FORUM ARTICLE

Future-proofing weed management for the effects of climate change: is New Zealand underestimating the risk of increased plant invasions?

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Published online: 3 June 2016

Abstract: Climate change may exacerbate the impacts of plant invasions by providing opportunities for new naturalisations and for alien species to expand into regions where previously they could not survive and reproduce. Although climate change is not expected to favour invasive plants in every case, in Aotearoa-New Zealand a large pool of potential new weeds already exists and this country is predicted to be an 'invasion hotspot' under climate change. In particular, ornamental garden plants originating from warmer native ranges are likely to naturalise and become invasive when climatic constraints are lifted. This forum article synthesises research on potential synergistic effects of plant invasion and climate change and discusses the general implications for management of weeds under climate change in New Zealand. A comprehensive assessment of three recently naturalised subtropical species (*Archontophoenix cunninghamiana*, *Psidium guajava* and *Schefflera actinophylla*) illustrates the potential risk of invasions by such species arising with climate change. Despite two recent Department of Conservation reports giving policy recommendations for conserving biodiversity under climate change, in which the potential of new weeds was highlighted as one of the most imminent threats, very little action has been taken. We argue that climate change needs to be accounted for in current weed management policies. Specifically, prediction of potential new weeds needs to be improved, considering up-to-date research and using best-practice modelling tools. Better surveillance for new infestations through spatial prioritisation by habitat suitability and use of well-managed citizen science projects is required. Education campaigns to raise awareness of climate change effects and new weed threats are essential. With an ever-increasing number of potential weeds but limited resources available, it is crucial that more preventative management is taken. Conservation managers, scientists and the general public need to combine their efforts to future-proof New Zealand weed management for the effects of climate change.

Keywords: alien plants; climate change; environmental weed; plant invasion; weed management; weed risk assessment

Introduction

Invasive plants (weeds) have been shown to severely reduce native plant abundance and diversity across the globe (Vilà et al. 2011). Of further concern, plant invasions and their negative impacts are likely to increase in the future, as climate change is expected to mostly favour weeds (Bradley et al. 2010a). Climate change will provide opportunities for alien plant species to expand into regions where previously they could not survive and/or reproduce (Walther et al. 2009). In particular, ornamental plants originating from warmer native ranges may escape cultivation when climatic constraints (such as frosts) are reduced and subsequently may naturalise and become invasive. Climate change may also benefit alien plants indirectly, such as by reducing biotic resistance of native communities to invasion (Diez et al. 2012), by changing interactions with natural enemies (Lu et al. 2013), or by promoting disturbances such as fire which may provide new opportunities for certain weed species (McGlone & Walker 2011).

Climate change will not always benefit weeds (Bradley et al. 2009; Sorte et al. 2013; Leishman & Gallagher 2015) and the variation in impact may differ geographically. A recent study using an ensemble of species distribution models (SDMs) and various climate change scenarios, showed an increase in numbers of invasive species in temperate regions and a decrease in invasions in the tropics (Bellard et al. 2013). In particular, Aotearoa-New Zealand was identified as one of the future hotspots of invasion under climate change, regardless of the climate change scenario used. In this forum article, we argue that the susceptibility of New Zealand to exacerbated impacts from plant invasions under climate change has not been adequately recognised by policy makers and urge a management response to future-proof New Zealand from this threat.

Current perspectives on weed management under climate change in New Zealand

Although the problem of plant invasions and climate change has been highlighted internationally, little in the way of conservation management strategies or scientific research exist in New Zealand to tackle this challenge. In 2011 the New Zealand Department of Conservation (DOC) published a report from a management perspective, assessing *Potential effects* *of climate change on New Zealand's terrestrial biodiversity and policy recommendations for mitigation, adaptation and research* (McGlone & Walker 2011). This report stated that 'New Zealand must act' in reference to both greenhouse gas emission reductions and adaptations to climate change impacts in order to conserve biodiversity. In particular, the report highlighted weeds as an issue: 'arrival of new weeds and increased invasiveness of existing weeds is one of the most troubling likely consequences of climate change' (McGlone & Walker 2011). Christie (2014) restated this view in a further DOC report focusing on a framework for adaptations to climate change. Nevertheless, to our knowledge, climate change is currently not addressed in weed management policy or practices (e.g. in regional pest management strategies/plans), neither at the local government level (territorial local authorities or TLAs) nor nationally by DOC. Indeed, longer-term challenges such as climate change are often neglected due to everyday weed management challenges and resource limitations (Pyke et al. 2008). Moreover, effects of climate change may be underestimated if they are not immediately apparent.

