

Chapter 31

Potential Futures of Biological Invasions in South Africa



John R. Wilson , John Measey , David M. Richardson , Brian W. van Wilgen , and Tsungai A. Zengeya 

Abstract Biological invasions are having a moderately negative impact on human livelihoods and the environment in South Africa, but the situation is worsening. Predicting future trends is fraught with many assumptions, so this chapter takes an outcome-orientated approach. We start by envisaging four scenarios for how biological invasions might look like 200–2000 years from now: (1) “Collapse of Civilisation, but no return to Eden”, there is no advanced human civilisation left on Earth and current biological invasions play out in full; (2) “New Pangea”, a combination of the unregulated and rapid movement of species around the world and other global change drivers leads to the biotic homogenisation of areas that were previously distinct biogeographic regions such that the concept of biological invasions no longer has meaning; (3) “Preserve or Use”, while parts of the Earth continue to be utilised, some areas are actively managed and native biodiversity and biogeographic distributions are maintained; and (4) “Conservation Earth”, a highly advanced civilisation restores the Earth to a state prior to the human-mediated movement of organisms (i.e. biological invasions are reversed).

Based on various horizon-scanning exercises and our own deliberations, we discuss how technological, socio-political, trade, global change, and ecological-

J. R. Wilson (✉)

South African National Biodiversity Institute, Kirstenbosch Research Centre, Cape Town, South Africa

Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Stellenbosch, South Africa

e-mail: john.wilson2@gmail.com

J. Measey · D. M. Richardson · B. W. van Wilgen

Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Stellenbosch, South Africa

T. A. Zengeya

South African National Biodiversity Institute, Kirstenbosch Research Centre, Cape Town, South Africa

Centre for Invasion Biology, Department of Zoology and Entomology, University of Pretoria, Pretoria, South Africa

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917

evolutionary processes in South Africa might affect biological invasions by 2070 (i.e. when people born today will be the key decision-makers). Finally, we explore how planning, regulation, funding, public support, and research might affect invasions by 2025 (i.e. over the next planning/management/political cycle). There are many things we can neither predict nor influence, but, in part based on the insights from this book, we highlight some actions that could enable the next generation to decide what they want their future to be. A greater focus on appropriate and innovative training opportunities would increase the efficacy and responsiveness of the management of biological invasions. A shift in regulatory approach from “identify and direct” to a variety of flexible, inclusive, and sophisticated approaches underpinned by evidence might provide more societally acceptable means of addressing the multitude of competing interests. Greater co-operation on biosecurity and implementation with neighbouring countries would assist prevention measures. Finally, monitoring and research aimed at documenting, tracking, and predicting invasions and their impacts would assist with efforts to identify priorities and help us to understand the consequence of different management and policy decisions. While this was a sobering exercise, it was also empowering. If South Africans can agree on a long-term trajectory for how they want to deal with biological invasions, the potential consequences of decision-making over the short-term will become much clearer.

31.1 Introduction

This book on biological invasions in South Africa has focussed on the current state of invasions in South Africa and the processes that have led us to this point. It has highlighted the fascinating interplay between socio-economic factors and biological processes that have determined which alien species have been introduced, where they have spread to, what impacts have occurred, and how South African society has responded. This is largely because the book set out to be encyclopaedic (van Wilgen et al. 2020a, Chap. 1). However, biological invasions are fundamentally dynamic and are an important component of global change (van Wilgen et al. 2020b, Chap. 29). It would therefore be remiss not to conclude with an evaluation of what the future might bring. This chapter examines possible scenarios for biological invasions globally and in South Africa, and aims to show how different events and decisions could set us on radically different trajectories.

There has been an increasing wave of interest in conducting horizon-scanning, both for conservation generally and for invasion science specifically, with the aim of anticipating and preparing for problems (Ricciardi et al. 2017; Sutherland and Woodroof 2009). However, such exercises typically only consider what could happen over the next few planning cycles. This chapter takes a different approach. Although we rely heavily on existing projections, we focus first on the long-term (i.e. on what the “end-points” might be), and work back through time. Our approach was inspired by a recent exercise that considered potential futures for human

civilisation and identified four basic trajectories: civilisation could conquer space; technological transformations could be such that what we now recognise as ‘human’ would no longer be relevant; civilisation could continue to develop, but with no transformative changes (*status quo*); or there could be a catastrophic end (Baum et al. 2019). These trajectories form the basis for evaluating the consequences of actions taken now. Thinking in this way balances short-termism that permeates most planning and political cycles and pitches thinking back into ‘Long Now’ time scales consistent with the functioning of ecosystems (Brand 2008). On this basis, and noting that the focus is on biological invasions rather than other global change drivers, we consider invasions over three time-periods:

- The long-term: the transfer of species across biogeographical barriers by humans in South Africa started slowly probably around 2000 years before present and has accelerated particularly over the last 200 years (Deacon 1986; Faulkner et al. 2020, Chap. 12). What will the situation look like in South Africa 200–2000 years from now? We assume that there will have been no significant shifts in tectonic plates (although there might be significant tectonic activity, important shifts in ocean currents, and sea-level changes), and assume that substantially new and diverse phylogenetic lineages will not yet have evolved.
- 2070: the need for inter-generational thinking is a principle embedded within conservation science; the choice of a 50-year time horizon is meant to reflect this. Specifically, what will South Africa look like when children born today become the decision makers? (although the age profile of decision-makers might and maybe should shift).
- 2025: current decisions are, of course, still made in the context of policy and management planning horizons, usually covering no more than the next 5 years (e.g. elections or government funding cycles).

For the 2070 and 2025 time periods we consider how different events and drivers are likely to put us on a trajectory to one of the long-term scenarios.

31.2 The Long-Term: What Will Invasions Look Like 200–2000 Years from Now?

Below we sketch out four long-term scenarios (Table 31.1). The inspiration for these came largely from the scenarios of Baum et al. (2019) and post-lunch discussions at the wine farm Lovane (close to Stellenbosch). However, they undoubtedly also arose from nascent ideas buried deep in our memories of concepts more eloquently expressed by other authors.

First, we consider “Collapse of civilisation, but no return to Eden”. In this scenario, a disastrous event (or series of events) leads to the extinction of *Homo sapiens*, or, of more specific relevance to biological invasions, leads to a situation

Table 31.1 The possible causes, outcomes, and consequences for South Africa of four long-term scenarios for biological invasions (i.e. 200–2000 years from now)

| Scenario | Possible causes | Description | Examples from South Africa (with a focus on the Fynbos Biome). |
|---|---|---|---|
| Collapse of civilisation but no return to Eden (Fig. 31.2a) | <p>“...nuclear war, collision between Earth and a large asteroid or comet, super-volcano eruption, global warming, runaway artificial intelligence, physics experiment disasters, major disease outbreaks, and scenarios involving multiple major catastrophes” (Baum et al. 2019).</p> | <p>Substantial intercontinental human-mediated dispersal of organisms ceases, but the impacts of existing biological invasions play out in full.</p> <p>Dispersal processes would be akin to the situation before human civilisation (Wilson et al. 2009). Over time, biogeographical breaks would re-establish, and there would be a drift back towards fundamental biogeographical/community ecology principles (if any exist). However, it is likely that that the phylogeographic signal of biological invasions would be long-lasting as many native species would have been driven to extinction by invasive species before they could adapt resulting in the loss of evolutionary lineages (e.g. the replacement of marsupials and monotremes by placental mammals), with a general but transient shift from K-selected to r-selected species.</p> | <p>In South Africa, amongst many other effects, the Fynbos Biome would disappear and be transformed to a mixture of alien shrubs and trees. Over about a third of the country, where annual rainfall is <350 mm, invasive <i>Prosopis</i> trees would dominate. Such ecosystems would no longer support large mammalian herbivores.</p> |
| New Pangea (Fig. 31.2b) | <p>Narrow utilitarian concerns dominate decisions due to the need to respond to crises; the valuation of biodiversity changes significantly; or there is a complete breakdown in global co-operation in biosecurity.</p> | <p>Biogeographical patterns and dispersal rates are changed to such a degree that the alien/native distinction is no longer meaningful (cf. Wilson et al. 2016). As pathways of introduction and spread are not managed, there will likely be a suite of panmictic organisms that come to dominate the globe.</p> <p>The globalisation of dispersal has already lead to the homogenisation of many faunas and floras (though the introduction of alien organisms can, in special cases, also lead to differentiation). In this scenario homogenisation would be taken to the extreme. Species distributions would be a function of their climate niches and either their utility for humans or their inherent competitiveness. Biological invasions will have no meaning in this scenario.</p> | <p>Trees and shrubs in the Fynbos Biome might be controlled to preserve water supply, but the Fynbos would likely be transformed by other species (e.g. invasive grasses). The area would become indistinguishable in species from other areas of the world with a similar climate (currently Mediterranean-type ecosystems). Rangelands will be transformed by a suite of herbaceous, woody and succulent invaders, some (but not all) of which may be palatable. The potential for livestock production will decline.</p> |

