




# Futures for invasive alien species management: using bottom-up innovations to envision positive systemic change

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## Abstract

Invasive alien species (IAS) pose a key threat to biodiversity, the economy and human well-being, and continue to increase in abundance and impact worldwide. Legislation and policy currently dominate the global agenda for IAS, although translation to localised success may be limited. This calls for a wider range of responses to transform IAS management. An under-appreciated strategy to achieve success may come from bottom-up, experimental innovations (so-called “seeds”), which offer alternative visions of what may be possible for IAS management in the future. We present an application of a participatory process that builds on such innovations to create alternative visions of the future, with actionable pathways to guide change. Through a series of workshops with practitioners and academics, we used this process to explore alternative positive futures for IAS management in South Africa. We then identified a set of domains of change, that could enable these visions to be actioned by appropriate stakeholders. The domains of change highlight the social–ecological nature of the IAS sector, with interconnected actions needed in financial, cultural, social, technological and governance spheres. Key domains identified were the need to shift mindsets and values of society regarding IAS, as well as the need for appropriate and functional financing. This participatory futuring process offers a way to interrogate and scale bottom-up innovations, thereby creating optimism and allowing stakeholders to engage constructively with the future. This represents an important step in fostering the potential of bottom-up innovations to transform IAS management.

**Keywords** Futures · Biological invasions · Invasion science · Non-native species · Scenarios · Transformative change · Visioning

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## Introduction

Invasive alien species (IAS) are one of the five direct drivers of global change in the Anthropocene, with an estimated 20% of Earth's surface at risk from invasions (Balvanera et al. 2019). Globally, IAS are a key threat to many endangered species and habitats (Crooks 2002; Maxwell et al. 2016), while also presenting threats to human health, wellbeing and economies (Pyšek and Richardson 2010; Rai and Singh 2020). Despite increases in policy-orientated research in invasion science (Pinto et al. 2022) and in the development and implementation of legislation and agreements to manage and prevent this threat, there appears to be no saturation in the accumulation of alien species introductions worldwide (Seebens et al. 2017). This trend is linked to the complexity of the invasion process, which is affected by systemic global changes, including environmental change (e.g. climate change, ocean acidification), socio-economic drivers (e.g. globalised trade, human migration, land use change, socio-economic development) and socio-cultural drivers (e.g. awareness and values, communication, recreation and tourism) (Essl et al. 2020). Although there may be localised successes in preventing invasions and managing their impacts, the complexity of biological invasions as a both driver and passenger of change, combined with a lack of strategic, innovative and appropriately resourced management has led to a sector that is dominated by negative stories, trends, and a perception by many that, globally, we are “losing the battle” to appropriately manage IAS (Pyšek et al. 2020).

Futuring approaches provide a way to visualise and plan for different possibilities and interpretations of how the future may unfold, and to prioritise actions in the present which may lead to more desirable conditions for IAS management going forward (Miller 2018). For example, the scenarios developed by Roura-Pascual et al. (2021) to understand how social change may affect global biological invasions, highlight the potential for continued increases in IAS, and the need for large-scale change to prevent further spread. There are a wide range of approaches to generate such scenarios, ranging from quantitative modelling approaches, qualitative narratives of the future, and hybrid approaches that combine the two (Hichert et al. 2021b). Generally, future scenarios in the field of invasion science use predominantly quantitative approaches. However, qualitative or hybrid approaches have been valuable in exploring the future of complex social–ecological systems, given novel emergent dynamics and unanticipated drivers of change which may reshape system dynamics (Swart et al. 2004). Such novel dynamics are not well-accounted for in quantitative approaches, which tend to be constrained by past and present understanding of

dominant system drivers and dynamics. Qualitative futuring approaches that focus on “weak signals” or “wild cards” as first indications of impending changes, can highlight potentially radically alternative future pathways (Cook et al. 2014). These signals can take the form of bottom-up initiatives that have transformative potential (Bennett et al. 2016). Exploring how such initiatives may help to create a more ecologically and socially sustainable world in the future may provide an underappreciated source of knowledge and capability for tackling invasions (Wiek and Iwaniec 2014; Bennett et al. 2016).

Recent reviews of innovations in the field of invasion biology suggest several emerging innovations and approaches which may become increasingly transformative in tackling the challenge of IAS in the future (Ricciardi et al. 2017; van Rees et al. 2022). These include technological innovations such as gene editing, detection via remote sensing or environmental DNA (eDNA), data collection via technology-assisted citizen science and data sharing via open-source databases. However, most of these innovations are top-down approaches initiated and coordinated by governments, large corporations, or non-profit organisations. Innovations in the IAS field also often take the form of policy approaches. International agreements (e.g. the Convention on Biological Diversity, Article 8h), national-level legislation and reporting (e.g. van Wilgen and Wilson 2018) and voluntary self-regulation (e.g. in the horticultural or pet-trade industries; Niemiera and von Holle 2009) have been focal areas. Although some nations have prioritised the prevention and management of IAS (e.g. New Zealand; Peltzer et al. 2019) many countries lack the capacity to address the threat of invasions (Turbelin et al. 2017). A further key problem with the use of policy or top-down approaches is that they are geared towards supporting existing regimes, typically those implicated in creating the problem in the first place (Castro-Arce and Vanclay 2020).

The current focus on top-down approaches in IAS management may ignore the substantial contribution of local or bottom-up innovations that emerge organically from society. These kinds of initiatives are rooted in particular contexts and are often driven by engaged citizens, responding to persistent problems in their society (Castro-Arce and Vanclay 2020). Such initiatives may be vital in creating “transformative change,” systemic changes that fundamentally alter a society's culture, institutions, and practices (Loorbach et al. 2020), which are increasingly recognised as being critical to addressing the social and environmental sustainability challenges facing society (Díaz et al. 2019; IPBES 2019). Transformative innovations, often called “social innovations”, are initiatives which both change the system in which they are embedded and respond to social needs and challenges (Dias and Partidário 2019). This literature stresses that transformative innovations will not simply be technological, but also

social, including processes, practices, design and policies, with the primary objective of provoking transformations of the system via shifts in power, values and routines (Westley et al. 2017). Social innovations may come in the form of local experimentation, producer/consumer-driven solutions, policy-driven innovations and recognition of indigenous solutions (Ziegler et al. 2022). For such innovations to become truly transformative they must also have the potential to be amplified in some way, either by scaling out (impact greater numbers of people or environments), scaling up (impact higher levels of institutions via policy) or scaling deep (impact culture, beliefs and norms) (Lam et al. 2020b). Scalable innovations are flexible and accessible and can be used easily by individuals, businesses, researchers and entrepreneurs, who can develop them to create further novel solutions (Loorbach et al. 2020). A recent review of social innovations for biodiversity did not yield any results of this framing's application to IAS and therefore is a particular area for further exploration (Ziegler et al. 2022). Such innovations can offer radical alternatives to current thinking, especially related to what the future may look like and in this way counteract pessimism and polarisation (Loorbach et al. 2020).

We apply a participatory future visioning approach to the problem of invasive species management in South Africa, with the goal of exploring existing bottom-up IAS management initiatives that may help to create a more ecologically and socially sustainable future. We use the “Seeds of Good Anthropocenes” approach (Bennett et al. 2016) to generate these alternative futures and also pilot an extension of this process, where we identify clusters of actions to be undertaken by different actor groups, to arrive at pathways for change that are more explicitly defined. We discuss the potential contribution of qualitative, normative visioning processes to IAS management.

## Participatory future visioning processes

Participatory future visioning processes are a foundation of futures thinking, research and practice (Schultz 2015a). Foresight and futuring approaches allow individuals, organisations, or communities to explore the future to prepare for known risks, discern a target to aim for, or understand possible future “discontinuities”—substantial and possibly abrupt future changes that lead to novel and unexpected pathways (Miller 2015). Importantly, futures thinking is not merely a prediction tool, estimating future conditions based on current conditions and defined drivers of change (e.g. weather prediction). Rather, it is a methodological suite of approaches that provide a way to incorporate both data and people's individual or collective understanding and values, to explore and engage with the future (Peterson et al. 2003;

Dator 2019). Futures thinking has become an increasingly participatory process, which may have diverse objectives, including empowering stakeholders, stimulating innovation or social learning, managing conflicts, improving governance systems, and incorporating diverse knowledge types (Oteros-Rozas et al. 2015).

Participatory futuring methods have been identified by van Rees et al. (2022) as an area of innovation for IAS research and are increasingly used in the field (Table 1). These methods range in their desired goals (e.g. increasing awareness of change or exploring dimensions of uncertainty) and can be applied at different spatial (e.g. local, biome-specific, regional, global) and temporal scales (i.e. the time into the future being projected). This highlights the versatility of these methods and their potential value in addressing challenges faced in IAS management.

