimbabwe during the 1980s and 1990s (Frost and Bond 2008), the establishment of conservancies to protect Namibia's wildlife and benefit local communities (Mosimane and Silva 2015), policy shifts towards collaborative management in the context of land reform in South Africa (Kepe 2008) and development of a range of policy instruments and collaborative platforms to support stewardship of natural resources by communal and private landowners (e.g. Barendse et al. 2016; Cockburn et al. 2018a, 2018b, 2019; de Vos et al. 2019).

The region offers several examples of innovative policies and mainstreaming initiatives that explicitly account for impacts on ecosystem services and

society (Reyers et al. 2010a; Cumming et al. 2017). Shifts in South Africa's water law, for example, prompted the establishment of Catchment Management Agencies (CMAs) and Water User Associations (WUAs) to give voice to water needs at local and landscape scales (Palmer 1999; Munnik et al. 2016; Weaver et al. 2019). Similarly, the South African government's "Working for" natural resource management programmes, such as Working for Water, arose from the alignment of biodiversity goals (reducing invasive alien plants) with development goals (growing employment and water provision) (Turpie et al. 2008; Cadman 2010; Reyers et al. 2010b). Furthermore, conservation policies in support of private and communal stewardship and conservation initiatives (e.g. Cadman 2010; Boudreaux and Nelson 2011; Barendse et al. 2016; Rawat 2017; Cockburn et al. 2018) have allowed for the establishment of a diversity of protected and other area-based conservation instruments in the region, managed by diverse stakeholders ranging from private individuals to traditional institutions and the state.

Despite such progressive and enabling policy shifts (Shackleton et al. 2001; Turpie et al. 2008; Sowman et al. 2014), actions and outcomes on the ground have not always been as expected (Young and van Aarde 2011; Roux and Nel 2013) or desired (Pillay 2004; Kepe 2008; Wilhelm-Rechmann and Cowling 2011; Isaacs and Witbooi 2019). The implementation of the current co-management policy on protected areas in South Africa, for example, has led to widespread reports of ineffective biodiversity conservation, a lack of substantive changes in power relations between communities, traditional governance structures and the state (Cundill et al. 2013; Krüger et al. 2016; Masterson et al. 2019b; Pollard et al. 2020), societal conflict (Cundill and Fabricius 2010; Thondhlana et al. 2016; Thondhlana and Cundill 2017) and unequal and insufficient benefit sharing (Bollig and Menestrey Schwieger 2014; Hauck and Wynberg 2014; Krüger et al. 2016; Cundill et al. 2017). Many water catchment management forums have proved toothless or unrepresentative (Munnik et al. 2016), and "Working for" programmes have struggled to achieve intended job creation and environmental outcomes, partly as a result of inappropriate performance indicators (van Wilgen and Wannenburgh 2016). Although South Africa's biodiversity stewardship programmes have seen significant success in collaborative public-private conservation (Rawat 2017), they have also led to a narrow view of biodiversity stewardship among conservation practitioners and the exclusion of important private or communal conservation actors (Cockburn et al. 2019).

As southern African researchers have shown, many of these issues have resulted from "missing capacities" in many stakeholder groups (Cundill et al. 2013), often linked to the degradation of local institutions under apartheid (Weyer et al. 2019). In the case of co-management of protected areas, the lack of local capacity and agency is compounded by a lack of bridging institutions and ignorance of the multiple values of nature and traditional institutions in management decisions and policies (Cundill et al. 2017; Masterson et al. 2019a), a problem that also applies to the governance of urban green spaces (Gwedla and Shackleton 2015). In the case of negotiating governance pathways towards more participatory and equitable access to natural resources, Clifford-Holmes et al. (2016, 2018) usefully identified the "muddled middle" – the territory between "rules in form", for example the South African National Water Act 36 of 1998, and "rules in use", for example the implementation of well-managed wastewater treatment works or environmental flows – where sustainability and equity intentions flounder. Moreover, there is growing evidence of non-governmental organisations and research institutes playing an important role in facilitating collaborative resource management in instances where formal government institutions are not functioning as intended (Cockburn et al. 2018a, 2020).