Despite these calls to action, there has only been one comprehensive study investigating the effects of climate change on weeds in New Zealand (Sheppard 2013a). This study investigated whether the predicted warming in New Zealand of 0.7–5.1°C by 2090 combined with fewer frosts (Ministry for the Environment 2008) may enable subtropical or tropical alien plant species to establish or expand their range southwards. Results from this study are summarised below, and showed that the risk posed by such species under climate change is real and must be considered in management strategies.

New Zealand's weed invasion debt

The concept of invasion debt describes how a region may develop the propensity for future invasions to arise due to four processes: new species being introduced, naturalisation of already introduced species, spread of naturalised species and increased impacts of alien species (Rouget et al. 2016). Although all stages of invasions are considered in this context, invasion debt particularly addresses what traditionally has been described as the lag phase: the many species already introduced but not yet invasive. The invasion debt is generated due to invasive species (particularly weeds) often showing delayed responses (i.e. a lag period) to socio-economic activity affecting propagule pressure and to changes in environmental conditions that favour invasions (Essl et al. 2011, 2015). New Zealand potentially has a massive invasion debt and consequently weed management poses a great challenge to conservation in New Zealand (Stanley & Bassett 2015). Currently, DOC considers 328 alien plant species to be environmental weeds (Howell 2008), with additional species listed in TLAs' regional pest management plans. From the existing pool of the more than 25 000 alien species present in New Zealand, 2436 species are confirmed as naturalised (Howell & Sawyer 2006), and each year around 20 additional plant species naturalise (Howell 2008). A subset of these naturalised and naturalising species will become invasive, which demonstrates the extent of New Zealand's current weed invasion debt. Considering both this invasion debt and the already substantial number of current weeds, management action may appear daunting, especially if climate change is added into the equation. The large pool of potential weeds present in New Zealand includes a large number of cold-sensitive plant species, which are more likely to naturalise and become invasive under climate change compared to a probably much smaller number of alien species that may suffer from climate change (McGlone et al. 2010; McGlone & Walker 2011). Climate change is thus likely to exacerbate New Zealand's invasion debt.

Weed management is most cost-effective at the early stages of weed invasion (Stanley & Bassett 2015). Best practice weed management is preventative, focusing on eradication of weed species with populations consisting of very small numbers of individuals, while large entrenched populations are best suited to biocontrol programmes and site-led control at high value sites. Resources deployed on attempting eradication or even long-term management of rapidly expanding or entrenched weed populations is often wasted (Stanley & Bassett 2015). For example, of the 111 DOC weed programmes with eradication as their end-goal, eradication has only been achieved in four, in each of which the alien species had infested an area smaller than one hectare (Howell 2012). Harris and Timmins (2009) demonstrated that if weed management is postponed until a species has become widespread, on average it is 40-times more expensive to remove and attempts are less likely to be successful than if managed earlier. Thus, one logical focus of weed management agencies should be on identifying and removing small populations of newly naturalised alien plant species that have a high likelihood of expanding their geographic ranges and becoming invasive weeds (Higgins et al. 2000). However, the assessment of climate suitability for New Zealand risk assessments is based only on current climate suitability to the region or conservancy of interest. Climate change is not implicitly incorporated into these assessments or rankings of potential weeds (Stanley & Bassett 2015). Therefore, we may be failing to initiate early cost-effective management for a substantial number of newly naturalised alien plant species. Without such management, the next generation of biodiversity managers are likely to face an even greater invasion debt. Conversely, we may currently be spending scarce resources on plant species that are less likely to become weedy under climate change.

How real is the risk of targeting the wrong weeds under climate change?

Given the long-term implications of not incorporating climate change into weed management, just how real is the risk of targeting the wrong weeds under climate change conditions? In recent years, empirical studies across the globe have accumulated evidence of the impacts of climate change on plant invasions. SDMs, which relate occurrence data of a species to the environmental conditions at these locations (Elith & Leathwick 2009), have frequently shown increased potential distributions of weeds under climate change (e.g. Bradley et al. 2010b; Kleinbauer et al. 2010; Sheppard 2013b). However, several weed studies in Australia predict reduced distributions (O'Donnell et al. 2012; Gallagher et al. 2013; Roger et al. 2015) suggesting outcomes are not always unidirectional. Manipulative experiments, which measure the performance of alien plants under experimental warming, elevated CO_2 levels or changing precipitation patterns, have also been used extensively and predicted mixed outcomes for invasive species (reviewed in a recent meta-analysis; Sorte et al. 2013).

