Bridging social–ecological systems and ecological economics to navigate polycrisis

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Abstract
Human societies and ecological systems experience interacting and compounding crises, a condition often described as 'polycrisis'. To better navigate it, we propose a synthesis agenda at the interface of ecological economics (EE) and social–ecological systems (SES) research. Through collaborative synthesis and building on a practical framework of crisis dynamics as shocks and creeping changes, we identify four research avenues that specify where integration is feasible and promising. We focus on (i) the mediating role of human-made infrastructures in shock propagation; (ii) the influence of polycrisis dynamics on risk perception and behavioral response; (iii) trust and variations in collective action in response to threats; and (iv) shifting social–ecological meaning through the lens of diverse values of nature. For each avenue, we outline frontier questions that connect EE and SES, and examine interdisciplinary methodologies to address them. We also provide three specific examples with causal loop diagrams representative of the research avenues. We conclude by discussing the implications of combining EE and SES perspectives, and invite scholars from both traditions to engage more systematically together with the infrastructures, institutions, and power relations through which crises are experienced and governed.
Keywords:, resilience, shocks, creeping changes, biosphere, Anthropocene

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1. Introduction

The expansion of human activities over the past century paralleled profound biosphere degradation (Folke et al., 2021). Consequences manifest in the form of 'crises'—climate extremes, conflicts, biodiversity loss, weakening of international cooperation, etc.—which reinforce one another. This condition is frequently referred to as a 'polycrisis' (Lawrence et al., 2024; Delannoy et al., 2025a, 2025b), and calls for a paradigm shift in how crises are understood and managed.

Two bodies of scholarship appear well suited to navigating polycrisis[1]: ecological economics (EE) and social–ecological systems (SES). EE foregrounds the economy as embedded within biophysical constraints, interpreting crises as symptoms of overshoot and of distributional conflict (Costanza et al., 2020). EE employs a large spectrum of approaches including societal metabolism, heterodox macroeconomics, ecological unequal exchange, or institutional and regulation theories (e.g., Dorninger et al., 2021; Jacques et al., 2023; Dyca et al., 2024; Bouffange, 2026; Haberl et al., 2026). On the other hand, SES focuses on how wellbeing and risks emerge from interactions between human activities and the biosphere, notably through non-linear and cross-scale feedbacks (Biggs et al., 2021). Central to SES is the interplay between fast and slow variables (Walker et al., 2012), and how it gradually builds or erodes capacity for adaptation and transformation—often framed under the umbrella concept of resilience (Biggs et al., 2012; Folke et al., 2016). While EE and SES share intellectual roots (Schandl et al., 2025), they remain largely applied separately to the study of crises. We argue that this is a critical gap, as both approaches are complementary and have the potential, when combined, to provide a coherent account of polycrisis that explains how infrastructure, institutions, and power relations shape exposure to, the spread of, and responses to crises.

In this paper we outline an agenda that synthesizes EE and SES to strengthen how polycrisis is evaluated and acted upon. We first provide a practical framework for understanding crises as the results of 'shocks' and 'creeping changes'. Through iterative cross-disciplinary elicitations, we identify four research avenues, each with concrete questions: (i) the mediating role of human-made infrastructures in shock propagation; (ii) the influence of polycrisis dynamics on risk perception and behavioral response; (iii) trust and variations in collective action in response to threats; and (iv) shifting social–ecological meaning through the lens of diverse values of nature. We exemplify how our framework makes the research questions practical through causal loop diagrams, drawing case studies from the ShockTracker database, a collective and continuously updated collection of social–ecological shocks with descriptions of drivers, impacts, and dynamics (Wassénius & Rubin, 2025). Finally, we present for each avenue a set of methodologies for addressing the research questions, as an open path for integrating EE and SES traditions.

2. A practical framework for understanding polycrisis

Crisis is an ambiguous concept which today typically refers to prolonged and volatile turmoil unfolding across multiple scales and dimensions (Koselleck & Richter, 2006; Revault d'Allones, 2016). For practical analysis, we propose to see crises as the interrelations of two processes: 'shocks' and 'creeping changes' (Delannoy et al., 2025a). Shocks are sudden events that produce noticeable deviations in system functioning, often with non-linear propagation once critical thresholds are reached. Examples of shocks include wildfires, pandemics, market crashes, or ecosystem regime shifts. Creeping changes, by contrast, are slow processes with the potential for significant impacts on society or the biosphere (Delannoy et al., 2025a). They may be hard to detect, go unnoticed, or be ignored, such as in the cases of antimicrobial resistance, intergenerational inequities, and biodiversity loss—all of which show gradual change, yet remain unaddressed in light of the threat they pose (see respectively: Naghavi et al., 2024; Thiery et al., 2021; Keck et al., 2025).

Importantly, the concept of crisis is agent-relative. Shocks and creeping changes are positions on continuous spectra of suddenness (rate of change) and magnitude (size of change) (Fig. 1), which are

[1] We use "a polycrisis" when referring to a specific configuration of interacting crises, and "polycrisis" as a broader analytical condition or field of inquiry. This distinction reflects our view that multiple, concurrent, and cross-scales polycrises may coexist (see Section 2).

defined with respect to the expectations and capacities of actors (e.g., households, firms, regulators, resource users) and therefore can vary within one system. The same event may be anticipated by some actors and surprise others, and its impacts can be highly heterogeneous across groups or communities because exposure and vulnerability are uneven. This is particularly true for climate shocks, which disproportionately affect vulnerable populations, many of them in the Global South, despite these populations and countries having contributed least to the greenhouse-gas emissions driving climate change (Dong et al., 2024; Hazrana et al., 2025; Schöngart et al., 2025).