The southern African SES community has made important gains in understanding the interplay of structure, power and agency to "make things happen" (Westley et al. 2013) in governance transitions. We have learned, for example, that sustainable and just landscape-level governance requires intensive engagement at local level, particularly with traditional governance systems and other traditional institutions (O'Farrell et al. 2019; Wolff et al. 2019). However, this engagement may be difficult to scale (Cockburn et al. 2018b). Whereas initiatives that seek to build sustainable resource governance can leverage existing structures and skills in some urban and agricultural landscapes (Cockburn et al. 2019; O'Farrell et al. 2019), many rural landscapes require extensive investment in the development of the necessary skills and capacities for local people to exercise agency and develop the requisite informal and structural institutions (Cockburn et al. 2018a, 2018b; Wolff et al. 2019; Pollard et al. 2020).

Several gaps remain in our understanding of just and sustainable governance of SES in southern Africa. Perhaps most fundamental is the inherent incongruity of applying natural resource management instruments that embody colonial and neoliberal values to a postcolonial state, where colonial and apartheid legacies have resulted in racially highly skewed access to natural resources and public services (e.g. Shackleton and Luckert 2015; Masterson et al. 2019a; Venter et al. 2020). Although there has been progress in understanding how to work in more

equitable and just ways within existing structures, the southern African SES research community has not yet risen to the challenge of imagining pragmatic, context-appropriate alternatives that incorporate the diverse values of nature and how they are embedded in knowledge and governance systems (Tengö et al. 2017; Masterson et al. 2019b; Merçon et al. 2019). Such alternatives (promising examples exist in food system research, e.g. Drimie et al. 2018) could guide the development of specific types of bridging institutions to navigate challenges such as widespread land reform in southern Africa (Clements et al. 2020), models of conservation that do not only rely on ecotourism and trophy hunting (Lindsey et al. 2020), providing equitable green spaces in cities (Gwedla and Shackleton 2015; Venter et al. 2020) and more sustainable governance of our oceans (Brodie Rudolph et al. 2020).

6. Spatial relationships and cross-scale connections

Cross-scale connections and feedbacks emerge when ecological and social components at different spatial or temporal scales interact, with the potential to create a range of (often unpredictable) system dynamics (Allen et al. 2016; Lindborg et al. 2017). Despite their importance in SES, cross-scale interactions and feedbacks remain challenging to identify, assess and quantify (Scholes et al. 2013; Selomane et al. 2019). Several useful insights regarding the implications of cross-scale interactions for ecosystem services and SES have emerged from southern African research, particularly in the realms of protected areas and freshwater governance, which we focus on here.

It is increasingly recognised that protected areas are SES that interact with one another, with the landscape in which they are embedded, and with a range of broader-scale patterns and processes (Cumming et al. 2015; de Vos et al. 2017). Southern African protected areas are diverse in tenure, including those governed by local, regional and national governments, private landowners and communities. This means they are influenced by political, legislative and socio-economic processes that function at different scales (de Vos et al. 2019). Protected areas are increasingly expected to justify their contributions, both to biodiversity conservation and local livelihoods (Cumming 2016). This holds particularly true in southern Africa, where protected areas have a history of displacement and exclusion of certain population groups (Spierenburg and Brooks 2014; Cundill et al. 2017), where government budgets for conservation are diminishing (Smith et al. 2021) and where the potential to generate jobs and revenues from ecotourism and hunting is high (de Vos et al. 2015; Clements et al. 2016a).

SES research on protected areas in southern Africa, including a SAPECS-led special feature (de Vos et al. 2017), has led to several key theoretical and practical contributions on how location and spatial variation affect ecosystem service provision and societal well-being at different scales. The resilience of protected area networks is shaped by geographic proximity of different units, through the influence of proximity on both ecological connectivity and socio-economic interactions, and is enhanced by the diversity of protected area tenure types (Maciejewski and Cumming 2015a, 2015b; de Vos et al. 2019). At broader scales, protected areas in the region are influenced by shifting global societal preferences, volatile international markets, anthropogenic climate change and uncontrolled movements of species and disease (e.g. COVID-19) (Cumming et al. 2015; de Vos et al. 2016; Clements et al. 2020). Furthermore, broad-scale socio-economic factors (e.g. visitor demand to see high densities of charismatic African wildlife) have the potential to drive fine-scale ecological management. This can lead to a systemic scale mismatch that can reduce long-term sustainability in cases where economic and conservation objectives are not well aligned (Maciejewski et al. 2015; Clements et al. 2016b; Biggs et al. 2017; Mannetti et al. 2017).