A recent study showed for the first time that newly naturalised alien plants from warmer native ranges are likely to become more invasive under climate change in New Zealand

(Sheppard et al. 2014). *Archontophoenix cunninghamiana* (bangalow palm), *Psidium guajava* (common guava) and *Schefflera actinophylla* (Queensland umbrella tree) were used as model species for this research as they are typical of those that may become problematic with climate change: they are bird-dispersed, woody species of subtropical or tropical origin, and known to be invasive in other countries. These subtropical/tropical plants are precisely the sort of species likely to be ranked relatively low under current risk assessments because of perceived lack of fit with New Zealand's historical and current climate. SDMs predicted a substantial increase in suitable habitat under climate change for these three species (Sheppard 2013b; Table 1). Regional decreases in suitability, as found in some other studies assessing alien plant distributions under climate change (e.g. Bradley et al. 2009; Gallagher et al. 2013), were only rarely predicted for these species. For example, the northernmost part of New Zealand is predicted to become less suitable for *A. cunninghamiana* under some climate change scenarios (Sheppard 2013b). This might be associated with the reduced precipitation projected for that region becoming a limiting factor (Ministry for the Environment 2008). A large-scale field experiment conducted over 18–22 months at six sites throughout New Zealand validated the model predictions (Sheppard et al. 2014). However, both the field experiment and a drought shadehouse experiment showed high drought tolerance in these species, inconsistent with the model-based interpretation. This unexpectedly high drought tolerance shows the importance of incorporating data on the physiological response of plant species into SDM-based risk evaluations (Sheppard 2014; Sheppard et al. 2014).

Growth rates under elevated CO_2 and temperature either remained constant or increased for seedlings grown in environmental chambers (Sheppard & Stanley 2014; Table 1). For subtropical species, decreased mortality due to increasing minimum temperatures and decreasing frost occurrences appear more critical. Key responses to climate were shown due to the inclusion of various sites and seasons in the field trials: for example, a 1°C difference in average minimum temperatures between two winters at the same site (Auckland) increased survival from 0% to 100% for *S. actinophylla* (Sheppard et al. 2014). Our research further highlighted why spread of these species is a concern: they are likely to impact on native species, in particular posing a high risk of outcompeting related native species (Sheppard & Burns 2014; Sheppard et al. 2014; Table 1).

This comprehensive assessment of three subtropical alien species illustrates the risk of new environmental weeds in New Zealand associated with climate change. Furthermore,

Table 1. Synthesis of the results of a comprehensive study on the effects of climate change on subtropical alien species in New Zealand, highlighting various factors indicating invasion potential for the three model alien species.

	Archontophoenix cunninghamiana	*Psidium guajava*	*Schefflera actinophylla*
Average predicted spread by 2090 under climate change (Sheppard 2013b)	101% increase 82 000 km^2 suitable	70% increase 114 000 km^2 suitable	112% increase 20 000 km^2 suitable
Drought tolerance (Sheppard 2014; Sheppard et al. 2014)	High	Medium-high	High
Minimum cold tolerance (Sheppard et al. 2014)	5.7°C avg. winter temp. 8 frost nights	5.7°C avg. winter temp. 8 frost nights	6.7°C avg. winter temp. 2 frost nights
Performance under elevated temperature (Sheppard & Stanley 2014)	Growth rate unaffected	Increased seed germination, growth rate unaffected	Growth rate unaffected
Performance under elevated CO_2 (Sheppard & Stanley 2014)	Equal growth	Equal growth (but increased branching)	Increased biomass
Susceptibility to invertebrate herbivory (Sheppard & Burns 2014; Sheppard et al. 2014)	Low	Medium	Low
Traits (Sheppard & Burns 2014; Sheppard et al. 2014)	High RGR High biomass High survival High SLA Seed germination?	At times high RGR At times high biomass High survival High SLA High seed germination	High RGR High biomass High survival High SLA Seed germination?
Competitive effects (Sheppard & Burns 2014)	Strong	Medium	? ‡
Invasiveness elsewhere	Brazil only	Widespread	Tropical islands, Florida
Other attributes	Bird-dispersed Shade tolerant	Bird-dispersed Can re-sprout from cut stumps	Bird-dispersed Shade tolerant Can re-sprout from cut stumps Can grow as epiphyte
Weed risk assessment score†	9	21	10
Invasion potential	High	High	High (under climate change only)

‡Could not be assessed due to high mortality of native species.
†The weed risk assessment does not account for climate change.

Lamoureaux and Bourdot (2014) found that an SDM predicted a substantial increase in the distribution of an invasive agricultural weed in New Zealand, yellow bristle grass (*Setaria pumila*), under climate change.