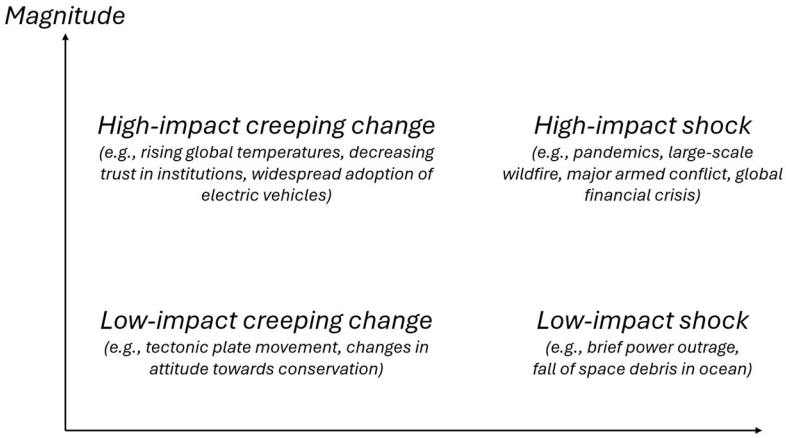

Figure 1 | Perturbations to a system can be characterised by their magnitude (vertical axis) and suddenness (horizontal axis). While both shocks and creeping changes can vary continuously along these axes, shocks tend to be more sudden (right-hand side) whereas creeping changes tend to be less sudden (left-hand side).

Shocks and creeping changes interact through feedbacks that can be reinforcing or balancing, with resilience outcomes depending on which feedbacks dominate and on whether stabilizing mechanisms are maintained, degraded, or deliberately strengthened (Walker et al., 2012). These interactions can be illustrated with the ball-and-cup metaphor (Fig. 2), where a ball represents the system state and the basin its resilience. A large shock can tip the system across a threshold even when the basin is deep. Creeping changes can hence erode resilience by making the current basin shallower, so that smaller shocks trigger regime shifts; or reinforce an emerging regime by deepening an alternative basin after a transition has begun. Conversely, policy and institutional design can aim to create balancing feedbacks that deepen the current basin (stabilization) or, in contexts where the status quo is undesirable, lower barriers to deliberate transformation while avoiding uncontrolled collapse.

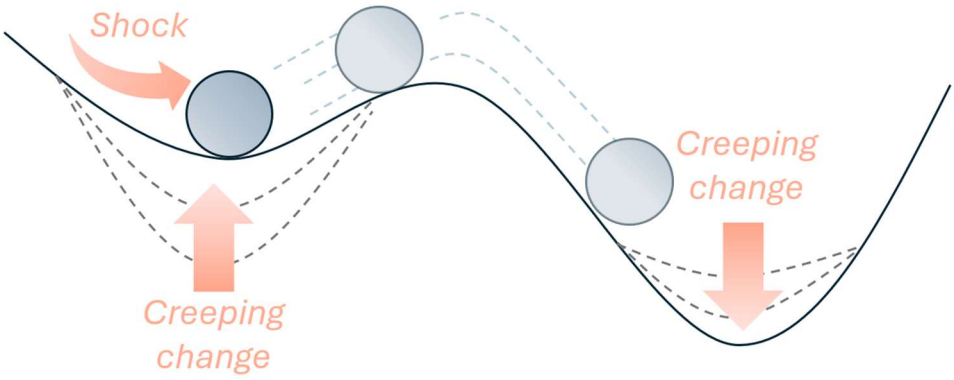

Figure 2 | Interactions between shocks and creeping changes. From left to right: as a shock impresses a force on the ball, the object is set in motion. A creeping change can make the basin in which the ball sits shallower, increasing the chance of the object skipping into the second basin, i.e., the new stable state. Creeping changes can also act as forces that deepen the basin, making it more likely to fall in, and difficult for the ball to return to its original stable state.

In our framework, a polycrisis arises when crises (i.e., shocks and creeping changes) interact and produce harms greater than the sum of those generated by each alone. This definition enables viewing the interaction of crises through infrastructures, institutions, perceptions, trust relations, and values that are deeply politically and economically entrenched. These mediating conditions shape who is exposed, whose risks are recognised, whose capacities to respond are supported, and whose losses are assessed and dealt with. While we recognize this definition is one among several competing formulations (see for instance Zaki, 2025 and Bieler, 2026), its value lies in allowing for multiple, concurrent polycrises, each with distinct mechanisms, boundaries, and temporalities. In doing so, we argue that it keeps crisis dynamics analytically connected to their political–economic and social–ecological contexts, and thus lays the foundations for a fruitful dialogue between EE and SES. These considerations form the basis of the research avenues.

3. Four research avenues

We identify four research avenues on polycrisis at the interface of SES and EE. Refined through collaborative synthesis, these avenues are used as a synthetic organising device, structured around propagation, interpretation, coordination, and meaning in polycrisis dynamics (Fig. 3). Rather than being exhaustive, they specify mediating mechanisms through which shocks and creeping changes become socially and materially organised: (i) the mediating role of human-made infrastructures in shock propagation; (ii) the influence of polycrisis dynamics on risk perception and behavioral response; (iii) trust and variations in collective action in response to threats; and (iv) shifting social-ecological meaning through the lens of diverse values of nature. Infrastructures shape how disturbances move through material and informational systems; risk perception shapes whether deterioration and disruption are noticed, interpreted, and acted upon; trust and shared expectations shape whether collective responses can be coordinated under uncertainty and unequal burdens; and values of nature shape what is recognised as loss, what is prioritised during disruption, and which forms of adaptation or transformation appear legitimate.

Figure 3 | Conceptual representation of the four research avenues.

3.1. The mediating role of human-made infrastructures in shock propagation

Infrastructure can be understood as any coherent structure that modifies the flow of materials or information in a system (Anderies et al., 2016). Throughout history, humans have repurposed natural infrastructures (e.g., wetlands, forests) and built extensive hard infrastructures (e.g., canals, transmission lines, seawalls, transport networks, and data centres). They have also developed soft infrastructures, understood here as institutions, including rules, norms, and shared strategies that shape how information is interpreted and how actors' coordination occurs (Anderies et al., 2016).

Infrastructures organise how shocks and creeping changes move through social–ecological systems. Hard infrastructures, including storage systems, transport networks, monitoring devices, and communication systems, mediate variation in material and informational flows and thereby increase predictability (Anderies, 2015). Shocks can disrupt this function through direct damage to physical assets, while creeping changes can gradually alter baselines, accelerate wear and tear, and reduce useful lifetimes (Ji et al., 2024; Erda, 2026). Soft infrastructures, including rules, norms, organisations, and shared strategies, shape how social–ecological change is monitored, attributed, translated into decisions, and enforced through collective action (Wiechman et al., 2024; Davidson et al., 2024). Institutional arrangements are also vulnerable to slow erosion and abrupt disruption. Creeping changes in trust, demographic composition, values, perceived risk, and wealth concentration can weaken institutional capacity, while shocks such as financial crises, disasters, regulatory change, or conflict can rapidly reconfigure authority, compliance, and legitimacy (Bhalla et al., 2024).