The futuring approaches most commonly used at present in IAS research do not, however, facilitate participatory “visioning”: developing normative representations of a desirable future, which consider the goals of the participants and explore pathways to the goals (Wiek and Iwaniec 2014; Johansson 2021). Visioning attempts to reveal barriers and opportunities within current dominant structures, and thereby facilitate systemic transformative change (Bennett et al. 2016). This is necessary in the face of the massive global challenges of the Anthropocene, where responsive approaches and dystopian visions of the future alone do not provide the necessary impetus for real change (McPhearson et al. 2016). Visioning therefore has a key role to play in research and decision-making, by facilitating the development of visions of a desired future, and identifying strategies to transition to desirable futures, while actively avoiding undesirable futures (Wiek and Iwaniec 2014). Participatory visioning approaches have been used to explore a wide range of issues such as land-use planning (Soria-Lara et al. 2021), food system resilience (Sellberg et al. 2020), local sustainability challenges (Lam et al. 2020a), landscape ecology (Iverson Nassauer and Corry 2004), biodiversity conservation (Chitakira et al. 2012) and urban transformations (McPhearson et al. 2016).

Although all visions of the future are subjective and depend on the worldviews of the participants who generate them, such visions can serve as a guide towards ambitious transformation which meets the normative goals of society. They can also be robust. Criteria, developed by Wiek and Iwaniec (2014) for creating useful and high-quality visions serve as a guide. These criteria include the need to be based in the principles of sustainability (i.e. have a normative framing), to use systemic thinking in the process (i.e. have interconnected visions), be internally coherent (i.e. free of incompatibilities and conflicting goals), be plausible (i.e. grounded in reality), be tangible (i.e. provide enough structure for meaningful action), be relevant (i.e. have relevance

**Table 1** Examples of participatory futuring approaches used in invasive alien species (IAS) research and management literature

Method	Method description	Example from IAS literature	Goal of paper	Future time scale	Scale	Participants
Scenario archetypes	Elaborates on “generic” images of the future by redesigning objectives under each archetype. Typical archetypes are Growth, Collapse, Discipline and Transform; or emission scenarios	Groeneveld et al. (2018)	Considers the implications of marine invasive species in Europe using the SRES (Special Report on Emissions Scenarios) as a starting archetype	30 years (2050)	Continental	Economists, ecologists, policy scientists, user groups
2×2 double uncertainty matrix	Explores dimensions of uncertainty by creating opposite extremes of key drivers of change. Generates a four-cell matrix, representing four alternative futures	Roura-Pascual et al. (2021)	Develops new global scenarios based on drivers of change that were the most relevant and most uncertain, including politics and demography, economy and trade, lifestyles and values, technology, and environmental/natural resource drives	30 years (2050)	Global	Invasion biology experts
Drivers of uncertainty + best/worst case scenarios	Explores dimensions of uncertainty via an expert-informed process to select drivers of change, which are then parameterised into scenarios according to their best and worst cases	Roura-Pascual et al. (2011) Essl et al. (2020)	Constructs four plausible futures for specific plant invader species in the Cape Floristic Region Constructs two best-and-worst-case scenarios for 15 relevant drivers of future potential impacts of biological invasions in different contexts (zonobioomes, taxonomic groups, realms and socio-economic development contexts)	30 years (2040) 30 years (2050)	Biome specific Global	Researchers and managers of IAS in the region Experts of invasion science, land-use change, global change, scenario construction, elicitation processes and environmental politics
Delphi	Increases awareness of change via iterative assessments from experts to describe future developments of a given topic, with the aim of consensus	Lauber et al. (2016)	Develops a range of estimates for how IAS could affect recreational fisheries, and identify uncertainties affecting the likelihood of various futures in the Laurentian Great Lakes	n/a	Location specific	Aquatic ecologists and fisheries managers

**Table 1** (continued)

Method	Method description	Example from IAS literature	Goal of paper	Future time scale	Scale	Participants
Horizon scan + Delphi	Increases awareness of change via identification of new and emerging issues and existing trends, using systematic information gathering. Combined with consensus-based exercises	Wilson et al. (2020)	Develops four scenarios for biological invasions in South Africa from a horizon scan of trajectories for humanity, based on emerging drivers of global change	5 and 50 years (2025, 2070)	Country specific	Local invasion biology experts
		Roy et al. (2014)	Uses a consensus-based approach to develop a ranked list of potential future IAS in the European Union, based on a horizon scan of potential threats	10 years	Continental	Invasion biology experts with expertise across representative geography/taxonomy
Model-based scenarios	Parameterises a set of scenarios generated by experts into a quantitative model (e.g. economic, food webs) to generate numerical estimates of change	Ready et al. (2016)	Generates a set of expert-derived ecological scenarios about possible effects of IAS on fish populations in the Great Lakes. Then, uses an angling model to project the impact that scenarios would have on angler behaviour and net economic value of fishing	n/a	Location-specific	Aquatic ecologists and fisheries managers (government and academic)
Narrative scenarios, 2 × 2 uncertainty matrix, mechanistic models, archetypes	Integrative/Combination approaches which use a combination of data-driven and expert-informed scenario approaches to generate a set of narratives about the future, which are then used for quantitative models	Lenzner et al. (2019)	Proposes an integrated conceptual framework for the development of scenarios and models on how IAS richness/impact may change in the future, by creating qualitative narratives, quantification of the impacts of drivers and the development of numerical models or their application to archetypes	Model-dependant	Global	Multiple expert panels proposed, including scientists, stakeholders, and decision-makers

Informed by Hichert et al. (2021a, b)

to real stakeholders who can undertake action), be nuanced (i.e. prioritised by desirability), be motivational (spark action), and finally, be shared (i.e. have a level of consensus, while highlighting diversity). Specific design principles can be used to help achieve these criteria, such as being conducted in a meaningful and iterative sequence, using techniques to stimulate thinking beyond negative futures, and being participatory by involving diverse stakeholders (Wiek and Iwaniec 2014). By engaging with such good practice criteria, visioning can provide a useful addition to the toolbox used to address complex social–ecological challenges.

### The “Seeds of Good Anthropocenes” initiative

A particularly promising approach to participatory visioning can be found in the global initiative “Seeds of Good Anthropocenes” (SOGA; Bennett et al. 2016; <https://goodanthropocenes.net>). SOGA combines the ideas of transformative bottom-up innovations with futures thinking approaches. Ultimately, this initiative aims to solicit and develop alternative visions of the future to create so-called “good Anthropocenes”—positive futures that have the characteristics of achieving the dual goals of human wellbeing and sustainability. This phrase is plural, as different people or societies may have different, and equally valid, ideas about what a “good” future may look like. The conceptual ideas of SOGA have been applied to several issues, including sustainability, food security, energy issues and biodiversity (Pereira et al. 2018; Falardeau et al. 2019; Raudsepp-Hearne et al. 2020; Sellberg et al. 2020; Hamann et al. 2020; Jiménez-Aceituno et al. 2020; Lam et al. 2020a; Lin et al. 2021; Lazurko and Keys 2022).

SOGA aims to provide an alternative to prevailing negative and apocalyptic visions of the future, which may impact humanity’s ability to creatively construct conditions for a more positive future for the Earth. However, it can be challenging to imagine such radically different futures. By anchoring futures with existing initiatives, more realistic pathways towards radical positive futures can be identified. To achieve this, SOGA uses the concepts of “seeds,” which are defined as *small-scale or experimental projects or initiatives that are not currently dominant or mainstream but have the potential to become transformative in some way* (Bennett et al. 2016; Hamann et al. 2020). These seeds employ new ways of thinking or doing, such as innovative social institutions, technologies, or frameworks, and they often use a bottom-up approach for transformative change. The potential for scaling these seeds and therefore creating further transformative impact beyond its original context is a key consideration. For example, Predator Free New Zealand (Russell et al. 2015; <https://www.tuiatetaiao.nz/>) has been identified as a seed initiative due to its innovative approach towards eliminating invasive alien predators in New Zealand

by 2050. It works with multiple stakeholders to ensure broad public support and involvement and, in this way, articulate a new vision for the country’s environment. The project started with isolated offshore islands and has since spread to a significant portion of mainland New Zealand, indicating the approach’s potential to be replicated on other islands with endemic species threatened by invasive predators.