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|--|---|--|--|
| <p>Preserve or Use (Fig. 31.2c)</p> | <p>There is a pragmatic global agreement to protect some areas based on historical biogeographical patterns, while ensuring that other areas are used sustainably for production.</p> | <p>The Earth is separated into discrete areas that are either: (1) set aside as natural and conserved based on some reference point; (2) are considered areas where key ecosystem processes are maintained without concern over the nativity of the system (e.g. novel ecosystems); or (3) targeted primarily for utilisation.</p> <p>Active interventions to maintain biogeographical patterns and processes would need to continue in perpetuity, with decisions made as to which areas to preserve as natural (i.e. with the goal of retaining historical biogeographical distributions).</p> <p>This would likely involve on-going conflicts and trade-offs, noting that once biogeographic distributions have eroded it can be very difficult to reverse them. This might point to the need for fairly authoritarian rules governing protected areas, and global rules governing trade and transport to ensure biosecurity.</p> | <p>Governmental protection would achieve and maintain the goal of ensuring patches of the Fynbos Biome were kept alien-free, but large areas would still be used for urban and agricultural purposes.</p> <p>South African megafauna are confined to protected areas, which have to be intensively maintained and kept alien free.</p> |
| <p>Conservation Earth (Fig. 31.2d)</p> | <p>Humankind collectively decides that the Earth should be preserved <i>in toto</i> for posterity.</p> | <p>Substantial intercontinental human-mediated dispersal of organisms ceases, and the impacts of existing biological invasions are curtailed and in many cases reversed.</p> <p>Biodiversity patterns and processes return to some historical reference point, and from there allowed to carry on in essence without human intervention. Evolution is allowed to continue, and rates of extinction, speciation, and dispersal return to rates that were observed before human interventions. The current mass extinction is brought to an end (cf. the first scenario where the impacts of biological invasions would continue). Human impacts (e.g. through tourism) are kept at negligible levels.</p> | <p>Alien species in the Fynbos Biome would either be entirely removed or managed such that they have negligible impacts. The biome would be restored to a reference point. This might require the reintroduction of appropriate megaherbivores like elephants, hippopotami, and rhinoceri, and top predators like lions.</p> |

We have not explicitly considered interactions with other global change drivers (e.g. catastrophic climate change might lead to a collapse of civilisation), but recognise that such factors might be the ultimate drivers of what happens

where there is no longer an advanced civilisation that is capable of the intercontinental dispersal of species in a manner akin to either mass dispersal or cultivation (Wilson et al. 2009). The consequences of existing biological invasions would play out in full (Rouget et al. 2016), but there would be no new human-mediated introductions (or the few that occur would be akin to natural dispersal).

Second, global trade and transport continue to accelerate, and the rate of introduction of species and the subsequent invasions are not (possibly cannot) be controlled. Biogeographical barriers become fully eroded such that there is essentially global dispersal—the Earth could then be considered as a single continent from a biogeographic perspective. The concept of a “New Pangea” has a long pedigree, with some of the potential consequences codified by Rosenzweig (2001). In this scenario, local variation disappears and biotic homogenisation associated with globalisation becomes complete. This scenario has been termed a World of Weeds (Quammen 1998), although it is important to note that the New Pangea would also consist of globalised crops, livestock, and pets (McKinney 2005). Indeed, the beginnings of this can be seen with the globalisation of agriculture. For example, a McDonald’s hamburger with a coffee contains at least 19 plant species from all of the eight global centres of cultivated plant diversity identified by Vavilov (1926). All of these species are cultivated all around the world (Procheş et al. 2008b). However, the lack of effort to retain or protect non-utilitarian species and natural biogeographic distributions would lead to steep declines in biodiversity at a global scale.

Third, we consider a scenario that is somewhat similar to the Earth we know today—“Preserve or Use”. The Earth is divided into broad use types: areas that are transformed; areas used for sustainable agriculture, forestry production, or harvesting (e.g. fishing); and natural areas that are protected. Current levels of protection vary—around 14.7% of land area and 4.1% of the oceans are formally protected (UNEP-WCMC and IUCN 2016). This does not mean that such areas are devoid of alien species (Foxcroft et al. 2013) or that the eradication of alien species from such areas is possible or in some cases desirable—a third of all formally protected land is still subjected to intense human pressures (Jones et al. 2018). There are also significant moves to ensure that biodiversity is appreciated and considered everywhere. For example, in urban ecosystems the native/alien dichotomy is but one of many factors considered when formulating management strategies for “the whole landscape” (Hobbs et al. 2014; Potgieter et al. 2020, Chap. 11). Nonetheless, the distinction between alien and native is important and should be made explicit if biodiversity is to be conserved (Pauchard et al. 2018). This scenario requires a societal consensus that persists over time (e.g. in a “Preserve or Use” Earth a sense of enormous well-being is gained both by conserving native wildlife and by feeding the pigeons and sparrows too). The overall area that should be set aside is the subject of on-going debate, with recent proposals suggesting it should be as high as 50% (Buscher et al. 2017; Noss et al. 2012; Wilson 2016).

Although Earth is currently in a “Preserve and Use” state, we do not consider this scenario to be the *status quo* as we do not believe the current situation is sustainable. While some progress has been made controlling biological invasions, especially in protected areas (Foxcroft et al. 2013) and on islands (Greve et al. 2020, Chap. 8; Jones et al. 2016), problems with invasions are worsening in most cases (Millenium Ecosystem Assessment 2005), and globally the number of alien species that naturalise and become invasive in new areas keeps climbing, with no indication that it will plateau soon for most taxonomic groups (Seebens et al. 2017). Based on current drivers, we believe we are drifting towards the New Pangea.

Finally, we propose a “Conservation Earth” scenario in which the whole planet is conserved as a ‘cradle of life’. Human-mediated dispersal of organisms stops; invasions are eradicated; other human-mediated drivers of global change are reversed; and the Earth is actively restored to how it was before widespread human influence (including before biological invasions). For this scenario to be realised, humans would need to have developed radically advanced technologies in ecological restoration; there would need to be profound modifications to current biodiversity (from genes to ecosystems) and physico-chemical processes (e.g. the creation of soils); and the impact of humans on Earth (i.e. their footprint) would have to decline to negligible levels. However, once “Conservation Earth” was achieved, further human interventions could cease. This is perhaps the most sci-fi of our four long-term scenarios, but it is compatible with, and perhaps a likely outcome of, two of Baum et al. (2019)’s trajectories for human civilisation—the technological transformation trajectories, and the astronomical trajectories.