As hard and soft infrastructures are coupled, they affect where pressures accumulate, how disturbances travel across sectors and places, which groups experience disruption first and longest, and how these processes feed back on resilience (Hull & Liu, 2018; Yu et al., 2024). What currently remains underdeveloped, however, is an account of how shocks and creeping changes propagate through coupled hard–soft infrastructure configurations and when this coupling stabilises systems or converts disturbances into compounding crises. For example, recent socio-metabolic research has called for closer links between material-flow analysis and SES, precisely because resilience depends on more than technologies or resource stocks alone (Haberl et al., 2026).

On this basis, we suggest three lines of inquiry for bridging SES and EE in relation to infrastructures. First, what are the conditions under which coupled hard and soft infrastructures buffer interacting shocks rather than amplifying them (see Box 1) and, more specifically, which design, financing, and governance attributes most strongly influence these outcomes? Second, how are creeping changes linked to political–economic investment cycles, such as slow deterioration and recurrent disturbance regimes, and how should evaluation of decision-making take stock of them? Third, to what extent does the co-evolution of hard and soft infrastructures lock systems into brittle configurations or enable an assemblage that strengthens resilience to uncontrolled cascading impact events?

Addressing these questions requires expanding infrastructure research toward frameworks and models of coupled hard and soft infrastructures. While infrastructure modeling is well established in engineering and risk analysis (Alderson et al., 2015; Ji et al., 2024), existing approaches often underrepresent institutional rules, coordination networks, investment incentives, maintenance regimes, and other forms of soft infrastructure that shape how shocks and creeping changes propagate (Chester et al., 2023; Davidson et al., 2024; Wiechman et al., 2024). Future work could therefore connect societal metabolism data with empirical representations of soft infrastructure, including collaborative and institutional networks (Bodin et al., 2016). Combined with network models of infrastructure interdependence and institutional resource regime analysis (Dyca et al., 2024), this would allow researchers to ask when infrastructure systems absorb disturbances, when they displace costs onto other groups or ecosystems, when they amplify cascading impacts, and whether property rights or instruments are coherent with the cumulative human pressures generated.

Box 1 - Droughts in the Panama Canal

The Panama isthmus experienced a compounding series of severe droughts in 2014 and in 2023 (Carse, 2017; Tandon, 2024). In 2014, water levels in the Panama Canal fell from ~27m to 24.5m, significantly reducing water availability for domestic use, and disrupting global cargo traffic with an estimated economic impact of US$1.25 billion (Carse, 2017). In 2023, water levels in the Canal dropped by nearly 2m, causing a 30% decline in shipping traffic (Muñoz et al., 2025) and an important displacement of local communities (Panama Canal Water Crisis, 2025).

Climate scientists identified the El Niño Southern Oscillation as one of the atmospheric drivers of the 2023 event (Tandon, 2024; Woodwell Climate Research Center, 2024; World Weather Attribution, 2024). Through the gradual reduction of rainfall intensity in the wet season and the earlier onset of the dry season, this reduction in precipitation acted as a shock to an exposed infrastructure, as its functioning is reliant on an abundance of freshwater. The drought-induced stress in the Panama isthmus was exacerbated by a growing demand for global cargo shipping and an associated increase in vessel size, which required larger volumes of water to cross the Canal's dam system (Woodwell Climate Research Center, 2024). Economic activities had already intensified freshwater demand per transit, heightening the Canal's susceptibility to drought (Woodwell Climate Research Center, 2024) as each ship transit requires on average 197,000 m³ of freshwater (Carse, 2017).

During the 2023 drought, the Panama Canal Authority, in agreement with the national government, proposed to satisfy the freshwater demand from surrounding water reservoirs to reduce operational strain (Carse, 2017; Panama Canal Water Crisis, 2025). While this intervention would have enabled shipping traffic to continue, though at a lower frequency, it aggravated the impacts of the drought on the lives of local Panamanians especially for agriculture, cattle rearing, river tourism (Chico et al., 2024; Burk, 2025) and domestic use (Woodwell Climate Research Center, 2024). Overall, the crisis in the Panama Canal involved the compounding of climatic shocks and creeping changes—including the increase in shipping traffic through the Canal, aggravated by local water management interventions (Fig. 4).