The SOGA process (Pereira et al. 2018) is grounded in the criteria for creating high-quality visions of the future (Wiek and Iwaniec 2014) and has several beneficial potential outcomes, which have practical utility to fields like invasive species management. Firstly, it is based on the idea of creating positive and motivational visions, which have a strong anchor to reality (seeds). It uses specific tools to encourage a systemic understanding of the issue (see “Methods”). This approach also encourages participants to explore the landscape of innovation at a general level, to gain an overview of new approaches and stakeholders, and therefore shift from a problem-centred to a strengths-based approach (Hamann et al. 2020). Further, it allows connections between different sectors to be made by providing these actors with a canvas for dialogue. These connections can allow collaborations to “germinate”, and, along with the positive nature of the visions, develop agency and a shared understanding of the problem (Falardeau et al. 2019). Another beneficial outcome of the SOGA process is the development of “futures literacy”, the awareness of the potential of current contexts to contribute to desired futures and making different attitudes about the future explicit (Sharpe et al. 2016). This SOGA process has also been used in the creation of tool such as the IPBES Nature Futures Framework, which additionally provides a heuristic tool to map visions onto three people-nature value orientations, thus providing a boundary object for practitioners and policymakers to reflect specifically on values (Pereira et al. 2020). Ultimately, the SOGA process generates a set of focal points for practical actions to forward the desired vision of the future, including articulating who might be best placed to undertake a specific action (Chesterman et al. 2022). We applied the Seeds of Good Anthropocenes approach to the issue of invasive alien species management in South Africa, as a case study, focussing on creating these points of action for realising visions and guiding further research.

## Methods

### Case study: IAS management in South Africa

South Africa has a long and rich history of IAS management (van Wilgen et al. 2022). Despite a huge investment of resources, biological invasions currently pose the second largest threat to biodiversity, after habitat transformation, in

most of South Africa (Van Wilgen et al. 2020c). The country hosts an estimated 1422 alien species (Van Wilgen et al. 2020a) and control operations are struggling to keep pace with the increasing number of species, the extent of invasive alien species and the escalation in the types, magnitude and complexity of impacts caused or exacerbated by invasions. Woody invasive alien plants, especially trees, pose a particular problem due to their impacts on water and fire risk (Le Maitre et al. 2016). The approach to managing invasive plants in South Africa currently centres around governmental public works programmes, especially the “Working for Water” (WfW) programme (but other programmes such as “Working on Fire” also contribute). These programmes primarily focus on large-scale job creation for unemployed and/or previously disadvantaged groups, by providing funding for smaller operations to undertake IAS control within the WfW framework, and have been hailed as a bold, innovative approach to IAS management (van Wilgen et al. 2022).

Despite the unique nature of the WfW programme and the relatively large investment made into the programme, invasions in South Africa have increased, and control only extends to a limited portion of invaded areas (van Wilgen and Wannenburgh 2016). A recent review found that the goal of decreasing or slowing the erosion of ecosystem services by invasive alien plants has not consistently been met across South Africa (van Wilgen et al. 2022). To date, the principal objective of WfW to maximise employment across as broad an area as possible has resulted in available funds being spread too thinly to meet environmental goals, and, in many cases, social goals as well (van Wilgen et al. 2022). The main metric monitored is ‘person days’ of employment, which provides no indication of improvement in ecosystem services and is a poor indicator of socioeconomic impact, given the short-term, unstable nature of these contracts (van Wilgen and Wannenburgh 2016). The programme has been relatively inflexible in its ability to respond to new priorities and discontinuing lower priority projects has been unsuccessful due to the inability to withdraw funding tied to the poverty relief aspect of the programme (van Wilgen and Wannenburgh 2016). The programme is also administratively intensive, and funding cycles often do not coincide with crucial times for follow-up clearing. This means that adaptive management is often not possible in practice, and innovations are difficult to incorporate into the system. Agile, local solutions that build on initial government investment are therefore needed. A comprehensive review of the IAS management and research sector in South Africa can be found in Van Wilgen et al. (2020a).

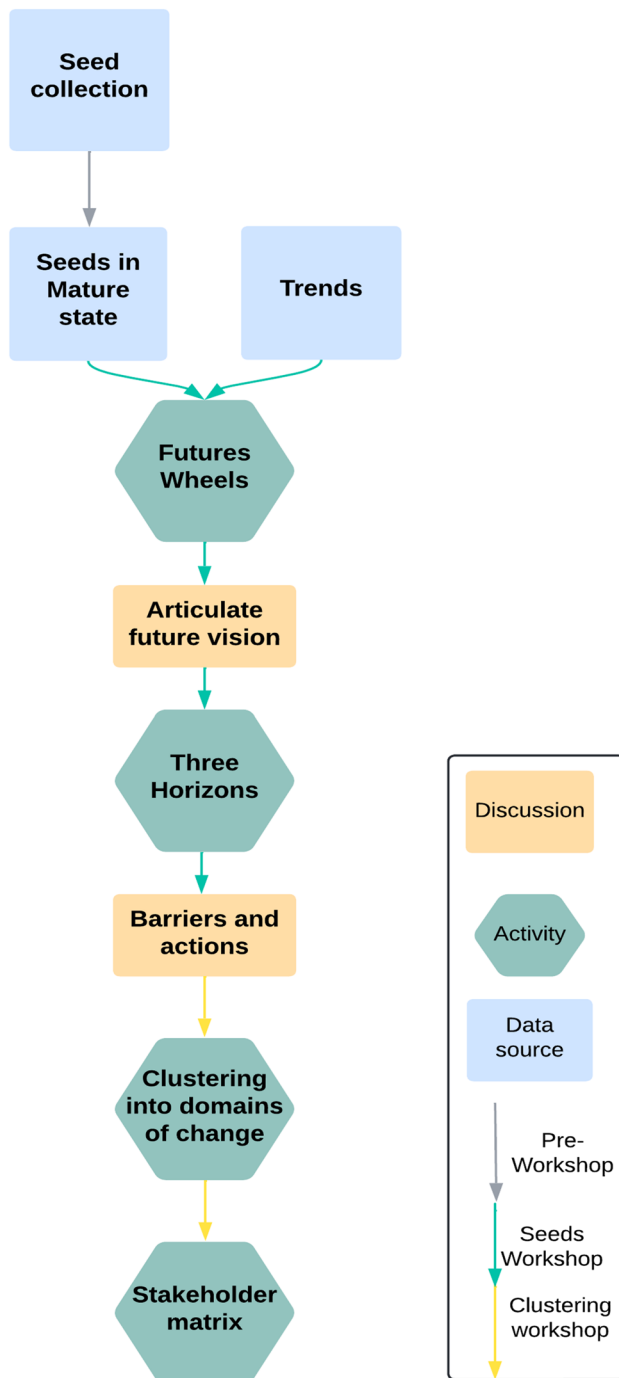
While the situation would be much worse without these control efforts, and localised successes (especially using biological control) do exist (van Wilgen et al. 2020b), there is a general feeling that South Africa is “losing the battle” against IAS and their impacts on the environment and

society. Key challenges to effective management include poor monitoring, a lack of ecological indicators of success, short-term and disjointed funding, working in a bureaucratic and opaque institutional context, a lack of buy-in from civil society, patchy approaches which do not focus on the worst invaders or the most invaded areas, a lack of a comprehensive and responsive policy environment, a lack of strategies specific to particular invasions, ineffective land management, and a research-management information gap (Shackleton et al. 2016; Foxcroft et al. 2020; Lukey and Hall 2020; Wilson et al. 2020; Cheney et al. 2020). Conflicts of interest also greatly complicate the management of many of the most widespread invasive plants (van Wilgen and Richardson 2012). Similarly, invasive alien animal control has had mixed success and struggles with stakeholder management and a high degree of conflict (Davies et al. 2020). These challenges cause inconsistent results and failures, resulting in disillusionment in the management sector. This context provides a prime opportunity to investigate alternate methods and the incentive to re-envision the future.

### Seeds of Good Anthropocenes process

The visioning process used in the Seeds of Good Anthropocene initiative uses a novel scenario-building method which combines two futuring tools: “Futures Wheels” and “Three Horizons Frameworks” (Pereira et al. 2018; Hamann et al. 2020), also called a Manoa Mash-up. The original Manoa method was developed to create divergent thinking and maximise the difference from the present (Schultz 2015b), and is based on the use of Futures Wheels (see below). The Manoa Mash-up adds a Three Horizons tool to this process. The SOGA process additionally uses the “seeds” concept as a starting point for generating visions and facilitating discussions about the future. The goal of this process is to stimulate creativity in how participants approach complex issues and move beyond dystopic visions of the future towards collectively creating positive pathways for systemic change (Bennett et al. 2016; Pereira et al. 2018).