There is somewhat of a continuum between “New Pangea” and “Conservation Earth”, with “Preserve or Use” as an intermediate and possibly unstable state. There are, however, some qualitative differences. “Preserve or Use” differs from “New Pangea” in the retention of significant historical biogeographical patterns (e.g. Australia has a unique recognisable fauna, and the fishes of the Amazon are distinct from those of the Mekong or the Nile). “Preserve or Use” differs from “Conservation Earth” in the constant need for human intervention to ensure sustainability while maintaining biosecurity. Notably, if civilisation were to collapse, we suspect that it might already have moved significantly towards a “New Pangea” scenario. Therefore, while under both “Collapse of civilisation, but no return to Eden” and “Conservation Earth” there might be few if any humans left on Earth, these scenarios would look very different in terms of biogeography.

These scenarios are also not exhaustive, and we acknowledge that they deal with the interaction of global change drivers rather crudely. For example, climate change alone might lead to a complete reorganisation of the world’s biomes. These novel biomes might be distinct and separated by biogeographical barriers maintained by future civilisations, and so might be valued both for their intrinsic uniqueness and their utilitarian value. We feel, however, that the four potential futures we outline are

useful as they provide a small set of different trajectories against which current events and decisions in biological invasions can be assessed.

31.3 The Year 2070: What Will Biological Invasions Look Like in South Africa When Children Born Today Are the Decision Makers?

In considering what South Africa might look like 50 years from now we considered five main themes that have emerged from recent horizon-scanning exercises in invasion science (Caffrey et al. 2014; Dehnen-Schmutz et al. 2018; Ricciardi et al. 2017): technological advances; the political socio-economic milieu; trade; the link to global change drivers; and potential evolutionary and ecological responses. We tried to envisage potential changes, and how these might influence biological invasions consistent with one of the long-term scenarios [excluding the collapse of civilisation scenario where the influence of catastrophic events on biological invasions would be irrelevant compared to the catastrophe itself] (Table 31.2). These projections are our own, but were inspired by horizon scanning; studies of the current and future trends in the Anthropocene; and deliberations during a 1-day workshop entitled “Where to with invasion science in South Africa?” organised by the Centre for Invasion Biology (C-I-B) in November 2018.

31.4 The Year 2025: What Will Biological Invasions Look Like After the Next Funding/Political Cycle?

The choice of specific events over the next 5 years that are likely to happen or that are already happening (e.g. challenges to the current regulations) are our own, but as before were inspired by: the recent report on the national status of biological invasions in South Africa (van Wilgen and Wilson 2018); South Africa’s draft National Strategy on Biological Invasions (van Wilgen et al. 2014); the C-I-B’s strategic plan for 2025; and insights from the 2018 C-I-B workshop on “Where to with invasion science in South Africa?”. We found it difficult, however, to link these events to the long-term trajectories. Therefore we categorised events in terms of whether they are likely to cause biological invasions to worsen (consistent with “Pangea Earth”); keep invasions roughly static (“Preserve or Use”); or reduce the impacts seen (consistent with either “Preserve or Use” or “Conservation Earth”) (Table 31.3). We also selected and discuss events under themes that we feel operate over this time-scale—planning, regulation, funding, public support, and research.

Table 31.2 How changes over the next 50 years in technological advances; the political socio-economic milieu; trade; global change drivers; and evolutionary and ecological responses might place biological invasions in South Africa along a trajectory to one of the scenarios outlined in Table 31.1

| Direction | Possible causes | Possible outcomes | Potential examples for South Africa |
|---------------------------------|--|---|--|
| 2070 towards "New Pangea" | Lack of investment to improve technologies to control invasive species/existing effective control technologies (e.g. herbicides) are banned. | Management is either ineffective or infeasible leading to large areas of land dominated by invasive species of low value. The costs of restoring ecosystem functioning (e.g. soils) means that restoring these 'invasion bad-lands' is uneconomical. | Biotechnological solutions are available to produce sterile forestry trees but the use of such technology is currently disincentivised, e.g. by the Forest Stewardship Council standards that do not allow genetically modified organisms (Brundu and Richardson 2016). Similarly, a reluctance to use biological control to combat pines means that pine invasions continue unabated (Hoffmann et al. 2011). The lack of a functioning process to approve pesticides effectively becomes a moratorium [e.g. delays in the approval of corvidicides mean attempts to eradicate invasive birds fail (Davies et al. 2020, Chap. 22)]. A lack of collaboration between South Africa and its geographic neighbours leads to the establishment of new invasions that subsequently cross the border [e.g. alien freshwater crayfish established in Swaziland when permits to culture them in South Africa were refused (Nunes et al. 2017)]. |
| | <i>Socio-political:</i> Conflicts of interest and denialism prevent regulation and management. Government priorities shift from biosecurity and biological invasions to what are perceived as more immediate concerns. | Previously demarcated protected areas are eroded by invasions to the point where they cannot conserve local biodiversity. Alien and native species receive the same existential rights in law, leading to a cessation in efforts to control invasions. Access to private properties to control incursions is denied, and the rate of new invasions accelerates. Propagule pressure increases significantly, together with the establishment and invasion of many new species. | A failure in regional biosecurity efforts would lead to significant increases in the rates of species spread between South Africa and the rest of Africa (Faulkner et al. 2017), with regional biosecurity determined by the weakest link. The absence of appropriate mycorrhizal symbionts historically limited establishment and spread of <i>Pinus</i> species in South Africa; but widespread inoculation has effectively removed this barrier. Other alien plant taxa might similarly establish if missing mutualists are introduced (Richardson et al. 2000a). |
| | <i>Trade:</i> There is an acceleration and escalation, without concomitant international agreements or regulations. | Facultative symbionts, not previously present, are introduced, and allow species to spread (Le Roux et al. 2020, Chap. 14). Pests of agricultural crops have global distributions, requiring significant control measures and precluding particular crop genotypes. Some monocultural production become unsustainable due to global pathogens (Wingfield et al. 2015). | |

(continued)

Table 31.2 (continued)

| Direction | Possible causes | Possible outcomes | Potential examples for South Africa |
|---------------------------------------|--|---|--|
| | <p><i>Global change:</i> Various drivers (e.g. habitat modification, over-harvesting, climate change) interact, such that the fundamental niches of many species shift dramatically.</p> | <p>Species shift in range, show adaptation, or decline. It is increasingly difficult to define a species' native range, and communities are almost all novel. The priority for conservation efforts shifts towards maintaining ecosystem functions and a few iconic species.</p> <p>The suite of invasive species changes with elevated levels of nitrogen and carbon dioxide and changes to the climate (some invasive species decline in importance and others previously deemed of low risk become high risk). As a result, our ability to predict based on the history of invasiveness and impact elsewhere declines.</p> | <p>Native trees can establish and dominate in areas that were previously grassland or savanna, i.e. bush encroachment (Nackley et al. 2017). Similarly, the alien tree <i>Schinus molle</i> is widely planted but not yet widely naturalised. Under climate change, fynbos and grass-land area are predicted to become more amenable to establishment, leading to more widespread invasions (Richardson et al. 2010).</p> |
| | <p><i>Ecological-evolutionary:</i> The continuing introduction of new taxa disrupts existing food webs, creates novel community interactions, leads to rapid evolution, and creates opportunities for some species at the expense of others.</p> | <p>Co-xenic symbioses are unpredictable and enable previously innocuous species to become invasive, leading to invasional meltdown (Simberloff and Von Holle 1999).</p> <p>There is continuing selection for "super" weeds and pests that grow fast and dominate.</p> <p>Invasions accelerate in unpredictable ways as adaptations allow species to establish outside of their native niches.</p> | <p>Nitrogen deposition triggers regime shifts to alternative stable states allowing incursion and persistence of alien taxa (Richardson et al. 2000b).</p> <p>Droughts will become more frequent in the Western Cape, and this effect will be compounded by invasive trees that reduce streamflow from catchments; water supply schemes will be more likely to fail, with serious economic and social consequences.</p> |
| <p>2070 towards "Preserve or Use"</p> | <p><i>Technological:</i> Substantial investment into research and development keeps pace with novel demands of invasive species.</p> <p>Effective management approaches are accepted and used judiciously.</p> | <p>Active and passive surveillance allows incursions to be detected timeously and controlled before they become widespread invaders (Wilson et al. 2017).</p> <p>Protected areas are kept largely clear of invasions.</p> <p>Costs of management are kept within fiscally acceptable levels.</p> | <p><i>Puccinia psidii</i>, a South American myrtle rust fungus, is now commonly associated with alien eucalypt taxa in South Africa, but this pathogen has spilled over onto native forest Myrtaceae species in South Africa with as yet unknown impacts (Le Roux et al. 2020, Chap. 14).</p> <p>Guttural loads have changed their physiology and behaviour in order to become established in a novel Mediterranean ecosystem after only 20 years (Vimercati et al. 2018).</p> <p>CRISPR technology is licenced worldwide and proves to be a valuable tool in invasive species management in South Africa.</p> <p>Application of widely available tools such as Google Earth (Visser et al. 2014) allows for monitoring linked to effective interventions.</p> |