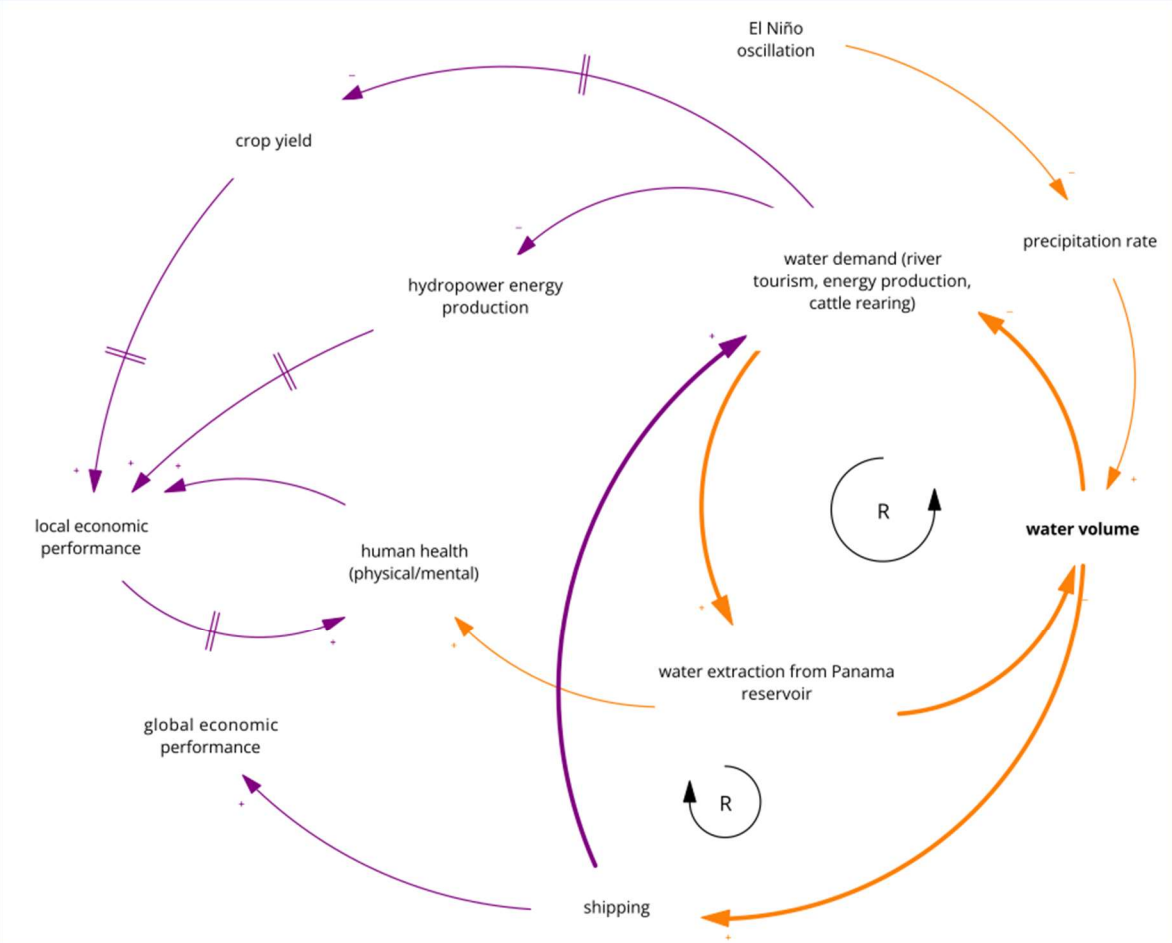

Figure 4 | Causal loop diagram describing the main interactions between creeping changes (purple) and shocks (orange) in the Panama Canal droughts of 2014 and 2023. Double lines indicate delayed relationships and R indicates a reinforcing loop. Note that the diagrams and boxes are illustrative applications of the framework rather than full causal reconstructions.

3.2. The influence of polycrisis dynamics on risk perception and behavioral response

Risk perception is central to understanding and responding to polycrisis, yet it is also challenged by the temporal dynamics through which crises unfold. Creeping changes are especially difficult to mobilise against because their signals are gradual, contested, and often absorbed into everyday experience. As a result, people may come to treat recently experienced conditions as normal: for instance, the perceived remarkability of temperature anomalies can decay over short time windows, so that objectively unusual conditions rapidly come to be experienced as ordinary (Moore et al., 2019). This process is consistent with prospect theory and shifting baseline syndrome, both of which suggest that people judge change relative to familiar reference points rather than against fixed or absolute standards (Kahneman & Tversky, 1979; Soga & Gaston, 2018). As these reference points shift, the same physical deterioration may register as a smaller perceived loss than it would have under an earlier baseline. This weakens the motivation to bear present costs for prevention and helps explain why creeping changes often fail to trigger collective action. Expectations about future conditions and others' behavior therefore become central to whether people prepare for slow-onset risks and sustain cooperation over time (Andrews et al., 2024; Syropoulos et al., 2025; Tuytens & Haberstroh, 2026). Present-oriented preferences may further reduce attention to gradual change, while shocks can disrupt existing priorities and either strengthen or undermine long-horizon commitments (Law et al., 2024; see Box 2).

Shocks pose a different challenge because they are filtered through salience, affect, and habituation. Salient events are more likely to be treated as decision-relevant, while affect shapes whether they generate urgency and protective action. This can distort probabilistic judgement, as vivid or recent shocks tend to be overweighted, while less visible or less recent risks are discounted, producing cycles of overreaction and neglect (Johnson & Tversky, 1983). Similar salience effects may also shape expert and institutional risk assessments, where highly visible risks can receive disproportionate attention relative to slower or less measurable forms of harm (Delannoy et al., 2025c). Salience, however, does not guarantee response. As harm scales up, psychophysical numbing can reduce sensitivity to additional losses, weakening motivation precisely in the high-damage tail that dominates polycrisis outcomes (Slovic & Västfjäll, 2010). Repeated or prolonged exposure can also produce habituation. During the 2009 H1N1 outbreak, anxiety and protective behaviors declined within days after initial spikes (Jones & Salathé, 2009), and precautionary measures decreased over subsequent weeks even when perceived risk remained high (Ibuka et al., 2010).

Amidst polycrisis, the link between risk perception and response becomes more uncertain, as overlapping crises redirect attention, reshape how governance interventions are judged, and affect willingness to comply with collective measures or support investments with immediate costs and delayed benefits. This is what happened for instance following the first COVID-19 wave, when climate concern declined and acceptance of most climate policies increased, with the shifts covaried with pandemic-related beliefs and evaluations of government response (Drews et al., 2022). This raises three questions. First, what are the conditions under which compounding shocks weaken the link between public concern and support for policy action? Specifically, we support the exploration of the extent to which this effect depends on the belief of crisis interdependence and institutional effectiveness. Second, how do creeping changes and shocks reshape risk perception by shifting reference points, and which strategies may help reduce the resulting biases? Third, how do creeping changes affect behavioral readiness and support for preventive action before damages become visible?

To better understand how polycrisis dynamics shape risk perception and affect appropriate behavioral responses, we propose the use of methods enabling the exploration of causal relationships and moderation/mediation effects, alongside longitudinal designs that capture changes over time and practice theory approaches (e.g., Iragena et al., 2026; Nolte et al., 2026). At the same time, insights from past shocks and creeping changes can be explored through comparative analyses and hybrid modeling (Brown & Rounsevell, 2020; Webster et al., 2025), to assess how different factors have influenced risk perception and responses in the past. Such approaches can support modeling of future scenarios and help mitigate biases in both perception and response to shock impacts, and should be part of the emerging synthesis of behavioral ecological economics (Della Valle et al., 2025). We contend

264 that the loss and damage literature offers a promising bridge between EE and SES for examining why
265 risk awareness may not lead to adaptation, why responses may be delayed or maladaptive, and how
266 unequal capacities, vulnerabilities, and responsibilities or power relationships shape the space for action
267 in the face of crises (Gawith et al., 2020; Boyd et al., 2021).
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Box 2 - Floods in Valencia, Spain

On October 29, 2024, the eastern coast of Spain was shocked by torrential rainfall, causing extensive flooding and mudslides across the city of Valencia and the surrounding region (Copernicus, 2024; WMO, 2024). The floods led to more than 200 casualties (European Space Agency, 2024) and affected over 325,000 people, destroying 53,000 ha of cropland and damaging 3,200 km of road infrastructure (Copernicus, 2024). Due to the impact on real estate, €3.1 billion in insurance claims were requested, which contributed to nearly €11 billion in total economic losses (Munich RE, 2025).