We applied the SOGA approach in a workshop held on 4 May 2022, in Stellenbosch, South Africa, with the aim of exploring innovative initiatives in the field of IAS flora and fauna management, and their potential to create different futures for this sector in South Africa. The key components of the process are summarised in Fig. 1. The primary goals of this workshop were to build optimism by exploring potentially transformative futures that build on existing initiatives; to understand common barriers to scaling up ideas and to facilitate knowledge sharing between practitioners, researchers, and policymakers. The workshop was attended by 19 participants, from diverse institutions and sectors, and included academics, practitioners and policy makers. The participants were split into four groups of approximately



**Fig. 1** Process diagram, illustrating the data sources, activities, and discussions used in a series of workshops in South Africa. Insert: figure key

five diverse members, based on factors such as professional role (e.g. academic, policy, practitioner) and gender. This participant number is the standard practice for conducting SOGA workshops, to allow for in-depth discussions between groups, and for dynamics within groups (e.g. Pereira et al. 2018; Sellberg et al. 2020).

A diverse set of seeds that form the basis for the visioning process were identified through literature and internet searching, expert interviews and snowballing. Once an initial list of South African IAS seeds had been developed by the lead author, a subset of 12 of the most divergent seeds, or those which were of particular interest to the participant group, were identified as a starting point for the workshop. These were selected by the project team to provide diverse examples across sub-sectors within IAS management e.g. alternative uses of invasive species or alternative financing models, and therefore the selection was non-random. Some participants were actively involved in certain starting seeds, but they were not placed in groups to which those seeds were allocated, to prevent one individual from dominating the thinking on a specific seed. A short description of each of these 12 seeds was sent to the participants prior to the workshop (available in Table S1).

Context for the day was provided through presentations on (1) the uses and opportunities of futures thinking in the face of global change, including climate change, globalisation and inequality; and (2) the forces of change applicable to IAS, based on the current global literature. The latter included a discussion of the predicted continued increase in invasions worldwide, the issue of invasion debt, scenarios for global invasions that have been developed, and probable drivers of future invasions.

With this priming, the first exercise in the SOGA process, i.e. developing “futures wheels”, was started (Glenn 1972). Each of the four groups received three divergent seeds, along with a description of the seed in its “mature form”—that is if the seed grew or transformed to become part of mainstream, everyday activities. Groups then completed a futures wheels exercise for each seed, where the first-order impacts are placed in a concentric circle around the mature seed, and the second wave of impacts/consequences are placed in another circle around the first. These impacts are broken down in terms of their Social, Technological, Economic, Environmental, and Political impacts, as well as impacts on Values (known as STEEP-V domains). The futures wheels thus help participants to develop connections between an emerging change (or seed) and its consequences (Pereira 2021). The three completed futures wheels within each group were then placed next to one another to compare and connect their content. This exercise ended with asking participants to identify common themes and components which would make up their vision of the future and explain their thinking to the whole group.

The next step in the process uses the Three Horizons Framework (Curry and Hodgson 2008), which enriches the future narratives generated during the futures wheels exercise. This framework facilitates an understanding of emerging change, how this influences today’s dominant conditions and what needs to change to enable alternative futures to

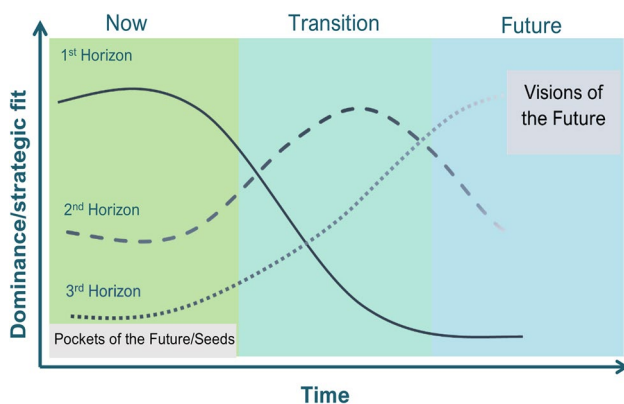


emerge (Pereira 2021). Three Horizons is a visual diagram (Fig. 2) that helps facilitate these conversations (Curry and Hodgson 2008), as it centres on three different “horizons” or depictions of systems in different timescales; the past, the future, and the transitions between them. The first horizon (H1) reflects current conditions and asks participants to specify what about the current conditions they would like to see diminish, and what “pockets of the future” they like to see expand. The next step populates the third horizon (H3), which is the desired future that the participants began identifying in the futures wheels exercise. The final step in the process is to identify the intermediate stages between H1 and H3. This transition phase (H2) describes what needs to fundamentally change for H3 to occur. This stage therefore represents the medium-term and is often unstable as transformations happen (Curry and Hodgson 2008). At this stage, each group was tasked with articulating achievable “next steps” and actions to be taken to move the seeds from the H1 to the H3. Most of the discussion concentrated on H2. Each workshop group completed one of these diagrams, which were then presented to the rest of the groups and discussed.

The final step of the workshop was to use both the futures wheels and the Three Horizon diagrams to discuss common actions, barriers, and opportunities for growth across groups. Following the workshop, the participants were invited to complete an online evaluation form to understand their perceptions of the workshop, whether it was able to meet its goals, and how to improve the process (responses in Fig. S7).

### Thematic clustering and stakeholder actions

A criticism of the SOGA approach is that it is sometimes difficult to move directly to action from the Three Horizons tool, as the mechanism for undertaking the



**Fig. 2** The Three Horizons Framework, indicating the decline of the first horizon representing current conditions (solid line), the increase of the third horizon from emerging innovations/seeds to a specific vision of the future (small dashed line), and the transitional or intermediary second horizon (large dashed line)

transition steps in the second horizon typically requires a number of power shifts amongst stakeholders (Rutting et al. 2022). Expanding on the current SOGA approach, we therefore ran an additional follow-up mini-workshop to identify actionable domains of change and associated stakeholder-specific actions needed to move from the present to the desired future (based partly on Chesterman et al. 2022). During this workshop, the majority of the co-authors of this paper ( $n = 11$ ; all of whom attended the initial workshop) evaluated the outcomes of the workshop and identified “domains of change” or core thematic areas associated with a cluster of related actions. During this mini-workshop, we clustered the transition actions generated in horizon 2 of the Three Horizons process, and the actions/opportunities identified in the final workshop discussion, by grouping similar actions together, using the online whiteboard platform Miro (miro.com). Initially, this was achieved using the STEEP-V framework, for a deductive clustering approach. All participants logged in to the software and were encouraged to move sticky notes of actions to others that were of a similar STEEP-V domain, for example, an economic action or an environmental action. If an action fitted between two STEEP-V domains, the participants could place it in between these domains. These groupings were then examined, and a further inductive round of clustering was done, where some actions were moved to another group of a similar nature, even if it was in another STEEP-V domain. For example, harnessing technological advancements such as mobile applications (technological domain) and funding scientific research centres (economic domain) were both seen, on reflection, to be about making strategic investments into research and technology.

The final groups of actions were then given a descriptive name and inserted into a “stakeholder matrix”, which listed a set of stakeholders who could potentially achieve actions in IAS management (see Table S2). These stakeholder groups were initially developed by workshop facilitators and then discussed with the mini-workshop participants to check for relevance. In this final step, the actions under each domain of change were distributed across the different stakeholders, according to the stakeholder group/s who could undertake the action. Actions could be listed under multiple stakeholder groups, or in some cases, identified as an action requiring participation from all stakeholders.