Research on freshwater systems has similarly provided useful insights on spatial relationships and cross-scale connections in SES. Deterioration of water quality and quantity in water source areas, which occupy a small fraction of the land surface area but supply a large amount of water to the surrounding regions, can have a disproportionately large impact on downstream users. Nel et al. (2017) found that just 8% of South Africa's land area contributes 50% of the country's run-off, supporting at least 51% of its population and 64% of its economy, but only 13% of these key water resource areas are currently formally protected. Furthermore, land-use choices in a catchment have consequences for water quantity and quality in downstream areas (Biggs et al. 2017; Brill et al. 2017a; Alavaisha et al. 2019). The disconnect between water source and water use means that the full social-ecological impacts of development in water source areas are often not apparent to decision-makers or users. The RESILIM-O programme (Pollard et al. 2020) addressed this challenge by mediating co-learning between water users in the middle and lower Olifants River catchment, to understand how inter-basin transfers in the upper catchment and impacts of low flows in the lower catchment can have catchment-wide impacts (Pollard and Retief 2020). These types of studies

and processes can provide information and understanding that enables strategic investments in land protection in key areas to leverage benefits across much larger scales.

The spatial connectivity of freshwater ecosystems makes their governance intricate (Kingsford et al. 2011) and calls for some degree of polycentric governance arrangements with cross-scale feedbacks (Biggs et al. 2017). This can be challenging, however, when national-scale policies are perceived to restrict local-scale management autonomy (Biggs et al. 2017; Brill et al. 2017a), or where management and funding models for connecting the source and benefit areas do not exist (Nel et al. 2017). Where effective arrangements are in place, combining top-down and bottom-up management targets can create complementary feedbacks that benefit the resilience of catchments (Roux et al. 2016; Biggs et al. 2017; Cockburn et al. 2018a). Pollard and Du Toit (2011) and Pollard et al. (2014) have developed a framework for exploring cross-scale connections and their outcomes for integrated water resources management. This framework calls for reflexive institutions that can engage across scales, identify feedbacks and learn (linking to the "innovative governance institutions and incentives" theme).

Southern African research on protected areas and freshwater systems has also demonstrated that the spatial scale at which studies and assessments are done can have significant consequences and needs to be carefully considered (Hamann et al. 2015; Maciejewski and Cumming 2015a; Ament and Cumming 2016; Brill et al. 2017b). A more holistic and nuanced understanding of a particular SES often requires perspectives and insights from multiple scales (Scholes et al. 2013). Synthetic and conceptual research by the SAPECS community has identified areas of progress in accounting for cross-scale dynamics in sustainable development indicators (Reyers et al. 2017; Selomane et al. 2019; Reyers and Selig 2020); approaches for undertaking cross-scale assessments in SES (Scholes et al. 2013); and a novel framework for thinking about alternative trajectories of development and the drivers of global impacts as a function of feedbacks resulting from wealth and ecosystem service dependence (Cumming et al. 2014; Hamann et al. 2015; Cumming and Von Cramon-Taubadel 2018).

Going forward, the roles of power structures and values (Cundill et al. 2017; de Vos et al. 2018) are still poorly incorporated in most formal approaches to cross-scale interactions and SES analyses. Southern Africa is an important region for addressing this gap, given the considerable inequality and associated power asymmetries that play out across the landscape. Recent and ongoing work explores these issues in the context of land reform (Clements et al. 2021) and access to ecosystems and ecosystem services (Shackleton et al. 2018a).

7. Regime shifts, traps and transformations

SES are complex adaptive systems that display nonlinear dynamics and sometimes undergo large, unanticipated systemic changes (Scheffer 2009; Preiser et al. 2018). Two related types of systemic change are pertinent in the study of SES: regime shifts and transformations. Regime shifts are large, persistent and often sudden changes in the structure and function of SES that have been documented in many systems around the world and have significant impacts on ecosystem services and human well-being (Biggs et al. 2018). Transformations similarly involve the fundamental reorganisation of an SES into a different characteristic structure, with different feedbacks and dynamics (Folke et al. 2010; Biggs et al. 2016; Pereira et al. 2020b). The key difference is that regime shift research usually focuses on examples of inadvertent change that often leads to the loss of well-being, whereas transformation research focuses on interventions that can shift a system to a configuration that produces improved well-being outcomes. Both concepts are linked to social-ecological traps, which refer to systems "stuck" in undesirable configurations (Cinner 2011; Enfors 2013; Boonstra et al. 2016).