| | |
|---|--|
| <p>Species that were previously widespread invaders are brought under control.</p> | <p>Funding for research on biological invasions keeps pace with invasions.</p> <p>Biological control reduces the spread of widespread invaders, and in essence stops the impact of some invasions (Henderson and Wilson 2017; Hill et al. 2020, Chap. 19).</p> |
| <p><i>Socio-political:</i> Appropriate regulations are enacted for pathways, species, and sites, at all stages of the invasion continuum. Strategies to combat biological invasions are developed and implemented.</p> | <p>The Working for Water programme could perhaps remain an unshamed job-provision focussed component of a broader national programme of focussed biological invasion management. Management could then be more agile, less tied to political agendas, and therefore more effective and professional, and better able to focus on priorities (van Wilgen and Wannenburgh 2016).</p> <p>Government develops a policy, strategies are revised and adopted (Department of Environmental Affairs 2014), and interventions prioritised based on the return on investment and on how wide the benefits are (van Wilgen and Wilson 2018).</p> |
| <p><i>Trade:</i> Regional co-operation allows for collaboration on biosecurity, and international agreements are developed in response to biological invasions.</p> <p>Rigorous and reliable risk analyses are set as a standard for trade.</p> | <p>The Ballast Water Convention is implemented in full (Lukey and Hall 2020, Chap. 18; Robinson et al. 2020, Chap. 9).</p> <p>The Southern African Development Community facilitates greater biosecurity co-operation.</p> <p>By understanding the mechanisms behind Cactaceae invasions (the presence of detachable fragments in particular) it is possible to identify and regulate species that pose a risk while allowing trade in species that pose an acceptable level of risk (Novoa et al. 2015; 2016b).</p> <p>Red List Index is declining for many taxa in South Africa (Measey et al. 2019), but substantial proportions of biodiversity are covered by formal protection (Skowno et al. 2019).</p> |
| <p><i>Global change:</i> Habitat change is reduced or limited to areas already destroyed. Local species stocks can rebuild.</p> | <p>There would still likely be a significant extinction debt to be paid by species not in protected areas, with an increasing number of species that cannot survive in the matrix of used and changed habitats.</p> |

(continued)

Table 31.2 (continued)

| Direction | Possible causes | Possible outcomes | Potential examples for South Africa |
|-----------------------------------|--|---|---|
| | <p data-bbox="215 1162 259 1501">Naturally harvested stocks require protected areas to maintain breeding populations.</p> <p data-bbox="262 1162 363 1501">Some alien taxa that provide eco-system services would need to be replaced with new or modified varieties that can cope with the novel environments already set aside as “use” areas.</p> <p data-bbox="365 1162 412 1501"><i>Co-xenic symbioses</i> are unpredictable and require rapid removal with substantial human capital investment.</p> <p data-bbox="442 1162 565 1501"><i>Adaptations</i> by novel alien species allow opportunities for using new aliens providing ecosystem services following sufficient human capital and technological investments to prevent invasions and maintain their control.</p> <p data-bbox="568 1162 612 1501"><i>Ecological-evolutionary</i>: There is some biotic resistance to invasions.</p> | <p data-bbox="215 684 259 1134">Naturally harvested stocks require protected areas to maintain breeding populations.</p> <p data-bbox="262 684 363 1134">Some alien taxa that provide eco-system services would need to be replaced with new or modified varieties that can cope with the novel environments already set aside as “use” areas.</p> <p data-bbox="365 684 436 1134"><i>Co-xenic symbioses</i> are unpredictable and require rapid removal with substantial human capital investment.</p> <p data-bbox="442 684 565 1134"><i>Adaptations</i> by novel alien species allow opportunities for using new aliens providing ecosystem services following sufficient human capital and technological investments to prevent invasions and maintain their control.</p> | <p data-bbox="215 172 718 666">Significant advancements in habitat restoration allow invasions to be reversed. For example, Cape Town has an on-going large restoration project at the Blaauwberg Nature Reserve of a site that was previously a monoculture of <i>Acacia saligna</i> where different management approaches have been trialled (Holmes et al. 2012).</p> |
| 2070 towards “Conservation Earth” | <p data-bbox="568 1162 718 1501"><i>Technological</i>: Substantial advances in technology means the costs associated with managing decrease dramatically. Sustainable energy and food solutions are developed and implemented.</p> <p data-bbox="771 1162 921 1501"><i>Socio-political</i>: There are substantial shifts in cultural views that mean conserving Earth and preserving native biodiversity become top priority (e.g. via a new Green Deal type revolution).</p> | <p data-bbox="568 684 612 1134">The more efficient use of ecosystems leads to a considerably reduced agricultural footprint.</p> <p data-bbox="615 684 685 1134">Technology and engineering solutions allow for mitigation and stabilisation of global change drivers.</p> <p data-bbox="687 684 765 1134">More effective monitoring protocols result in enhanced tools for defining management priorities and strategies for interventions.</p> <p data-bbox="767 684 838 1134">More funding and support is provided for authoritarian interventions, e.g. the rigorous guarding of protected areas, and removal of alien species.</p> <p data-bbox="840 684 918 1134">Horticultural and pet trades focus only on native species and keeping alien species outside of strict captivity stops.</p> <p data-bbox="920 684 970 1134">There are fewer alien species so invasion debt drops dramatically.</p> | <p data-bbox="568 172 718 666">Significant advancements in habitat restoration allow invasions to be reversed. For example, Cape Town has an on-going large restoration project at the Blaauwberg Nature Reserve of a site that was previously a monoculture of <i>Acacia saligna</i> where different management approaches have been trialled (Holmes et al. 2012).</p> <p data-bbox="771 172 871 666">There is already a shift in horticultural trends toward native species (Botha and Botha 2000), but a step-change in both awareness and compliance is needed (Novoa et al. 2016a; Shackleton and Shackleton 2016).</p> |

| | | |
|---|---|---|
| <p><i>Trade:</i> Trade is tightly regulated or curtailed to prevent the introduction of alien species. A precautionary principle is adopted throughout.</p> <p><i>Global change:</i> Global change drivers are reversed in order to regain control of planetary destiny. Any that still exist have no real effect on decisions.</p> <p><i>Ecological-evolutionary:</i> Biotic resistance is stronger than anticipated. Greater adaptation by native biota so that the advantage of being alien is more transient than expected.</p> | <p>The introductions of new species and new genetic material ceases.</p> <p>Corridors between reserves are established to allow for natural gene-flow of wide ranging species. Reductions in extreme events and human-caused disturbance reduce the opportunities for invasion.</p> <p>The competitiveness of invasive species declines rapidly in time since date of introduction.</p> | <p>Recommendations given by Faulkner et al. (2020, Chap. 12) are strictly adhered to.</p> <p>The environmental factors promoting invasions (e.g. soils) are managed, and restoration achieved (Holmes et al. 2020, Chap. 23; Wilson et al. 2020, Chap. 13).</p> <p>This has yet to be shown in South Africa, but it is clear that evolution can be surprisingly rapid both in invasive species and in the response from native communities. For example, native insect herbivores might rapidly adapt to invasive plants reducing their rate of spread and competitiveness (though cf. Procheş et al. 2008a).</p> |
|---|---|---|