The downpour reached 491 l/m² in specific areas (World Meteorological Organization, 2024) and was triggered by a recurring weather phenomenon referred to as DANA (Depresión Aislada en Niveles Altos, Spanish for isolated depression at high levels) in the east of the Iberian Peninsula (Copernicus, 2024; World Meteorological Organization, 2024). The isolated rainfall pocket forms when cold air travels from the Atlantic Ocean and collides with warm air from the Mediterranean Sea. Global planetary warming and land use interventions at the local level have contributed to the creeping increase of regional temperatures, and have heightened the frequency of DANA events in lower latitudes, as per Murcia and Andalusia in 2024 (BBC News, 2019).

Early forensic investigations into the institutional responses to the event identified the government's late declaration of a level 3 flooding emergency (i.e. at the national level) as the primary social aggravator of the shock (Galvez-Hernandez et al., 2025). Similar cognitive biases to the ones mentioned in Section 3.2 could have contributed to the delayed response to the flooding emergency. For example, trend-extrapolation bias, the tendency to expect change to continue at the same pace and direction, neglecting potential acceleration or threshold effects (Ostinelli & Luna, 2024), could have skewed perceptions of the true flooding risk. However, in 2024 the rainfall evolved into an event of unprecedented magnitude, which had not been accounted for in the fiscal policy decisions taken by the Valencian government in the preceding years. One such decision affected the Valencian Emergencies Unit which had been defunded in 2023. During the DANA event, the absence or weakening of dedicated emergency-response capacity may have reduced the scope for preventive coordination and increased reliance on ex-post military and police deployment (Hagan, 2024; López-Carrión et al., 2025; Galvez-Hernandez et al., 2025; Martin-Moreno et al., 2025). Eventually, roughly 15,000 troops and police officers were deployed to support existing relief efforts (Hagan, 2024), but communities had already suffered severe damage due to the vulnerability induced by the austerity measures.

Another mechanism, self–other discrepancy bias, i.e., the tendency for people to believe that they are less at risk than are others in the environmental domain, might have influenced the local policymakers to underestimate the risk of a flood of unprecedented magnitude in Valencia (Pahl et al., 2005). The hypothesis is illustrated in Fig. 5, whereby, at the beginning of the decade, several areas that should have functioned as flood plains in case of excessive rainfall were converted into residential zones, encouraged by the permits for real estate development that the government distributed despite the spatial planning guidelines (Galvez-Hernandez et al., 2025). This creeping change increased the exposure of the community and eventually led to the streets of the city to morph into urban rivers (BBC News, 2019). During the shock public spaces such as schools, libraries, and parks had to be closed to the public (BBC News, 2025).

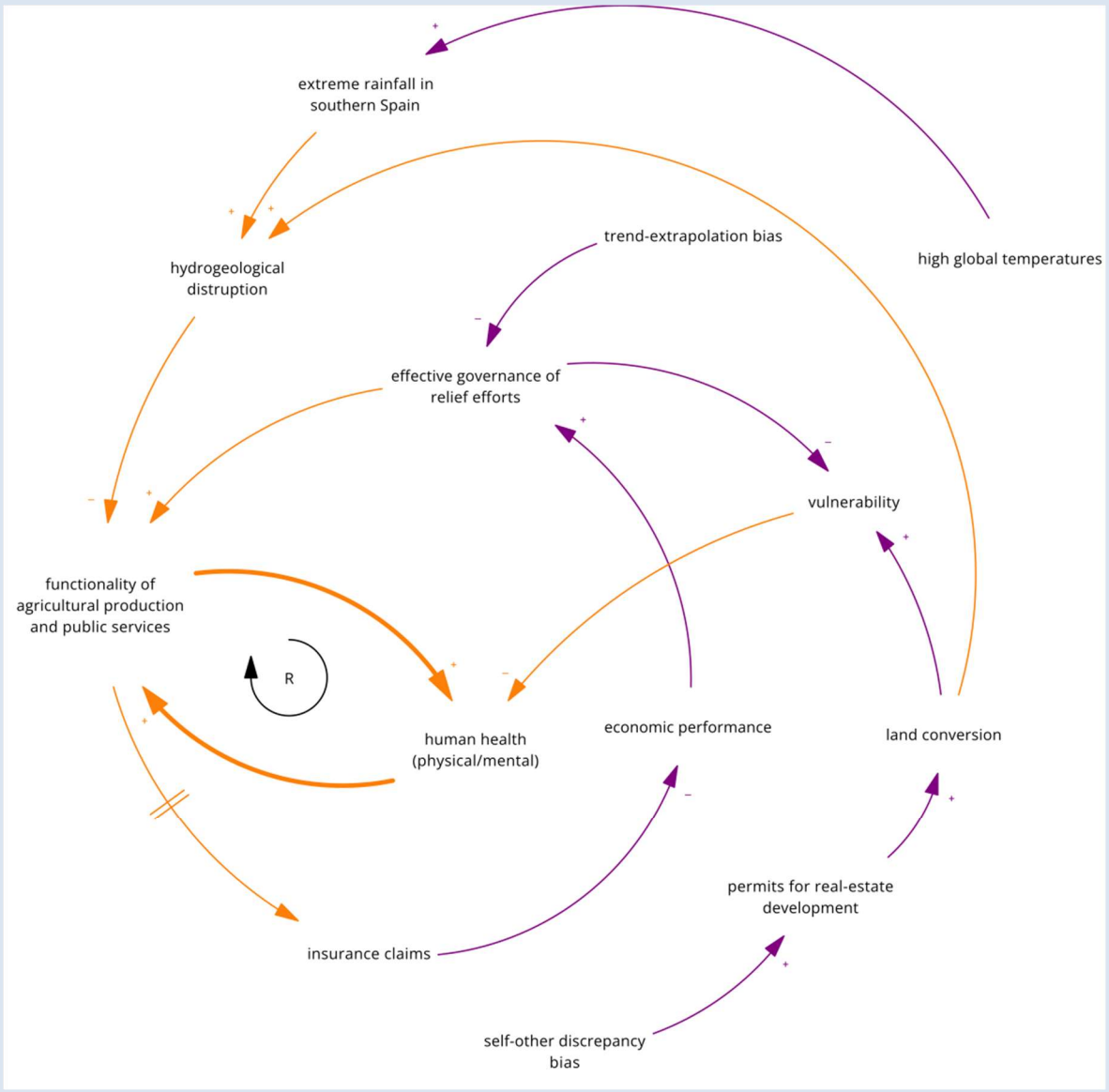

Figure 5 | Causal loop diagram describing the main interactions between creeping changes (purple) and shocks (orange) in the 2024 Valencia floods.