In southern Africa, research on social-ecological regime shifts has highlighted the impacts of these shifts on ecosystems and human well-being, particularly in the context of SES in poor, rural settings (Shackleton et al. 2014, 2018b; Blair et al. 2018). There has also been work on potential pathways to maintain or transform SES towards desired states (Luvuno et al. 2018; Achieng et al. 2020). Regime shifts in the region have been linked to long-term processes such as persistent poverty and inequality resulting from legacies of colonialism, past policies and systemically unjust processes (Hoffman 2014; Puttick et al. 2014; Shackleton and Luckert 2015; Boonstra et al. 2016; Pereira et al. 2020b). In South Africa, for example, land reform and changes in land use that came with the end of the apartheid era contributed to increased deagrarianisation and urbanisation (Hebinck et al. 2018; Shackleton et al. 2019b), with significant impacts on vegetation structure (Hoffman 2014; Puttick et al. 2014; Luvuno et al. 2018). Colonial and apartheid era land-use policies have also resulted in a legacy of unequal access to ecosystem services and a lack of social cohesion in landscapes, making it difficult to manage these landscapes equitably and sustainably (Cockburn et al. 2019). The impacts of climate change are likely to be a significant contributor to regime shifts in the

region (Jarre et al. 2013; Stevens et al. 2016; Luvuno et al. 2018; Ward et al. 2021).

Southern Africa has also been an important context for studying the dynamics of social-ecological traps and how these dynamics link to persistent poverty and a variety of sustainability challenges in the Global South (Brown 2016; Haider et al. 2018). Studies in southern Africa have deepened understanding of the interplay between fast-changing environments and slow-moving social responses, and how this may hinder sustainable development (Hänke et al. 2017; Cole et al. 2018). Drawing on multiple sources of data and a substantial body of work in South Africa, Shackleton and Luckert (2015) identified various shifts in rural livelihoods, including increased deagrarianisation, growing unemployment and less remittances, a shift away from provisioning services and an increased reliance on social grants provided through government transfers. These changes were driven by factors interacting at multiple scales, such as historical policies and erosion of social capital that hamper people's abilities to respond to local vulnerabilities. Similarly, Boonstra et al. (2016) suggest a typology of people's responses to conditions that either dampen or reinforce trap dynamics, using three cases (including one in South Africa) to show that many of the possible responses to trap conditions further entrench poverty and deagrarianisation.

At the same time, analysis of social-ecological traps in southern Africa has unlocked locally appropriate solutions. A deeper understanding of the interconnectedness of entrenched poverty, environmental degradation and hunger, for example, provided insight into how to break social-ecological traps in south-western Madagascar (Hänke et al. 2017). Similarly, a holistic perspective and gender lens on overdependence and unsustainable practices in the Barotse floodplain fishery in Zambia revealed that both social innovation (specifically around unequal gender roles) and technological innovations in fishing have the potential to provide possible escape pathways (Cole et al. 2018). Cumming (2018) used a systems perspective to show how diagnosing social-ecological traps can help to find solutions to problems of cooperation in conservation at multiple scales. In the context of agricultural transitions towards urban societies, Cumming et al. (2014) describe a model that suggests that development and urbanisation may result in weak feedbacks to the resource, which could result in trap conditions. These conditions include alienation of urban people from the ecosystems on which they depend, resulting in overexploitation of those ecosystems. Hamann et al. (2015) used this model to map and explore SES dynamics based on ecosystem service bundles, and identified the major drivers underlying different systemic dynamics.