Table 31.3 How changes over the next 5 years in planning, regulation, funding, public support, and research might place biological invasions in South Africa along a trajectory to one of the scenarios outlined in Table 31.1

| Direction | Possible causes | Outcomes | Current examples from South Africa |
|--|--|--|--|
| 2025: The extent and impacts of biological invasions increases. (“New Pangea”) | <p><i>Planning:</i> The lack of a policy on managing biological invasions in the country results in the lack of adoption and implementation of a clear strategy for dealing with the problem at a national level (Lukey and Hall 2020, Chap. 18). The planning, implementing, and review of existing control plans focus on inputs to control rather than the outcomes in terms of the biological invasions themselves.</p> <p><i>Regulation:</i> Legal challenges to current regulations succeed, leading to the repeal or suspension of the national regulations (Box 1.1, van Wilgen et al. 2020, Chap. 1).</p> | <p>Available resources are directed to random projects, with no clear goals</p> <p>What management happens is either ineffective or exacerbates the problem.</p> | <p>“Most alien plant control projects in South Africa have been given goals for the amounts to be spent, the number of people to be employed, and the areas to be treated. Monitoring of progress has a focus on these goals, and there are typically no goals that describe desired outcomes in terms of reducing plant invasions to manageable levels, what those manageable levels would be, and how long it would take to achieve them.” (van Wilgen and Wilson 2018, p 117)</p> |
| | <p>Inability to regulate the import of new species or to control those already here, means that the rates of introduction of new species that will become invasive increases.</p> <p>The removal of a mandate for many government agencies and private individuals to manage biological invasions results in a reduction in control activities.</p> | <p>Proposals to amend the A&IS Regulations were published in January 2018 (Department of Environmental Affairs 2018), but as of October 2019 these have not been promulgated in part due to an ongoing legal challenge to the regulations.</p> | |
| | <p>Many existing control projects would be curtailed, with insufficient funds remaining to effectively manage the remaining projects.</p> | <p>Cuts in funding to provincial conservation authorities has led to a decrease capacity, and a concomitant reduction in activities to monitor and control alien species (Impson 2016).</p> | |
| | <p>Landowners refuse access to their land, and do not adhere to notifications and regulations.</p> <p>Social media campaigns become active and disrupt on-going control efforts.</p> <p>Levels of motivation and satisfaction of people managing biological invasions declines radically.</p> | <p>Several civil action groups have arisen in and around Cape Town to oppose alien control. These include “Shout for Shade” (opposed to tree-felling) and “Friends of the tahrns” (van Wilgen 2012). People involved in animal control projects have been personally abused and received death threats (Davies et al. 2020, Chap. 22).</p> | |

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|---|--|---|---|
| <p><i>Research:</i> Research funding ceases due to changes in government priorities or inefficiencies in the allocation of funds.</p> | <p>There is less research to support decision makers and managers. Fewer graduates are exposed to invasion science, and the human capacity deficit increases.</p> | <p>There is less knowledge of the problem with which to motivate for funding or highlight the issues, leading to a negative feedback and further reductions in funding.</p> | <p>The Centre for Invasion Biology and the Centre for Biological Control depend on funding over 3–5 year cycles, and there is no guarantee that funding will continue (Hill et al. 2020, Chap. 19; Richardson et al. 2020a, Chap. 30). Science councils, such as the CSIR, have adopted research strategies that focus on industrialisation, moving away from environmental and public-good research.</p> |
| <p>2025: Biological invasions stay constant (“Pre-serve or Use”)</p> | <p>Scrutiny of management effectiveness highlights how management can be improved even in the absence of clear goals, and these recommendations begin to be implemented. There is some monitoring feedback allowing management to adapt and improve, but this is still largely ad hoc.</p> | <p>Both the national strategy on biological invasions and the CAPE strategy on invasive species have been developed, but not formally adopted. Responsibility for adoption is not always clear, as many different government departments need to collaborate closely. However, both documents have been cited and read by managers.</p> | <p>Levels of compliance are generally low, though there are increasing numbers of examples of permits, compliance, and enforcement (van Wilgen and Wilson 2018). Capacity to comprehensively implement the regulations remains a challenge.</p> |
| <p><i>Regulation:</i> Legal framework remains as it is.</p> | <p>While there is some compliance, there are still many instances of non-compliance, leading to a mixed adherence to requirements. The current regulations continue to have some impact, but not as much as desired.</p> | <p>The ability to carry out the necessary levels of control and follow-up continues. Spread of invasive species is curtailed, and losses of ecosystem services kept constant.</p> | <p>Government funding on work of biological invasions has increased steadily despite funding cuts in many other areas.</p> |
| <p><i>Public support:</i> Public appreciation of the problem of biological invasions, their consequences, and potential solutions remains at relatively low levels.</p> | <p>Many people remain ignorant of the problem, or challenge the motivations put forward for control, and do not take regulations seriously. Other stakeholders engage with the problem and assist.</p> | <p>Various industries (e.g. horticulture) have shown a commitment to comply with the regulations, although levels are still low (Cronin et al. 2017). In addition, there is ongoing disagreement about the value of alien species from a range of sources (freshwater anglers, foresters, and those engaged in the pet trade).</p> | <p>(continued)</p> |

Table 31.3 (continued)

| Direction | Possible causes | Outcomes | Current examples from South Africa |
|--|---|---|---|
| | <p><i>Research:</i> Research capacity is maintained due to renewal of existing funding.</p> | <p>Levels of understanding increase in line with issues. Management relies on existing, incomplete understanding, or trial-and-error approaches, but occasionally some real insight is provided. There are an increasing number of cases of uptake of research findings.</p> | <p>Currently, invasion science in South Africa is well funded, but this is under threat. There are a few collaborative research partnerships to encourage the flow of information between researchers and managers exist, but these are far from comprehensive (Foxcroft et al. 2020, Chap. 28).</p> |
| <p>2025: The impacts of biological invasion are reduced (“Preserve or Use”/“Conservation Earth”)</p> | <p><i>Planning:</i> A national policy on biological invasions sets out a vision for what can be achieved and leads to a strategy with clear goals that is adopted and implemented. In consequence management plans are developed for pathways, species, and sites.</p> <p><i>Regulation:</i> The regulatory framework is improved, and capacity to manage the implementation of regulations is increased.</p> | <p>Managers and decision-makers have a clear agreed vision of how biological invasions are to be dealt with.</p> <p>A monitoring program, focussed on clear goals, helps management to become more adaptive. Increased achievement of management goals leads to a reduction in impacts, or at least slows the rate of growth in impacts.</p> <p>Improved compliance and management of biological invasions, and reduced contestations; more resources from additional stakeholders directed to management; and increased control efforts reduce the extent of invasions over large areas leading to a reduction in impacts.</p> | <p>A national policy processes has recently been proposed. Various planning tools are available including a strategy and guidelines for management (Department of Environmental Affairs 2014, 2015). A framework of indicators is available to facilitate tracking progress in terms of the outcomes (Wilson et al. 2018).</p> <p>While the process has been initially slow, permits, notifications and directives are being issued (van Wilgen and Wilson 2018), as more criminal cases are successful prosecuted, people will be more motivated to comply.</p> <p>A risk analysis framework to provide evidence to support listing of alien species has been developed (Kumschick et al. 2018, 2020). If formally adopted, it could provide a transparent process and hopefully reduce legal contestations.</p> |
| | <p><i>Funding:</i> Levels of funding to manage biological invasions are increased.</p> | <p>The prospects for achieving control in priority areas is improved.</p> <p>The loss of ecosystem services from priority areas is reduced.</p> | <p>Currently, relatively generous funding is available, considering the demands on the South African fiscus.</p> |