### Results

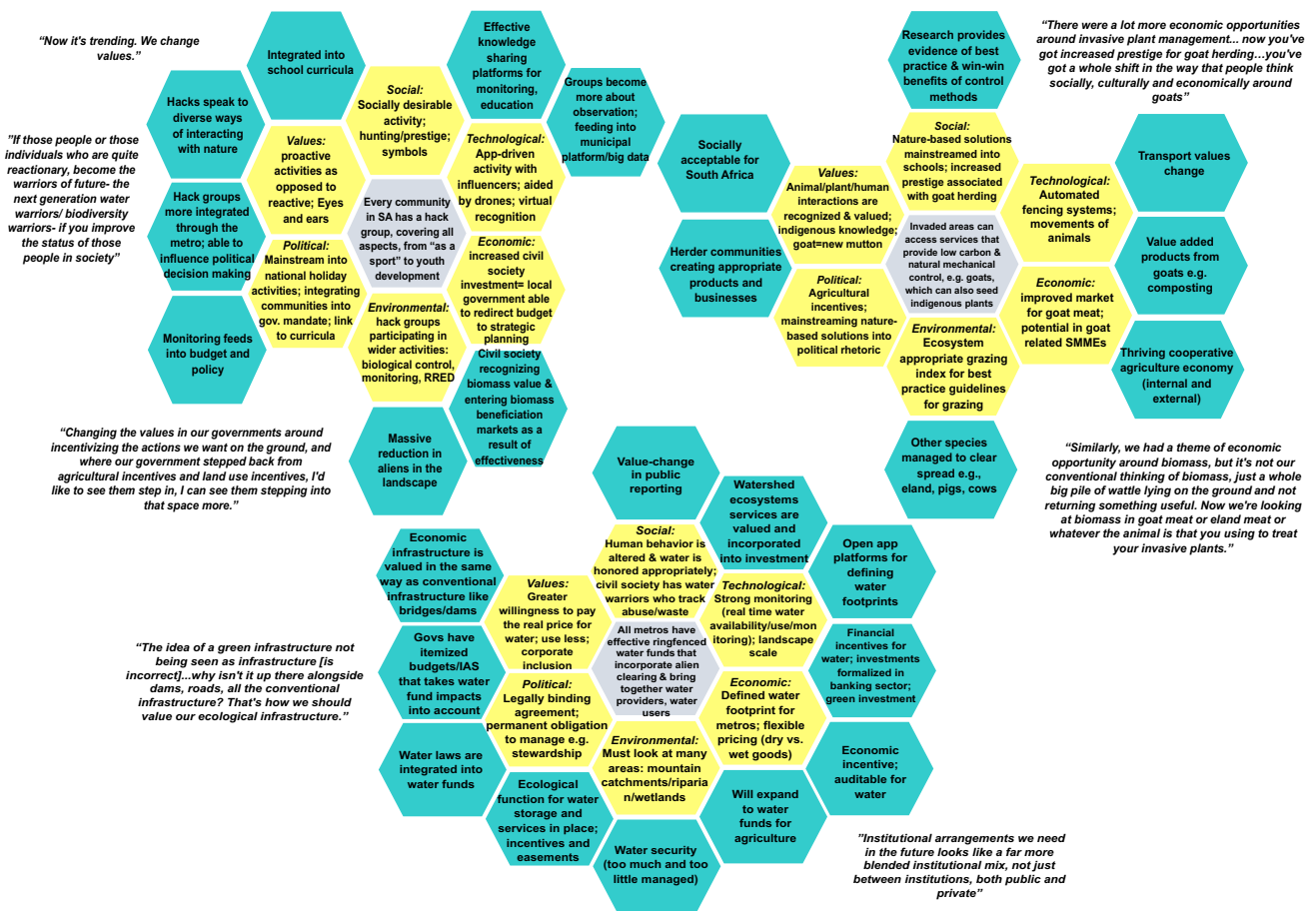
One of the group’s outputs is presented as a worked example (Box 1). The outputs from the other three workshop groups are presented in Figs. S1–S6.

**Box 1: Worked example of Group A's outputs from the "Seeds of Success" workshop**

The group presented in this worked example started with three "seed" initiatives. The first seed was related to "hack groups"- engaged groups of citizens who actively steward local natural areas or conservancies by removing alien plants as a social/community service activity. The mature state of this seed was conceptualised as "Every community in South Africa has a hack group of one form or another covering all aspects of tackling aliens, from 'as a sport' to youth development". The second seed was based on a private company which uses a flock of trained goats to manage alien plants and restore landscapes, in a stepped approach. This was conceptualised in a mature form as "All densely invaded areas are easily able to access a service that provides low-carbon, natural forms of mechanical control, such as goats, which can also seed

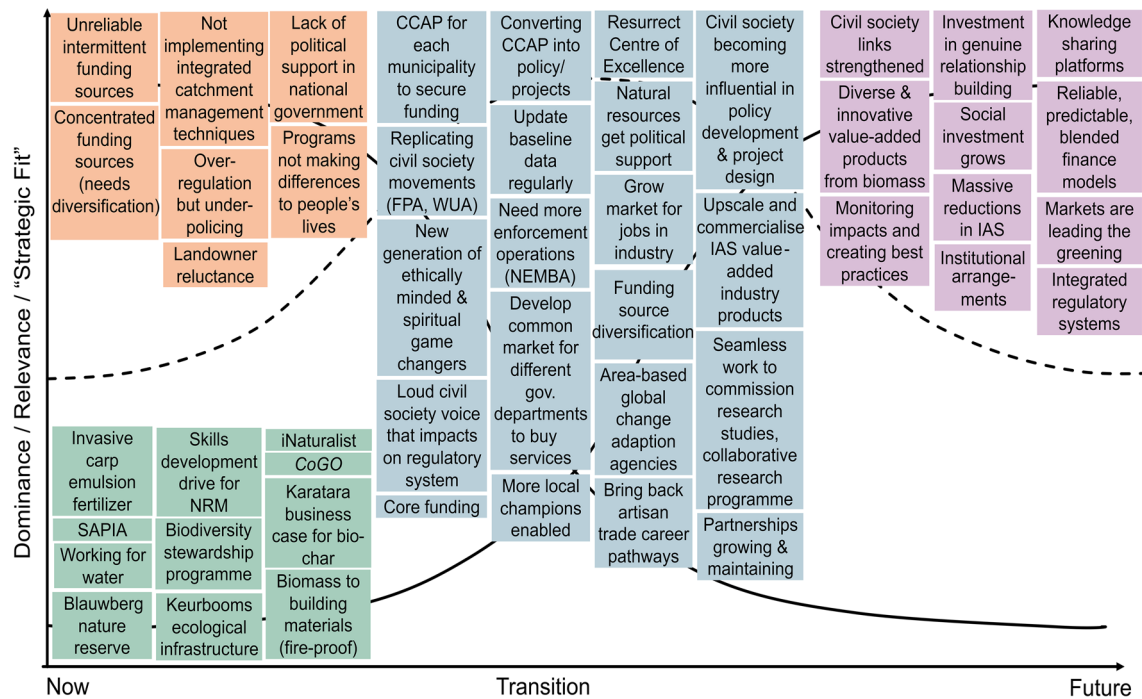
indigenous plants into cleared areas". The third seed presented to this group was a water fund, which is an innovative governance and funding model where downstream users of water pay for the upstream restoration of catchments. This was conceptualised in its mature form as "All metros and large towns in South Africa have effective, ring-fenced water funds in place that incorporate alien clearing". These three seeds were used as the starting point for the group's three futures wheels (Fig. 3).

These initial ideas were then further developed by each group using a Three Horizons diagram. Group A identified a future (Fig. 4, Horizon 3, purple) grounded in ecological infrastructure approaches and in changing the economic system around IAS, via predictable, blended finance models, and creating new and innovative markets for IAS products. This also included a need for markets to lead the way in greening of society, with strong links between the IAS sector and



**Fig. 3** Example of a Futures Wheel created by a group at the participatory workshop. Each group was given three starting seeds, shown in their "mature condition" (grey). The primary consequences of this mature seed are presented in yellow, while the second order conse-

quences (in teal) expand on the impact/changes seen because of the primary consequences. Relevant quotes from discussions are shown in italics around the wheels



**Fig. 4** Example of a Three Horizons diagram generated by a group, showing the first horizon of current conditions, including those that they would like to see diminish (orange) and grow (green); the second horizon (blue) indicating transitory changes or actions; and the articulated future with several desired characteristics (purple) for the inva-

sive alien species (IAS) management sector. *SAPIA* Southern African Plant Invaders Atlas, *FPA* Fire Protection Association, *WUA* Water Users Association, *CCAP* Climate Change Adaptation Plans, *NEMBA* National Environmental Management: Biodiversity Act 10 of 2004

civil society. As such, societal investment in this issue grows, resulting in large reductions in IAS. A strong monitoring component exists, which builds on knowledge-sharing platforms. This group identified many key transition steps (Fig. 4, Horizon 2, blue), some of which focussed on practical policy and legislative measures, including formalising and expanding Climate Change Adaptation Plans (CCAP) to secure funding, replicating useful civil society movements, and developing common markets for different government departments to buy cross-sectoral services. Other transition steps focussed on ways to engage civil society, including enabling local champions, enabling artisan trade careers, and having loud civil society voices. There were also actions centred around research, where a more seamless pathway between research and society exists, and where research is appropriately funded and politically supported. Undesirable current conditions that hamper these changes (Fig. 4, Horizon 1, orange) included issues with undiversified and unreliable funding, a lack of an enabling political environment, and a lack of integrated catchment management.

The reluctance of landowners to engage in management was also an undesirable feature. The group identified several seeds (in green) which currently exist, and which could help to arrive at the desired future, including biomass products, and ecological infrastructure innovations.