There is increasing work on social-ecological transformations in the region (Pereira et al. 2020a). In South Africa, alternative food system initiatives led by local entrepreneurs and activists are pushing back on the dominant food system regime with the aim of shifting towards a more locally sustainable and ethical food system (Pereira et al. 2019b). The Seeds of Good Anthropocenes project (goodanthropocenes.net) collects existing hopeful initiatives that have the potential to accelerate the adoption of transformative change (Bennett et al. 2016), including many examples from southern Africa. These "seeds" are used to develop future scenarios that paint an alternative picture to the dystopian futures that are often highlighted, and demonstrate radical options about the future (Pereira et al. 2018b; 2019a; Hamann et al. 2020). Building futures literacy in order to guide transformative change equitably through acknowledging diversity of people, perspectives and place is also critical, as demonstrated by scenario planning across a range of communities, including marginalised fishers (e.g. Gammage et al. 2021), national level stakeholder engagement around the South African food system (Malinga et al. 2013; Freeth and Drimie 2016), and providing options to decision-makers on just woodland management (Dziba et al. 2020).

Looking ahead, there is particular interest in advancing work on how to support social-ecological transformations in the region, in ways that are sensitive to the regional context, ecologically sustainable and socially just. Such research is challenging because it engages with ethical dilemmas and requires understanding of intertwined context-specific ecological, political, economic and cultural dynamics and demands the integration of diverse methodological frameworks (Pereira et al. 2019a). It also requires engaging with conflicting values and contested visions of the future (Preiser et al. 2017, 2021; Pereira et al. 2020c). In their paper on farming on the Wild Coast of the Eastern Cape in South Africa, for example, Shackleton and Hebinck (2018) suggest that there is no single pathway towards resilient livelihoods, with some people wanting to continue farming, while others are seeking a way out of an agrarian lifestyle. In another case in the Langkloof region of South Africa, the diversity of land uses and heterogeneity of land users have illustrated the importance of relational, pluralistic approaches to collaborative landscape management (Cockburn et al. 2019). Transformation in different policies, strategies and actions are needed to support each of these potential pathways and a number of them may need to be enabled simultaneously. Transformative scenario

planning and a variety of futures approaches are particularly powerful tools in this regard (Hichert et al. 2021). These tools are being applied in a variety of innovative ways in the region with the goal of facilitating and supporting transformative change (e.g. Pereira et al. 2018b; Hamann et al. 2020; Gammage and Jarre 2021).

8. Conclusion

The southern African region has become a hotspot for globally relevant SES research. SAPECS has provided an important platform to connect, leverage and advance SES research and practice in southern Africa, although much important work in the region is also being conducted outside this community. Our particular place-based context provides insights that are of relevance to informing and supporting transformation towards more sustainable, just and equitable futures in other regions in the Global South, and potentially more widely.

The southern African SES community has had a particular focus on adopting transdisciplinary approaches in the context of diverse and often conflicting stakeholder values and needs. Several important lessons have emerged from this experience, the most important of which is arguably the need for long-term commitment to a particular place to build the relationships and trust required for meaningful ongoing co-learning, action and reflection.

Another key research area of wider significance is the growing understanding of the multiple and cross-scale connections between ecosystem services and human well-being, and the far-reaching consequences of colonial histories and ongoing systems and structures of inequality. Work in the region has highlighted the need for more integrated and equitable approaches to address structural challenges in ways that link social and ecological outcomes across multiple scales. This, in turn, links directly to emerging work on knowledge co-production and supporting social-ecological transformations. The cross-scale dynamics that underlie structural challenges and outcomes of inequality highlight the need to move beyond current SES governance and management systems to approaches that embrace co-learning and polycentric governance and that challenge the status quo.

Lastly, work in the region has highlighted stark contrasts in SES governance capacity and approaches in different areas. It is clear that many areas in the region require extensive investment to develop the necessary skills and capacities to support sustainability transformations. This situation likely holds in many regions in the Global South.

Key areas of future SES work include the ongoing development of concepts, theories and methods to engage with SES dynamics, building on the strength in transdisciplinary practice in the region. Inequality and access to ecosystems and their benefits are particularly critical issues, and are closely linked to a growing focus on urban SES and rural-urban connections, decoloniality and issues of land reform, power and intersectionality, and diverse relations and understandings of people's connections to nature. These are, in turn, closely linked to a growing body of work on cross-scale social-ecological dynamics, and an emerging focus on understanding and fostering just and sustainable transformations that address the deeply intertwined social, economic and ecological challenges faced in the region.

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