| | | |
|--|---|---|
| <p><i>Public support:</i> Public awareness and appreciation of the problem increases, as part of an overall increase in environmental awareness through successful outreach activities and as part of a general global increase in awareness (e.g. through the Extinction Rebellion).</p> <p><i>Research:</i> Government sees invasion science as a key research need and opportunity for human capacity development in applied sciences and for greater regional research co-operation.</p> | <p>Increased understanding of biological invasions leads to improvements in management. Increased achievement of goals leads to a reduction in impact, or a slowing in the rate of growth in impacts.</p> <p>Political support for increased funding, and increased compliance with regulations. The extent of invasions over larger areas is further reduced, leading to a reduction in impacts.</p> <p>Regional research collaboration increases, perhaps through the auspices of the Southern African Development Community.</p> | <p>Several volunteer-type organisations in South Africa increase or supplement management capacity. These include “hack” groups, honorary rangers, and citizen scientists who contribute observations through platforms like iNaturalist. These could increase in number and effectiveness as awareness grows.</p> <p>The establishment of a government funded Centre for Invasion Biology (Richardson et al. 2020a, Chap. 30), and a team focusing on biological invasions based at the South African National Biodiversity Institute (Wilson et al. 2013), highlights the government’s appreciation of biodiversity and the need to undertake research on drivers of biodiversity loss.</p> |
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31.5 Possible Ways Forward: Examples from South Africa

God, grant me the serenity to accept the things I cannot change,
courage to change the things I can,
and wisdom to know the difference.

The Serenity Prayer (Reinhold Niebuhr)

In this chapter, we have outlined four long-term scenarios, and have described how events over the next 5–50 years will place us on a trajectory to one of these. Which end point is desirable is a choice for society, and some of the issues are highly contentious and incompatible [e.g. the right of your neighbour to keep a pet cat in their garden affects your right to enjoy a diversity of birds in your garden (Potgieter et al. 2020, Chap. 11)]. Such issues can, of course, also vary over space and time. Introduced species might increase local diversity over the short-term but reduce global diversity and even local diversity over longer time frames, due to the interplay between invasion and extinction debts (Rouget et al. 2016; Tilman et al. 1994). We illustrate these scenarios not to proselytise, but to highlight how the choices we make now could influence the future state of the Earth and what options (if any) are available to future generations.

Importantly, business-as-usual will ensure that current trends continue and that biological invasions will worsen due to an increasing number of alien species, growth in the extent of invasions, increasing impacts, and the continuing problems around conflict-generating species, ineffective management, and insufficient management capacity (van Wilgen and Wilson 2018). There are few studies on the impacts of alien species but available studies show that the reductions in the value of ecosystem services, productivity of rangelands, and in biodiversity intactness caused by alien species are low at present, but expected to grow rapidly (van Wilgen et al. 2008; Zengeya et al. 2020, Chap. 17). The challenge in South Africa will be to combine the current funding model (where most government funding to manage biological invasions is primarily for job creation), with one that also focuses on improving the efficiency of management and the outcomes in terms of reduced impacts and threats from invasions (van Wilgen and Wannenburg 2016). Shifting our focus from control to prevention would also improve returns on investment, but siphoning funds from current problems might exacerbate them. Practicing conservation triage, with a focus on priority areas, could lead to patchy successes, but is likely to meet stiff resistance as people are reluctant to admit that some areas have to be abandoned to save others. Similarly, the distribution of funding has been based on political and social concerns (e.g. the desire to spread funding across the country). Shifting this to a funding system based on ecological and environmental needs would be unpopular and might see a decline in political support and ultimately funding. Increasing investment in biological control would also increase returns on investment (Hill et al. 2020, Chap. 19), but is less politically attractive as it is not labour-intensive. Important questions remain unanswered. What will be required to turn this around, and will it be politically possible? What is the future of South Africa's legislative framework in the face of legal challenges (cf. Lukey and Hall 2020, Chap. 18)? There are, however, plenty of examples where change is possible.

Continuing investment in the management of biological invasions can be both vital for sustainable and equitable development and cost-effective, especially if economic incentives for invasive species management and overall restoration are implemented (Milton et al. 2003). Regardless of the trajectory and how we deal with the issue, we expect that in 50 years' time the most widespread invaders that cause the most impacts will be similar to those that occur now [for comparison, invasions in the Fynbos Biome are largely, though not entirely, the same as those 70 years ago with acacias, hakeas and pines dominating (van Wilgen et al. 2016)]. However, there will inevitably be some big surprises (e.g., the discovery of the Polyphagous Shot-Hole Borer, Paap et al. 2018; Box 11.3, Potgieter et al. 2020, Chap. 11).

South Africa as a society will need to make decisions as to what and how to prioritise for management. In the rest of this chapter we outline selected case-studies from this book to illustrate how decisions made over the next 5–50 years will determine the trajectory of biological invasions in the future.

31.5.1 Coastal vs. Off-Shore Ecosystems

Most of South Africa's rocky seashore has been transformed by the introduction of alien mussel species. This was not a deliberate choice and no technologies currently exist to alter this situation (Robinson et al. 2020, Chap. 7). The novel ecosystems created by these invasions have some benefits, and interesting impacts on biodiversity (Griffiths et al. 1992; Robinson et al. 2020, Chap. 7). Despite the current regulations, it will be difficult, but not impossible, to prevent new invasions of coastal species. There are also moves to protect large areas from habitat transformation. All this suggests that, for coastal systems, we are in a "Preserve or Use" state that is much closer to "New Pangea" than "Conservation Earth". In sharp contrast, very few off-shore marine invasions have been recorded, and there are no examples of invasive marine fish in South Africa. It might be possible to preserve this situation, and stay on a trajectory closer to "Conservation Earth", though this depends on the degree to which a sustainable blue economy can be achieved without leading to more species introductions and more impacts.

31.5.2 The Management of Invasions in Arid Rangelands: Prosopis Species

A large proportion of the land surface of South Africa is taken up by arid rangelands (Table 16.1, O'Connor and van Wilgen 2020, Chap. 16). These rangelands are being threatened by rapidly-expanding invasions of Mesquite (*Prosopis*) trees that reduce groundwater resources on which many towns and communities in the region are dependent (Le Maitre et al. 2020, Chap. 15), and reduce the capacity of rangelands to produce livestock. If *Prosopis* invasions continue to increase, there could be total

economic collapse in these regions, similar to that experienced in the Karoo in the 1920s as a result of invasion by *Opuntia ficus-indica* (Mission Prickly Pear) (O'Connor and van Wilgen 2020, Chap. 16). There is a need to diversify land-use activities to increase income in these areas, for example by combining livestock farming with game viewing, hunting and tourism (Milton et al. 2003). If successful, some of the income could be channelled back into *Prosopis* control. There are also initiatives that will explore the possibility of triple bottom-line accounting, and using this to underpin a system of tax incentives to allow landowners to recoup the costs of alien plant control. This, combined with more effective biological control, could reverse the negative trend in *Prosopis* invasions. Currently, however, we are in a “Preserve or Use” state that is shifting rapidly towards “New Pangea”, and if the similar on-going *Prosopis* invasions in Kenya and Ethiopia continue, many of these landscapes will become physically and functionally identical (and provide few ecosystem services).