**Future visions of groups**

A summary of each group’s future vision is available in Table 2, with further information about each starting seed, including its mature form, available in Table S1. There were several common factors in the visions developed. Firstly, in terms of visions of governance and political support, there was a desire across groups for a future with closely-knit partnerships for IAS responsibility. Improving the relationship of industry, civil society and academia with government was seen as essential to address issues with legislation enforcement, corruption, or governance vacuums, but also for partnerships amongst these different sectors. Collective governance and shared accountability were seen as the emergent outcomes of these relationship transformations. There was also a strong desire for a future with closer links

**Table 2** Description of future visions generated by four groups, indicating which seeds were used as their starting point. Italics indicates the formal name of seed initiatives

Group	Vision	Starting seeds	Relevant figures
A	A future focussed strongly on markets and industry as a means to arrive at improved connection between society and the issue of IAS, using concepts such as green infrastructure, common markets for services and the IAS product sector. Financing for management was also a key focus of the vision, as was a strong and responsive regulatory system	Diverse configurations of hack groups <i>Goat Army Africa</i> <i>Greater Cape Town Water Fund</i>	Figures 3, 4
B	A future vision focussed on relationality between people and nature (that is, acknowledging that each influences, and is influenced by, the other, and that people and nature are fundamentally intertwined), achieved via circular economies and ecological flows. The current political system would change, including how nature-human landscapes are valued, resulting in a duty of care to the environment and actors with transferable skills. The result of this would be connected, altruistic societies, who take pride in working to improve environmental and human wellbeing outcomes	<i>Blaauwberg Large-scale Sand Fynbos Restoration Project</i> Value-added products from invasive species ( <i>Hive Carbon</i> ) <i>Program “Skoon Veld”</i>	Figures S1, S4
C	A future vision where IAS management is driven by stewardship and close-knit networks, focussed on responsive management and collective governance, and strong communities of practice. Landscapes are multifunctional and communities are involved with sustainable management of IAS for job creation, with a grounding of shared values	Mapping invasive species using open-access satellite imagery Land management planning via Honeybush incentives <i>Upper Breede Collaborative extension group (UBCEG)</i>	Figures S2, S5
D	A future vision which views IAS management as part of the wider socio-economic development of South Africa, where job creation and poverty alleviation are seen as fundamental to being able to appropriately manage invasions. This would result in improved livelihoods for all, supported by responsible investment by government, industry, and civil society	Landcare catchment management finance plans ( <i>CoGo</i> ) (Collaborative Governance for Water Security Co-operative) Low-cost solution to monitoring alien biofouling species	Figures S3, S6

between people and nature, characterised by concepts like stewardship, multi-functional landscapes, relationality, or ecological flows. A further commonality was a vision for a future where joblessness and a lack of realised benefits for communities from IAS management are transformed into a society with meaningful work and equitably distributed benefit flows. Additionally, there was a common vision for improved access to, and management of, data, where open-access knowledge-sharing platforms are created to take advantage of technological advancements, but also building on the improved partnerships discussed above.

There were also rich differences between groups. For example, Group A focussed on a future which embeds industry and market-based instruments into IAS management, to achieve social and ecological goals. In contrast, Group B focussed on a completely new way for people and nature to interact, beyond the market. Radical ideas, such as the need for trauma-informed approaches, wealth taxes or compulsory community service were suggested as a way to bridge the conceptual divide between IAS management and systemic global challenges such as inequality. However, both groups

had the base-line value that the future pathways should ultimately result in improved livelihoods via more equitable benefits to society.

Funding for IAS management was a priority across all groups, expressed as this sector having adequate resources to appropriately manage the scale of invasions. How to realise this funding was, however, conceptualised differently in the various groups. Using value-added product approaches, green infrastructure, or partnerships between municipalities and businesses were some ways to approach this issue, but groups also saw the need to integrate ideas which go beyond the direct IAS management sector, such as climate adaptation and circular economies, into how IAS management is funded. Another group conceptualised funding in a broader manner, by appropriately recognising IAS impacts and therefore tapping into much larger funding bases for climate change, fire or water management.

## Domains of change and stakeholder actions

Eight “domains of change” were identified from the clustering process undertaken in the follow-up mini-workshop (Fig. 5). “Appropriate and functional financing” was a domain seen as fundamental to allowing many of the other domains to happen, such as the domain to “stimulate the IAS product economy”, and to make more “strategic investments into research and technology” in this field. The need for an ethos or values change in the government, the public and even within the management sector itself was another fundamental area for action, primarily relating to the need for much broader engagement on this issue, with multiple sectors acknowledging greater responsibility due to increased recognition about the severity of the IAS threat. Many of these domains highlight the social–ecological nature of IAS, such as the need to foster innovative partnerships, to advance collective action and, importantly, to advance equity and social inclusion via IAS management.

The key stakeholder groups identified as being able to undertake actions to advance these domains of change were (a) government, officials and policymakers; (b) private sector and industry; (c) non-governmental organisations and civil society; (d) researchers, students and academics; (e) funding partners; (f) practitioners, implementers and managers; and (g) regional bodies and international partners. The set of actions associated with each domain of change was mapped onto these stakeholders (Fig. 5; tool presented in Table S2). A key message emerging from this exercise was that many actions require coordinated input from multiple groups. For example, the government may be the funder of an action, while a non-governmental organisation may be responsible for implementation. Secondly, it was apparent that appropriate rules of engagement are required for all stakeholders to buy into, given the complexity of roles and responsibilities. However, we found that only a few actions could truly be assigned to all actors. These actions point to deeper underlying changes necessary for this sector, such as the need to shift mindsets (consciousness, attitudes, values) to support a new generation of gamechangers, the facilitation of civil society input and engagement, the need to grow and retain career options in the IAS sector (both professional and artisanal), enabling open-access data, an emphasis on healthy and innovative partnerships, as well as a social justice focus. The domain to “foster innovative partnerships” was the most difficult for participants to break into stakeholder groups, illustrating the collaborative nature of this domain.

## Discussion

Utilising tools and methods from the field of futures studies provides an opportunity to re-imagine complex and intractable social–ecological issues, such as invasive alien species management. This sector requires new ways of thinking and doing to counteract prevalent pessimism and failures. Here, we present an application of a participatory future visioning process to the South African IAS context. We also piloted an extension of the process to identify clusters of actions, and then allocate specific actions within them to different stakeholder groups. We found that using innovative, experimental, or bottom-up initiatives as a basis for visioning processes enabled the identification of pathways to create more sustainable futures. By using tools which encourage systemic thinking, shared visions can be generated which recognise the complexity of the challenges of IAS management and facilitate meaningful ways of understanding the interconnected actions needed to move towards these visions.

### Domains of change

One of the fundamental areas for action in the South African IAS management sector which emerged from the participatory visioning process was the need for a change of ethos and values, in terms of prioritising IAS for funding, research and collective action by all society. This reprioritisation speaks to the severe and increasing impacts of IAS worldwide, combined with a lack of recognition of the risks (Pyšek et al. 2020). There were, however, different conceptualisations of *which* values the future should be based on. One group spoke about the importance of relationality, achieved via circular ecosystems and ecologies. This suggests that what is needed is a reframing of how society relates to IAS, and more broadly to nature and the environment. A controversial idea that was voiced was that IAS could be viewed as a possible asset or pathway, which could be used to forge a stronger connection between nature, people and restored ecosystems, by expanding the IAS product economy. This does not discount the significant negative impacts that IAS may cause, but rather reframes the problem so that they can be managed with a consideration of broader trade-offs and appropriate levels of engagement.

These framings speak to the diverse ways in which people value nature, including IAS, which has ramifications for what type of human–nature relationships should be prioritised and acted upon (Balvanera et al. 2022). The recent IPBES Values Assessment conceptualised these different framings (IPBES 2022; Pascual et al. 2022), which can be related to the visions of the different groups in this study. Framings such as “living from nature”, where nature is a resource which provides human prosperity, was