3.3. Trust and variations in collective action in response to threats

Effective responses to polycrisis strongly depend on whether groups can sustain collective action under uncertainty. This capacity is shaped by social conditions that support coordination, including trust, shared norms and expectations, and perceptions of fairness. Trust is central to effective response because it shapes whether people are willing to accept short-term costs for longer-term collective benefits as they expect institutions and individuals to act competently and fairly (Mayer et al., 1995; Levi & Stoker, 2000). Specifically, (vertical) trust in institutions and social pacts, the subset of trust-based relationships that we focus on in this section, influences both perceived risk and willingness to follow guidance when personal experience is limited and uncertainty high (Siegrist & Cvetkovich, 2000; Aldrich, 2012).

Where institutional trust is strong, compliance and willingness tend to be higher. Where trust is weak, frictions in communication and resistance to guidance become more likely when coordination is most needed. Trust also varies within societies because experiences with institutions differ systematically across groups, shaped by legacies of inequality, harm, and quality of government (Kitt et al., 2021; Kim et al., 2022; Polasky et al., 2025). Our current understanding of how these initial distributions of trust

shape trajectories of response in polycrisis is weak, especially because evidence on trust dynamics during crises remains mixed and the interaction between shocks and the slow erosion of trust alters compliance and conflict in various ways.

Beyond trust, collective action under polycrisis also depends on social norms and shared expectations, which define what behaviors are considered acceptable, what risks are taken seriously, and what obligations people recognise toward others (Nyborg et al., 2016). Trust is partly sustained by expectations of competent, fair, and cooperative behavior, while norms provide anchor points that make certain responses appear appropriate or expected (Oyebode & Nicholls, 2023). These anchors can stabilise cooperation, but they can also entrench complacency or socially reinforced risk-taking: periods of apparent stability may generate overconfidence and contribute to the systematic underestimation of long-horizon risks (Jones et al., 2020). At the same time, norms are not fixed. Experimental and modeling work suggests that once a sufficiently visible minority adopts and signals an alternative norm, collective expectations can shift rapidly, with estimates around a quarter of a population in some contexts (Centola et al., 2018; Andreoni et al., 2021; Smerdon et al., 2020). Polycrisis conditions may therefore create both inertia and instability in collective action, as crises and political transitions can unsettle apparently stable patterns of institutional and interpersonal trust (Devine & Valgarðsson, 2024). In some cases, declining confidence in government may be offset by greater reliance on interpersonal networks, as observed during COVID-19 (Besley & Dray, 2024); in others, institutional failure may spill over into broader erosion of social trust (Sønderskov & Dinesen, 2016).

This avenue motivates three research questions. First, what are the effects of creeping changes on the social and institutional conditions that sustain trust? For example, we ask how service reliability and perceived fairness reshape trust and collective responses over time, and under what conditions shocks amplify that erosion or generate short-lived "rally" effects that support compliance. Second, how do norms and shared expectations evolve when creeping changes normalise deterioration while shocks intermittently reveal vulnerabilities? Specifically, studies are needed on how these dynamics produce non-linear shifts in behavior and cooperation. Third, to what extent do people's beliefs about others' contributions to cooperation shift responses and efforts? In particular we encourage research on conditions that may shape preparedness and recovery, particularly when shocks and creeping changes interact and reallocate burdens across existing communities and generations.

Methodologically, this avenue calls for connecting work on collective action, institutional dynamics, and social–ecological networks with behavioral methods that examine cooperation under public-good dilemmas. Climate-game or experiments can test how repeated shocks, minimum contribution rules, and perceived free-riding affect willingness to cooperate, while survey-based approaches can measure conditional cooperation and beliefs about others' contributions (Becchetti et al., 2024; Abraham et al., 2025; Milinski & Innocenti, 2025). Storylines and stress-test represent another valuable path for exploring conditions enabling resilience (Hochrainer-Stigler et al., 2025). These approaches should be combined together, and can be connected as well with case comparison and institutional analysis to examine how cooperation depends on histories of service provision, exposure to prior disturbances, and procedural fairness, especially after shocks when policy responses are implemented under uncertainty and unequal conditions. In such contexts, fairness shapes whether people accept decisions by authorities and cooperate with one another, while equity frameworks can help assess how interventions affect marginalised and vulnerable groups through procedural, distributive, and recognitional dimensions (van den Bos & Wilke, 1998; McDermott et al., 2013; Langemeyer et al., 2024).

3.4. Shifting social-ecological meaning through the lens of diverse values of nature

Values play a key role in how societies understand their position with respect to nature, with framings such as "Nature despite people", "Nature for people" or "People with nature" predominating worldwide (Reyers & Bennett, 2025). Values underpin cultural and normative shifts and therefore influence who or what is deemed important in all kinds of decisions including environmental decisions, and which losses are treated as acceptable. Shifts in these values could shape how people prepare for shocks, what

they protect during emergencies, and how they interpret trade-offs when risks or damages accumulate slowly.