31.5.3 The Need for Taxonomic Services and Well-Curated Comprehensive Lists of Alien Species

The status of knowledge of alien species varies markedly—high for mammals (Measey et al. 2020, Chap. 5), lower for plants (Richardson et al. 2020b, Chap. 3), lower still in marine systems (Robinson et al. 2016, 2020, Chap. 9), and almost non-existent for many soil and microbial groups (Janion-Scheepers et al. 2016; Wood 2017). But even for well-studied groups, there are errors and omissions in the lists of invasive species (Magona et al. 2018). South Africa lacks a comprehensive consolidated list of alien taxa (cf. van Wilgen and Wilson 2018). This is a problem as many alien species that are known invaders elsewhere in the world are present in South Africa but not yet incorporated into long-term planning and strategies. Continuing investment in taxonomy would increase our ability to identify and respond to incursions before they become widespread, and understanding the target species can be essential for management (Jacobs et al. 2017; Pyšek et al. 2013). By contrast, a dramatic reduction in research funding would see lists quickly become out of date which would undermine both risk analysis efforts (Kumschick et al. 2020, Chap. 20) and public support. Taxonomic services and alien species lists provide the foundational biodiversity information necessary for us to be able to choose between a “New Pangea” or “Conservation Earth” trajectory.

31.5.4 Regulatory Directions

South Africa is one of the few countries that has comprehensive regulations in place to manage biological invasions, and many parts of the regulations are innovative

(van Wilgen and Wilson 2018). While this is certainly commendable, there are many challenges to the effective implementation of these regulations, not least of which is a lack of capacity to monitor and, if necessary, enforce them. Section 18.8.2 of Lukey and Hall (2020, Chap. 18) highlights that compliance with the regulations by 90% of society will only be achieved if the 10% that do not comply are brought to book, which is not the case at present. Compliance will also only be achieved if the regulations are broadly regarded as just and equitable; this may not be the case with the current approach of “faultless liability” whereby landowners are responsible for the control of species they did not introduce. Currently, the regulations are either ignored, or people are unaware of them (van Wilgen and Wilson 2018), and some people have mounted legal challenges to them (Lukey and Hall 2020, Chap. 18). If the regulations remain ineffective, or are removed as a result of legal challenges, we may be heading towards “New Pangea”. A change in approach might be required to move in other directions, including subsidies and tax breaks, but a major step would be the development of a national policy on biological invasions to provide the basis for strategic and regulatory developments.

31.5.5 A New Green Deal and Landscape Stewards

The idea of linking environmental management to employment creation (i.e. labour-intensive alien plant clearing programmes) was an innovative solution to the need to raise funds for invasive plant control in South Africa in the post-apartheid consensus (when funds were also desperately needed for education, health, infrastructure development, security, and welfare). However, the management of invasions is still tied primarily to welfare and job creation, and while the allocation of funds has grown, managers are still assessed on input indicators (e.g. numbers of jobs created, and money spent) rather than output or outcome indicators (e.g. reductions in the area invaded and the impacts caused) (Wilson et al. 2018). Moreover, the approach limits the implementation of more effective high-tech solutions in some cases (van Wilgen and Wilson 2018). This “green deal” has thus failed to stem the spread of invasive species at a national scale, and business-as-usual would set us on a trajectory towards “New Pangea”. A combination of a new green deal and a ‘landscape steward’ approach could reverse these trends. More effective, goal-directed planning and implementation supported by a greater focus on training on project management and monitoring control effectiveness, and judicious use of new technologies (e.g. drones, precision control, DNA barcoding, remote sensing and monitoring, and improved taxonomic capacity), could improve management effectiveness and returns on investment. Continuous monitoring and maintenance of project outcomes as well as the development of nuanced interventions that are appropriate for the specific context would be more realistic if a more permanent connection is made between managers and the land they are managing, e.g. through a landscape steward type approach.

This would require a societal consensus around the need to avoid the longer-term impacts associated with invasions (i.e. beyond current political and funding cycles); the need to balance all the benefits of invasions (timber, fuel, fodder, carbon, food and recreation) against their negative impacts (on water, rangeland productivity, biodiversity, fire hazard and human health); an appreciation of the threat invasions pose to economic and social prospects and ultimately sustainable development; and an increased focus on supporting bottom-up community driven connections to the land that is being managed. But the idea of linking environmental sustainability and job creation is as valid now as it was 25 years ago. A new green deal based on explicit and commonly shared goals of environmental and social sustainability would set South Africa on the path to “Preserve and Use”, and ultimately to ensure that South Africa retains its unique character.

31.6 Conclusions

It's hard to make predictions, especially about the future.

Provenance uncertain, probably Danish (made famous by Niels Bohr)

While efforts to predict invasions are becoming more sophisticated (e.g., Essl et al. 2019; Gallien et al. 2019) and metrics exist for projecting how current indicators might change over time (Rouget et al. 2016; Wilson et al. 2018), scenarios for biological invasions will remain uncertain, particularly over longer time horizons. Most projections are implicitly or explicitly based on experience with invasions in the recent past. Conditions, including many drivers of invasions, are changing rapidly. Uncertainties are implicit in invasion science and will be best dealt with by clearly circumscribing invasion phenomena, measuring and providing clear evidence for such phenomena, and understanding their drivers and the mechanisms that generate consequences (Latombe et al. 2019). In the last section, we highlighted a few of the things that, for future generations to continue to have the choice of which scenario they want, will likely be needed: different priorities for different ecosystems (e.g. coastal vs. off-shore); the development and implementation of strategies for particular invasions (e.g. for *Prosopis* invasions); improvements in our foundational knowledge (e.g. through well-curated and comprehensive lists of alien species); a wide range of regulatory and other policy approaches; and novel ways to facilitate land management. However, it seems likely to us that in the next 200–2000 years we will reach a point when either the concept of biological invasions is irrelevant; invasions continue to be managed in the context of complex competing needs and interests; we have advanced to a stage where we can turn Earth as a whole into a biodiversity reserve; or civilisation collapses. We believe that the policy and management decisions we make over the coming years and decades will set us on one of these trajectories (Figs. 31.1 and 31.2). If we can develop a shared vision of how we want South Africa to look (e.g. a national policy on biological invasions), then this will provide us with a focal point for our efforts.