Appropriate and functional financing	Shifting mindsets and values	Foster Innovative Partnerships	Advance collective action	Strengthen regulatory institutions	Advance equity and social inclusion	Strategic investments in research and technology	Stimulate IAS product economy
Funding source diversification: ecosystem-based adaptation, disaster risk management 	Shift minds (consciousness, attitudes, values) about IAS management 	Create a collaborative culture amongst institutions working on invasives 	Civil society recognized & more influential in policy development & project design 	Prioritize areas, species, & actions for management: fight the worst battles first 	Social justice as a central priority 	Enable Open Access data 	Grow and retain career options in IAS sector: both professional & artisanal 
Seamless work to commission research studies, collaborative research programme   Supporting CCAP* by mainstreaming them into long-term economic planning e.g., IDP* and NDP*	Creating safe spaces to have conversations about deep beliefs and telling stories about environment   Learn to live with some invaders	Promote partnerships and consensus building e.g., by theory of change   Accountable for collaboration: requirement of funding at proposal & implementation phases	Building up local governance structures relevant to invasives (CMAs, FPAs, WUAs)*   Broaden political support base, especially for application of law	Readjust adaptive management to work with legislation   Need more enforcement operations (NEMBA* legislated actions)	Trauma counseling, using nature based safe spaces   Enhance and shift values in youth	Harnessing Tech advancements e.g., phone apps and citizen science   Creating an enabling environment for innovation (data platform access)	Mainstreaming benefits of clearing/monitoring: marketing, communication, accessibility   Change accounting system: what project deliverables matter
Implement incentives and advocacy-based on risks of IAS e.g., fire, floods, loss of ecosystem service  	Rules of engagement: decide how we work together  	Devise a reward system e.g., collaborative champion of the month  	Increase the number of formal civil society entities in IAS management  	Reviewing laws that can be enforced & supported  	Real upskilling of marginalized people  	Reward or prize system for innovations  	Upscale & commercialise IAS value-added industry products: plants & animals,  
Support & rewards for innovation (for both government and private sector)  	Accepting people where they are at (resourcing, childcare, hours of work)  	Foster innovative cross-private partnerships  	Develop user-friendly cross-sectoral procurement processes to manage IAS (fit for purpose)  	Enhance prevention: bio security, eradication, Early Detection Rapid Response  	Basic needs met across society, especially in IAS management jobs  	Update baseline data regularly and make publicly available  	Replicating civil society movements (e.g. FPA, WUA)*  
More funds earmarked for invasion sector  	Change definition of success: skills that are meaningful  	Create job role to connect departments  	Loud civil society voice that impacts on regulatory system  	Operationalize performance evaluation system e.g., in municipalities  	Socially responsible investments e.g., pension fund, blended investment  	Mainstream AI* and cloud computing  	Users Associations)  
Funding for marketing (real communication expertise)  	Promote success stories for awareness and spread  	Harness marketing students or projects to improve messaging  	Area-based global change adaption agencies  	Enforce accountability for invasions  	Foster supportive communities e.g. families, faith based orgs, NGOs*  	Integrated funding/knowledge sharing to understand links to global drivers e.g., climate, pollution  	Grow market for jobs in product industry  
Tapping into corporate social/environmental responsibility or pro bono work by firms  	New generation of ethically minded & spiritual game changers  	Facilitate and support conservancies and stewardships (mainstreaming co-management)  	Create institutional model where local community becomes custodian  	Benchmark international best practices  	Wealth tax integrated into society and used for environmental and social goals  	Improve the packaging of information (target audience, language, platforms, format)  	Improve job stability and transferable skills  
Innovative public private partnerships for funding e.g. business chambers, water funds  	Encouraging the new generation of environmental warriors to shift deeply held beliefs, myths, dogmas  	Partnerships growing & maintained by trust and relationship-building across sectors  	Documenting existing seeds (asset-based community mapping)  	Develop common market for different gov. departments to buy same services-cross-sectoral  	Transition from social grants (long term)  	Core funding for Invasion science and scientific centres  	Experimenting with socially engaged circular economies/ecologies  
Socially responsible investments e.g. pension fund, blended investment  	Compulsory community service - getting everyone involved in management  	Implement & participate in diverse community service work (levels of work, internships)  	Setting aside seed funding to support innovation and technological advances in invasion  	Scale up all biocontrol programs and work them into citizen science projects  	Providing basic training on social issues (e.g., trauma, economy, people skills) in schools, workplaces  	  	Ensure that IAS management discourse leads to economic development & employment  
  	Dignifying work in IAS management  	More local champions enabled  	More local champions enabled  	  	  	  	Further develop market for products  
All 	Government, officials, policy makers 	Private sector/industry 	Non-governmental Organisations, civil society 	Researchers, students, academics 	Funding partners 	Practitioners, implementers, managers 	Regional bodies, international partners 

**Fig. 5** Domains of change (bold headings), each with a set of associated actions, for the South African invasive alien species (IAS) management sector in the future. Some actions may fit into more than one domain. Stakeholders who may be able to influence an action are indicated as coloured dots below each action (colour key at bottom of the figure). *CMA* Community Management Association, *FPA* Fire Protection Association, *WUA* Water Users Association, *CCAP* Climate Change Adaptation Plans, *IDP* Integrated Development Planning, *NDP* National Development Plan, *NEMBA* National Environmental Management: Biodiversity Act 10 of 2004, *AI* Artificial Intelligence, *NGO* Non-governmental Organisation

seen in the product economy/green infrastructure vision (Group A); “living with nature” was seen in the vision which emphasised stewardship approaches (Group C); while “living in nature”, which emphasises that there is no separation between people and nature, was seen in the vision which emphasised relationality, nature as a healing resource and circular ecosystems (Group B). Acknowledging that these diverse framings have relevance for IAS management is vital, as dominant actors may either seek to impose their own preferred valuation and in this way, simplify and exclude other values (Balvanera et al. 2022; Pascual et al. 2022). Using participatory processes builds a collective understanding and improves equity in decision-making, and therefore encourages a more diverse array of actors to become socially legitimate (Woodford et al. 2016; Balvanera et al. 2022). This diversity of values and assumptions requires that participants in the visioning process engage not only intellectually with the problem, but emotionally, which results in rich discussions (Pereira et al. 2018), and reflects the fact that negotiation is central to managing transitions (Quist et al. 2011). A critical mass of stakeholders with a shared vision is, however, necessary for action, indicating that more of these visioning processes are needed for the IAS management sector in South Africa to arrive at a cohesive shared vision. As a participant said during feedback: “To really win the battle against alien species, we would need to include a broader portion of society. This sort of workshop is a first step, but change will take place when there is a core mass of people on board.”

Diverse framings link strongly to the need for more collective action on IAS across multiple scales. Invasions occur in increasingly complex social landscapes, where multiple land managers have responsibility and their actions (or inaction) affect one another (du Plessis et al. 2022). Coordinating control efforts in this type of “management mosaic” has been identified as a key strategy to enhance landscape-level management of IAS, that can be aided by coordination from both government and community-level organisations (Epanchin-Niell et al. 2010). Collective action arising only from bottom-up approaches, although addressing a disillusionment with top-down command and control, can be

hampered by large numbers of stakeholders and heterogeneity of incentives (Lubell et al. 2002). Therefore, approaches which can unite governmental expertise and resources with local knowledge and enthusiasm can be powerful (Higgins et al. 2007; Epanchin-Niell et al. 2010). Collective action for improved governance can thrive when local ownership, and social and financial capacity are available, but also when there is a shared normative belief amongst stakeholders that IAS require control and that others in the group are making investments in this control (Graham et al. 2019). Shared beliefs can be facilitated by emphasising actions that reflect local knowledge and understanding, as well as those that are based on collective norms (Winter 2010; Malpica-Cruz et al. 2016).

Public participation in IAS management is a key factor to both the “shifting mindsets and values” and the “advancing collective action” domains of change. Two key concepts may act as important ways to guide strategies for public participation, namely the leverage points perspective on transformative change and behavioural science principles. Firstly, leverage points are places in a complex system where a small shift may lead to large and fundamental changes to the system (Meadows 1999). These leverage points may be deep, indicating actions that address the ultimate causes of the problem and create enabling conditions for greater action e.g. by reconnecting people and nature, or shallow, indicating actions that are easier but may bring about limited change to the system (Abson et al. 2017). While both may contribute to addressing a problem, deep leverage points for conservation actions including awareness-raising strategies, changing behaviour by appealing to non-monetary values and effective and targeted education and training (Arponen and Salomaa 2023). Some IAS examples could include using existing environmental or recreational interests to create invasive species action (e.g. targeting recreational fishers to manage invasive fish by tapping into their motivation to spend time outdoors; Atchison et al. 2017) or using carefully designed citizen science initiatives to empower people to feel engaged with their local environments (Cardoso et al. 2017). Communication on climate risks such as fire, drought and floods may also be relevant for IAS engagement. Secondly, behavioural science principles may offer some ways to stimulate behaviour change, e.g. via “nudges”. Such principles include making the desired behaviour easy and convenient to do, using social norms and social proof that others are also undertaking the behaviour, providing feedback and visual cues on the behaviour, appealing to intrinsic motivations which appeal to people’s values and personal goals, and making the consequences of their choices or behaviour salient by highlighting their immediate impact (Lehner et al. 2016; Velez and Moros 2021). These principles have been applied in a limited way to IAS management (e.g. Shannon et al. 2020), but much more research is needed. Stimulating

public participation in IAS management will be key to creating the transformative change envisioned in the Seeds workshop, and combining behavioural science with a prioritisation of deep leverage points may help to achieve this.