Values can be expressed at different hierarchical levels such as transcendental values (i.e., fundamental life principles), contextual values (i.e., situation specific judgements) and as value types such as instrumental concerns about benefits and livelihoods, relational concerns about identity, responsibility, and reciprocity, and intrinsic concerns about nature's worth independent of human use (IPBES 2022). These perspectives rarely appear in isolation in real decision-making, and their relative salience can shift over time (Ortiz-Przychodzka et al., 2025). Some shifts are gradual, as when market integration and institutional incentives make extractive uses more socially legitimate. Others can be abrupt, as when shocks reorder priorities and reopen debates about what should be protected. Values shape both the drivers of creeping change and the management of shocks. For instance, in many contemporary management settings of resource governance, harvest limits are justified through instrumental aims such as sustained yield for particular commodities (Pauly & Froese, 2020; Putz et al., 2022). In other contexts, decision-making is anchored in reciprocity-based norms, exemplified by the Potawatomi "Honorable Harvest," which emphasises taking only what is needed and giving back to the land (Kimmerer 2025). These approaches can sometimes generate similar extraction levels in stable periods, yet they can diverge sharply when a shock forces triage. During a wildfire regime, for instance, instrumental priorities can focus response on protecting commercial timber and built assets, whereas relational or intrinsic priorities can shift attention toward habitats, culturally important species, and long-term ecosystem recovery.

In many settings, instrumental framings have been linked to marketisation and extractivist trajectories that contribute to creeping ecological degradation and to vulnerabilities that amplify shocks (Hickel et al., 2022). At the same time, relational values that emphasise stewardship and reciprocity are widely documented, but they can be displaced through global markets, colonial legacies, and cultural assimilation (Alessa et al., 2016). Such displacement can itself be understood as creeping change because it shifts what is considered normal and desirable in human–nature relations. Once institutional rules, livelihood strategies, and infrastructures align with instrumental priorities, value change can become self-reinforcing through everyday practice. Shocks can either deepen that lock-in or disrupt it. For example, the Greek economic crisis reshaped human-nature relations, in that it led to a reevaluation of instrumental framings in favor of a renewed engagement with nearby nature. It also spurred a rapprochement to relational values, as opposed to instrumental ones (Benessaiah & Chan, 2023). This process highlighted how deeply held relational values can also persist under long-term external pressure, as shown by Xhosa communities maintaining biocultural relations despite imposed Eurocentric framings (Cocks et al., 2012). Value change can thus be slow and resistant, yet not immovable. Shocks interact with creeping changes in shaping which values guide action (see Box 3).

This avenue highlights three research questions. First, how do prevailing mixes of instrumental, relational, and intrinsic values shape which creeping changes are tolerated, which ones are treated as urgent, and how do vulnerabilities accumulate prior to shocks? Second, when shocks occur, how do different value commitments shape response priorities and burden-sharing, and how do those responses feed back on the values that are reinforced through institutions, livelihoods, and daily practice? Third, under what conditions do shocks accelerate ongoing shifts in values, versus triggering reversals or pluralisation that expands the range of acceptable adaptation and transformation pathways?

Addressing these questions requires reframing economic and conservation practices around people–nature relationships and more-than-human relations. Research must examine how assemblages of instrumental, relational, and intrinsic values embedded in livelihoods, institutions, and practices shape what societies tolerate, ignore, or treat as urgent (Trisos et al., 2021). Deliberative, spatial, survey-based, and Q-methodological approaches can therefore be combined to examine how values shift before and after shocks (Keeler et al., 2025; Uggeldahl et al., 2025). Building on this, attention to "more-than-human synchronizations" — the intertwined rhythms of people, nature and livelihoods — can reveal where resilient economies exist (Mancilla García et al., 2024). Governance experiments and comparative studies across shocks and creeping changes can then track how crises redistribute

responsibilities and benefits, whose values guide responses, and whether disruption reinforces dominant instrumental framings or opens space for plural values and justice-oriented institutions (Langemeyer et al., 2024). This is particularly important in regard to the emerging ecological economics agenda for appropriate collaboration with communities in the Global South (Barkin et al., 2026).

Box 3 - Deforestation frontier, wildfires and erosion of values in Chiquitania, Bolivia

Between June and December 2024, 3,749 active wildfires raged in the Chiquitania region of Bolivia (Plan International, 2024). The fires displaced over 600 families in the Santa Cruz department alone (ACNUR, 2024) and affected nearly 4 million hectares of dry tropical forest (Plan International, 2024). Human and animal health were severely impacted, as were public services, including in-person school classes nationwide (Plan International, 2024).

The first creeping change has to do with the agrarian extractivism activity connected to land use change, which has evolved through the convergence of national states and economic elites interested in boosting agribusiness development, cross-border land rentiers seeking new income streams, global financial investors backing agribusinesses existing in the region, and workers and settlers hoping to make a living on the edge of the frontier (Ortiz-Przychodzka et al., 2025; Llanque et al., 2024). The establishment of an agrarian commodity frontier in the region contributed significantly to the change in land use and ecological dynamics. When heavy deforestation practices clear an area to make space for monocultures, the fire-resistant qualities of the local species is lost (Global Forest Watch, 2023; Devisscher et al., 2016). In Chiquitania, this enabled wildfire to spread extensively, causing the loss of forest cover and biodiversity (Agencia de Noticias Fides, 2024; Brújula Digital, 2025; Ortiz-Przychodzka et al., 2025).

A second creeping change concerns the erosion and reconfiguration of social–ecological meanings. The change in landscape architecture and the loss of endemic biodiversity in Chiquitania concurred with the erosion of human plural values of nature including contextual (i.e., value towards a particular element of nature such as a forest patch that burned down) and transcendental values (i.e., feeling like being part of nature). Moreover, the compounding drivers have generated a shift from relational values towards instrumental values of nature, which involves seeing ecological elements as a resource for monetary gains. For instance, 1,400 people reported that their relationship with nature was eroded due to the threat arising from their environmental surroundings (Ortiz-Przychodzka et al., 2025). The reconfiguration of territorial relations can therefore be read as a societal creeping change: it gradually alters livelihoods, expectations, and people–nature relations, while increasing the likelihood that future landscapes will be organised around more homogeneous and fire-prone land uses. This is especially dramatic for Indigenous communities for whom identity and biodiversity are ontologically bound (Llanque et al., 2024). When creeping changes and ecological shocks compounded in the Chiquitania region, they produced long-lasting social–ecological damage and may have increased exposure to future shocks.