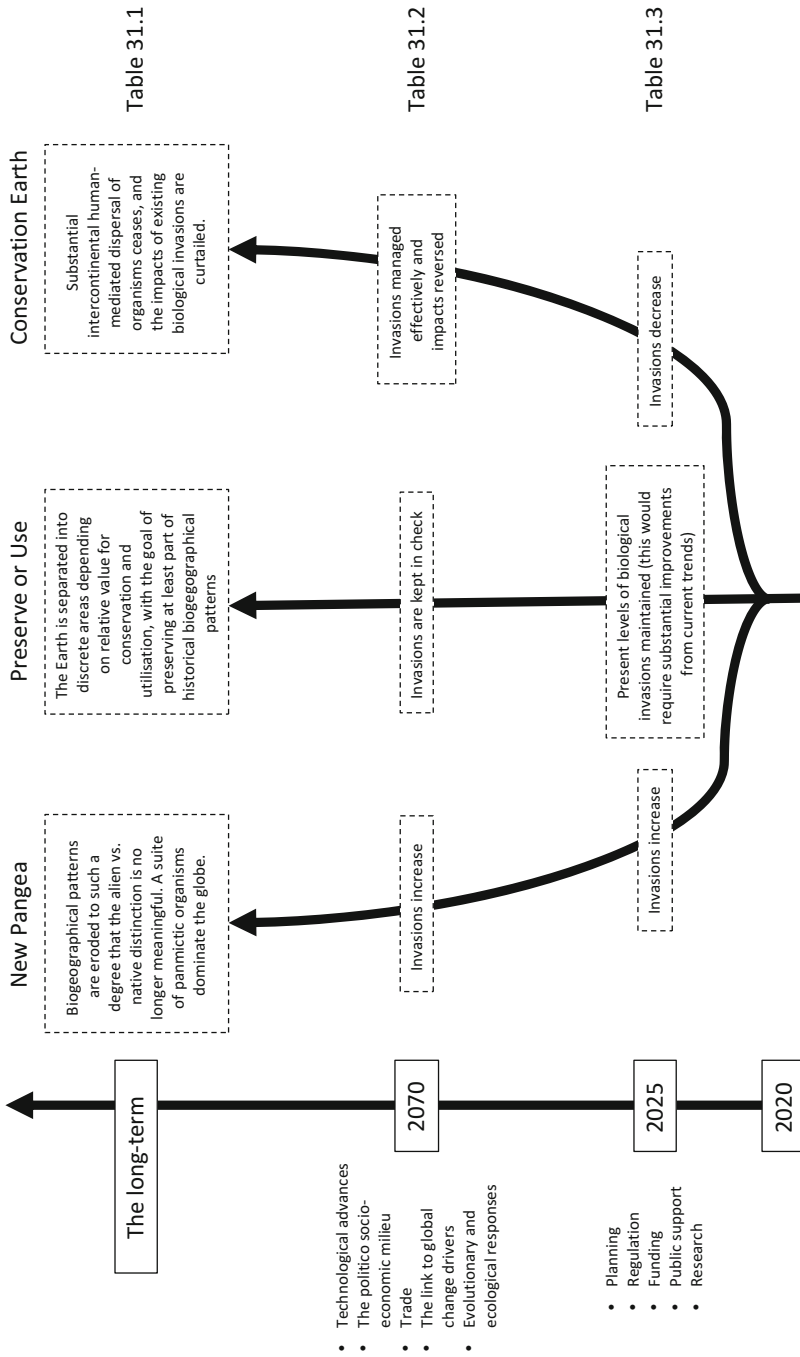


Fig. 31.1 A schematic showing the themes discussed in this chapter, i.e. how events and drivers over the next 5–50 years might place us on a trajectory towards “New Pangea”, “Preserve or Use”, or “Conservation Earth”. We have not included events that might lead to “Collapse of civilisation but no return to Eden” as these are often typified by unpredictable events not directly related to invasions; suffice to say that if civilisation were to collapse the impacts of invasions on biodiversity and biogeographic processes would not cease

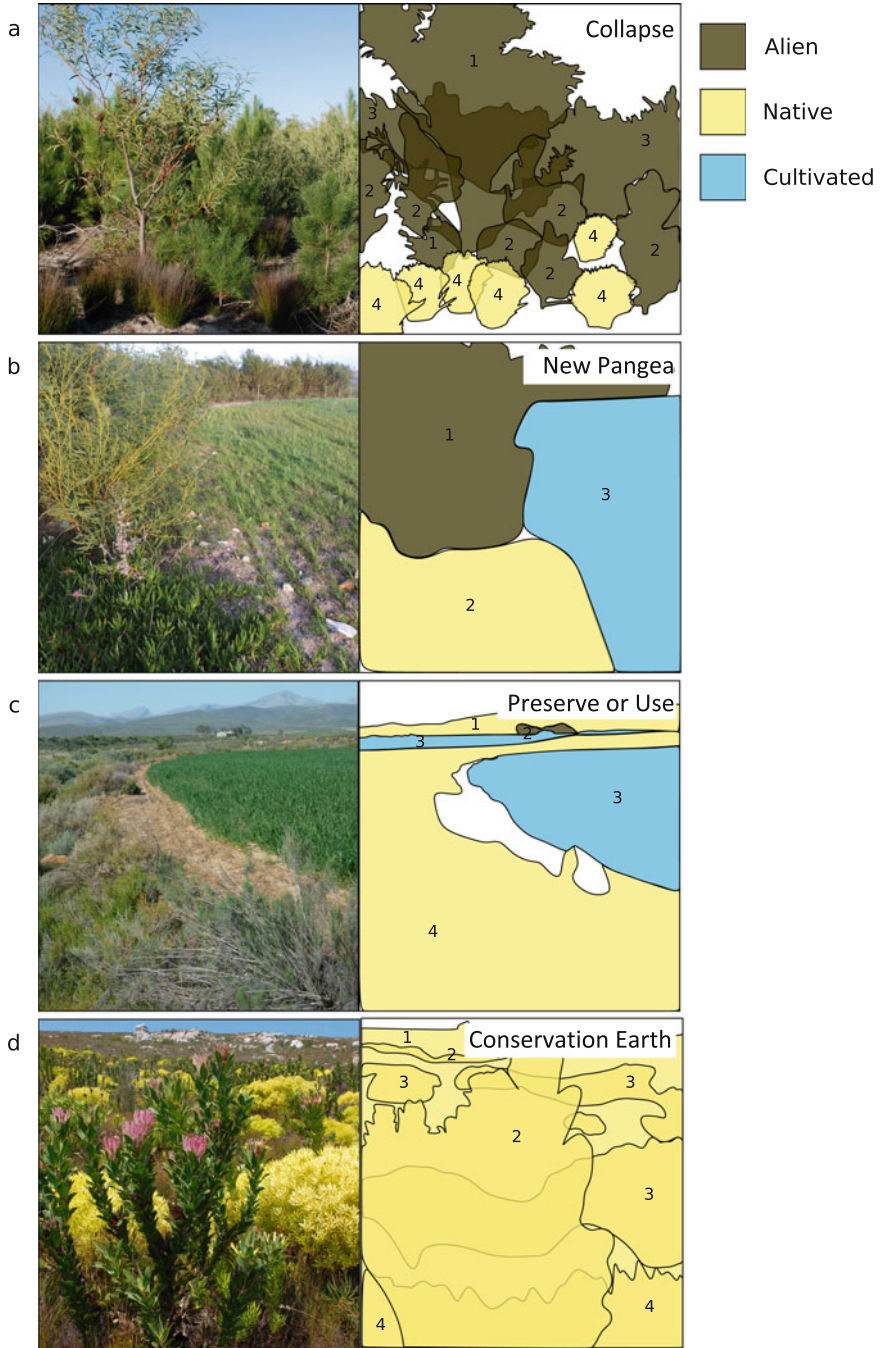


Fig. 31.2 Photographs illustrating potential futures of biological invasions in South Africa taken from the Western Cape in areas close to Stellenbosch. In the panels next to each photograph, the outlines of different species or vegetation types are numbered, and coloured according to whether they represent native, alien, or cultivated. (a) South Africa is transformed to a novel ecosystem

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Fig. 31.2 (continued) composed largely of alien species (“Collapse but no return to a Garden of Eden”). (1) *Acacia saligna*, (2) *Pinus* sp., (3) *Leptospermum laevigatum*, and (4) a Restionaceae. The photo was taken near Betty’s Bay by Brian van Wilgen. (b) The landscape is composed of a matrix of utilised areas and invaded areas that have little if any conservation value in terms of native species (“New Pangea”). (1) *Acacia saligna*; (2) *Carpobrotus* sp.; (3) a wheat field. The photo was taken on the Agulhas Plain by John Measey. (c) The landscape is composed of a matrix of utilised areas and areas that have significant conservation value in terms of native species (“Preserve or Use”). (1) A mix of vegetation types including Kouebokkeveld Shale Fynbos, North Hex Sandstone Fynbos, and Altimontane Sandstone Fynbos; (2) *Eucalyptus* sp. planted close to a homestead; (3) agricultural land; (4) Ceres Shale Renosterveld. The photograph was taken close to Ceres by John Wilson. (d) The unique vegetation of South Africa is conserved for future generations and natural per-human ecosystem processes are allowed to continue (“Conservation Earth”). (1) Agulhas limestone fynbos; (2) *Protea compacta* in flower; (3) *Leucadendron* sp.; (4) a Restionaceae. The photograph was taken near Betty’s Bay by Brian van Wilgen

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