A related domain of change was the need for more cooperative, innovative, and inclusive partnerships. Self-serving, inefficient, and siloed approaches are still common, especially in government structures (van Wilgen and Wannenburg 2016). These are characterised by top-down management, overregulated but under-policed legislation, and the domination of the sector by Working for Water, which can stifle innovations, such as using triage and/or integrated catchment management approaches (van Wilgen et al. 2022). This fragmented and bureaucratic landscape leads to significant frustration in the IAS sector, and therefore to high staff turnover. In the visioning process used here, this situation would transition into close-knit networks who work co-creatively with communities to create multifunctional landscapes, characterised by stewardship approaches. This echoes a wider call to encourage governance and partnership structures which emphasise the holistic, multi-scaler and cross-boundary collective action needed for management (Graham et al. 2019).

The issue of inconsistent or undiversified funding was a dominant area for change identified by all groups. An overall diversification of funding in the private sector, academia and government was seen as paramount to allow appropriate resources to flow towards IAS management. State funding, often inefficient and slow to materialise, needs to be complemented by innovative funding mechanisms (van Wilgen et al. 2022). Unlocking private sector investment in concepts like ecological infrastructure or climate change adaptation, could be a key method of incentivising IAS management. However, for these investments to be attractive to the private sector, a process of de-risking is necessary, as many of the relevant markets (e.g. carbon credits) are immature (Angelstam et al. 2017).

Stimulating the IAS product economy in the private sector was seen as one way to generate funding and action to achieve IAS management goals. Overcoming substantial logistical, technological and social barriers to commercialisation would, however, require defining the markets more clearly and delivering appropriate returns (Angelstam et al. 2017). This may initially rely on public sector funding to support bottom-up innovations that currently lack private investment (Angelstam et al. 2017). There are, however, many issues with creating an IAS product sector, primarily the creation of dependencies on specific IAS and thus unintended incentives for their continued presence, and the manifold challenges of creating traceable and certifiable value-chains. Success stories (such as the seeds approach used here) can, however, provide positive examples from which to potentially catalyse wider financing initiatives. They also

provide an opportunity to develop rigorous indicators for social, ecological and financial goals. By their very nature, start-ups and small businesses are quick to expose failures, especially financial ones, but this also provides for significant flexibility and rapid innovation, especially in reducing costs (Mills et al. 2015). Creating a dynamic platform for sharing such insights would be key towards maximising the return on such investments.

All groups also identified a strong need to advance equity and social inclusion, which is particularly pertinent to the context of South Africa, where the need for poverty alleviation and job creation are paramount. The IAS management sector is not exempt from these issues. The current approach of relying on the Working for Water model for job creation has been criticised for providing skills that are not well aligned with gaining employment in the formal economy, and for focussing on maximising short-term employment, rather than long-term poverty alleviation (McConnachie et al. 2013). A more diverse approach to skills training and employment is needed to allow IAS management to truly impact social welfare goals. To achieve this, seeds which actively contribute to advancing different dimensions of equity should be identified and investigated further.

Another key social justice factor is that, apart from job creation as a result of IAS management programmes, many poor communities depend on IAS for their wellbeing e.g. via their sale, or to provide products such as food, fuel or construction materials for their households (Shackleton et al. 2019c). Sustainable strategies for the management of IAS must therefore account explicitly for these dependencies. However, more research is needed to adequately understand these relationships and vulnerabilities. Radical ideas suggested at the workshop such as wealth taxes to redirect financing and achieve social goals, or compulsory community service to reconnect people and nature strongly link to these themes of redistribution, decentralised governance and poverty alleviation.

## Stakeholder actions

The wide array of stakeholders involved in IAS management, and their shared responsibility for action, underscores some of the challenges with making future transformative visions a reality. Different stakeholders may each play key roles in implementing a single action, or in actions that need to be linked together to create impact. It is in these complex dynamics that many of the common issues with taking visioning into the practical sphere emerge, such as overcoming lack of trust and power dynamics, or differing institutional mandates (Falardeau et al. 2019; Rutting et al. 2022). There is, however, an emerging field of research which explores these issues



specifically for the IAS management sector, which identifies several psychological, environmental, social and institutional factors which may influence stakeholder relations, and, therefore, how management takes place (Shackleton et al. 2019b). A recent framework by Carter et al. (2021) summarises some of these important variables, including personal factors (such as values, prior knowledge of the problem and worldviews), which are foundational to individual factors governing perceptions, social norms and emotions (e.g. interpersonal trust levels, perceived fairness, perceived efficacy, risk and uncertainty of management actions). Institutional factors (such as institutional trust and procedural fairness) and governance factors (such as mandates and values that drive engagement and framings of IAS) will also influence the acceptability of any interventions to different stakeholders, including the public (Carter et al. 2021). Such frameworks, along with research into conflict-generating IAS (Zengeya et al. 2017), allow stakeholders to grapple with complexity, and attempt to balance differing values and interests. Multiple streams of information are necessary for the acceptability and success of any interventions, built on foundations of trust, openness and transparency (Carter et al. 2021). Processes like futuring can directly contribute towards building these foundations, by revealing commonalities and differences in both individual, institutional and governance factors and creating a context to build a shared vision which accounts for these complexities.

### Futures studies as a frontier for action and research on IAS

Futures methods, such as visioning, can act as an impetus for action on IAS issues. However, visioning is one of many methods which can be used, depending on the goals of the process. Futures methods which improve the understanding of IAS as a social–ecological system (Hichert et al. 2021a), and encourage the incorporation of concepts such as complexity, tipping points and emergence (Sardar and Sweeney 2016) are particularly important. Further contributions of futures studies to IAS management could also include, for example, large-scale public participatory scenario building, philosophical work on how IAS valuation may change in a less biodiverse future or incorporating diverse knowledge bases into IAS management. It would be valuable to see how people not actively involved in IAS management would envision the future of this problem, so as to explore solutions to better engage the public in management. A potential challenge with the uptake of such tools in the IAS sector is that it is often dominated

by natural scientists, with limited social science engagement (Shackleton et al. 2019a). This emphasises the need to understand people’s perceptions of invasions and their responses to them, and diversify academic engagement on this issue.

The extension of the SOGA process, which explored the role of different stakeholders in implementing actions generated during the visioning process, is an additional frontier for further research. This process was successful in coalescing the actions of the group’s differing visions, without losing many of the differences in how the future was viewed. However, further research on how best to use the stakeholder matrix to support the scaling of promising seed initiatives is needed.

### Limitations

The primary limitation of the SOGA approach is that the outcomes are linked to the seeds used to initiate the process. If the seeds are not diverse and not sufficiently different from prevailing paradigms, there is a risk that the result will reinforce current thinking rather than stimulating a re-imagining of the issue (Pereira et al. 2018). Careful pre-selection of seeds to maximise their diversity using framings such as STEEP-V helps to counteract this. Convergence of future visions is also a possibility, as the Manoa method is designed to maximise the difference from present conditions, rather than the widest range of possible or divergent futures (Curry and Hodgson 2008). Introducing other tools, such as the 2 × 2 double uncertainty matrix (see Table 1) may help to create greater divergence, although convergence is still possible if the participants share a normative hope for the future (Falardeau et al. 2019). Incorporating new innovations in the SOGA approach would also be valuable in future work, such as using tools to explicitly define the power shifts necessary to facilitate transformations as illustrated by Rutting et al. (2022), or incorporating art and science-fiction storytelling to encourage creativity in the process (Lazaruko and Keys 2022). These limitations speak to some of the general criticisms of visioning—that it is dependent on who is in the room and what prompts are used to create the visions (Wiek and Iwaniec 2014). While these issues are important to acknowledge, this is a process where the outcomes, although valuable, are not the only goal.

### Conclusion

Creating shared visions of the future of IAS management is challenging, given the increased pace and escalating severity of invasions, the complexity of the issues stemming from

intersecting drivers of global change, and a lack of social science engagement on this issue. However, this kind of work is urgently needed to support action for transformative change to achieve improved environmental sustainability and societal wellbeing. Creating spaces for learning from existing innovations in the field, and for engaging constructively with the future is, therefore, an important priority. In addition, encouraging futures literacy and spurring more optimistic visions which speak to normative goals can be valuable in the effort to transform sustainability issues. We hope that the example of the application of the tools presented in this paper applied to the complex realities of IAS management in a resource-constrained developing country, where multiple innovative ways of doing and thinking nevertheless exist, serves to stimulate further initiatives in this direction.

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**Data availability** All material and data that support the findings of this study are available from the corresponding author, [JvV], upon request.

## Declarations

**Conflict of interest** The authors have no competing interests to declare that are relevant to the content of this article.

**Ethical approval** This research received ethical clearance for its activities via Stellenbosch University (REC: Social, Behavioural and Education Research (SBER)-Ref. 3880). Informed consent was received from all workshop participants.

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