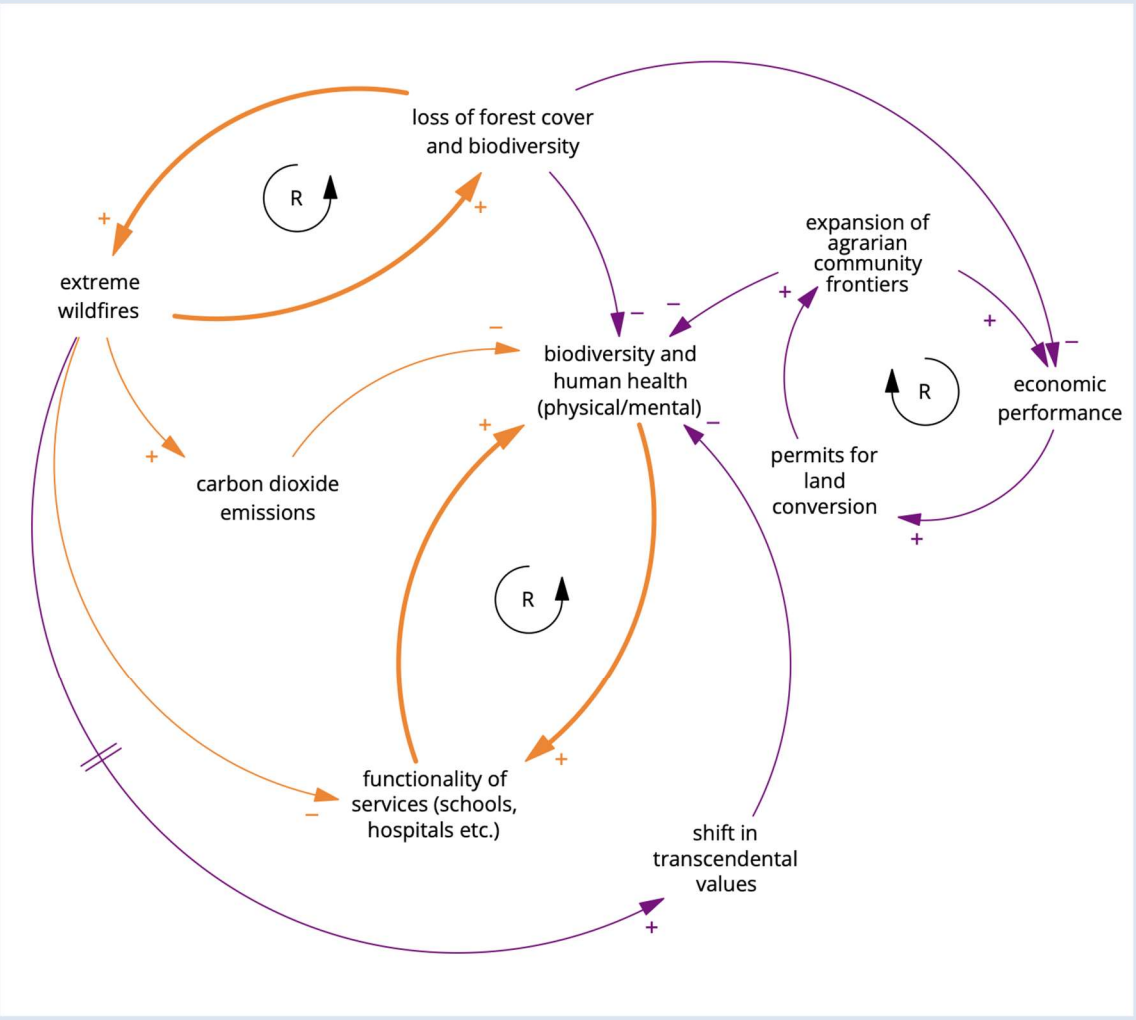

Figure 6 | Causal loop diagram describing the main interactions between creeping changes (purple) and shocks (orange) in the wildfires and erosion of values in Chiquitania, Bolivia, in 2024.

4. Conclusion

Ecological economics and social–ecological systems traditions each capture part of drivers and impacts of polycrises as well as potential responses to them, but common work needs to be strengthened. To support a bridge between EE and SES, we have outlined four research avenues that specify where this synthesis is feasible and promising. First, infrastructures mediate whether creeping changes and shocks are buffered or trigger cascading effects, and they provide concrete leverage points for resilience-building and deliberate reconfiguration. Second, risk perception, attention, and behavioral response shape whether slow deterioration is recognised early and whether repeated shocks generate learning or fatigue, with direct implications for the durability of prevention and investment. Third, trust, norms, and procedural fairness govern collective action under compound change and determine whether institutional guidance is followed. Fourth, plural values of nature shape what is treated as loss, what is prioritised under triage, and which adaptation and transformation pathways are seen as legitimate.

Polycrisis is not only the interaction of shocks and creeping changes. It is the interaction of shocks and creeping changes through infrastructures, institutions, perceptions, trust relations, and values that are politically and economically structured. We believe in the need to shift attention from naming crisis entanglement to explaining why vulnerability accumulates, how disturbances cascade, and under what conditions societies can redirect trajectories before disruption becomes collapse. The next step is to make these mechanisms empirically comparable across cases, while retaining the histories, values, and inequalities that make each crisis trajectory distinct.

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Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the authors used GPT-5.4 for spellchecking and as inspiration for rewording individual sentences, and GPT Image 2.0 to generate the central element of Figure 3. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Author contributions

L.D.: Conceptualization, Writing - Original draft, Writing - Review & Editing, Visualization, Supervision, Project administration. **G.R.:** Conceptualization, Writing - Original draft, Writing - Review & Editing, Visualization, Project administration. **B.A.B.O.:** Conceptualization, Writing - Original draft, Writing - Review & Editing. **F.B.:** Conceptualization, Writing - Original draft, Writing - Review & Editing. **N.C.-L.:** Conceptualization, Writing - Original draft, Writing - Review & Editing. **J.C.:** Writing - Original draft, Writing - Review & Editing. **G.D.:** Writing - Original draft, Writing - Review & Editing. **T.E.:** Writing - Original draft, Writing - Review & Editing. **J.H.:** Conceptualization, Writing - Original draft. **M.K.:** Writing - Original draft, Writing - Review & Editing. **N.S.K.:** Writing - Review & Editing. **N.L.:** Conceptualization, Writing - Original draft. **M.vE.:** Writing - Review & Editing. **E.W.:** Writing - Review & Editing. **A.W.:** Conceptualization, Writing - Original draft, Writing - Review & Editing, Visualization.

Declaration of interests

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

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