Besides warmer temperatures, changes in precipitation regimes and increases in climate variability in general, another important consideration is the effect of extreme events, which are projected to become more frequent and more intense with climate change (IPCC 2013). Extreme events are likely to increase disturbance, which may decrease the resistance of communities to invasion and result in more colonisation opportunities for alien plants (Diez et al. 2012; Sheppard et al. 2012; Leishman & Gallagher 2015). For example, more disturbances such as windstorms may provide 'resource opportunities' (Shea & Chesson 2002), with increased nutrient and light availability also frequently favouring invasive species (Daehler 2003). Climate change is also likely to facilitate the establishment and spread of insects, some of which will be specialist plant pollinators (Ward 2015). This in turn may help certain alien plants to overcome one of the ecological barriers preventing plant naturalisation (Blackburn et al. 2011). Indeed, some hemiepiphytic fig species (*Ficus macrophylla* and *F. rubiginosa*) had been in New Zealand for >100 years without naturalising, but the establishment of their obligate mutualist fig wasps (*Pleistodontes* spp.; Gardner & Early 1996) has enabled these fig species to naturalise in the North Island and establish seedlings epiphytically on a range of host species including native trees (Gardner & Early 1996; Young 2010). We should expect more of these examples under climate change conditions.

When more favourable climatic conditions present naturalisation and spread opportunities for alien species, human actions to mitigate risks become increasingly important. For instance, the sale of plants in nurseries beyond their range can aid the spread of garden plants. In Europe native species are being sold in commercial nurseries on average 1000 km further north than their natural range limit, which may give them 'a head start on climate change' (Van Der Veken et al. 2008). Thus, higher rates of spread can sometimes reflect human mediated dispersal, such as increased planting in gardens. Unfortunately, New Zealand plant nurseries (particularly in Auckland) promote the sale of subtropical and tropical species (e.g. palms), to create the illusion of tropical resort holidays for homeowners (MS, pers. obs.). In addition, certain policies aiming to mitigate climate change may result in negative outcomes for weed management, such as by planting biofuels and forestry trees that have a high potential to become invasive (Pyke et al. 2008). Prevention is the most cost-effective tool; banning plant species which are likely to become weedy under climate change conditions is the most effective form of management. However, this requires 'buy-in' from the public on understanding and managing for long-term outcomes (Stanley & Bassett 2015).

Management implications and research gaps

What should be done in New Zealand to mitigate the biodiversity threats posed by weeds associated with a changing climate? To date, efforts to combat plant invasions have largely been reactive. That is, a new species becomes invasive and subsequently a plan is developed to manage it: this strategy involves adaptation after the event has occurred (Perrings 2005; Thuiller et al. 2007). However, biodiversity and biosecurity managers in New Zealand now generally use mitigation as a strategy – using actions that reduce the likelihood of invasions before an event (Perrings 2005). With limited resources and an ever-increasing number of potential weeds, it is crucial that management efforts invest more in preventative actions where the cost-benefit is very high, prioritising species at an early stage of invasion (Harris & Timmins 2009; Stanley & Bassett 2015). While managers currently assess the risk of each weed species and rank the threat accordingly, very few (if any) take future climate into account when making their assessment. This is critical to accurately predict which species will become problematic weeds, so that prioritisation and allocation of resources can be done effectively.

Incorporating future climate into existing tools

Weed risk assessments (WRAs) based on current knowledge of species traits and invasion history can be useful tools for quick screening of potential new weeds, although WRAs have been called 'a waste of time' (Hulme 2012) because, among other factors, usually they do not account for variability and uncertainty. Indeed, contrary to our research results, applying the Australian WRA (Pheloung et al. 1999; adapted to New Zealand) gave only one of the previously mentioned study species a high risk score (*P. guajava*; moderate risk for *A. cunninghamiana* and *S. actinophylla*; Table 1), highlighting that it may not be adequate for assessing invasion potential under climate change. Hulme (2012) discusses various ways to refine WRAs but concludes that they will still be inadequate, suggesting scenario planning instead. Furthermore, even though scientists have developed quantitative models to assess invasion potential (which are likely more accurate and less subjective compared to WRAs based on risk scores), these are not used in weed management due to their time-consuming nature, complexity and lack of data availability (Leung et al. 2012). Although we agree with such calls for development of more accurate, quantitative assessments and their translation from science to user-friendly applications for conservation management (Hulme 2012; Leung et al. 2012), such progress will undoubtedly take time. Given New Zealand's large invasion debt, a rapid prioritisation scheme is essential. Therefore, managers are currently using less quantitative cost-benefit analysis and WRA approaches (Stanley & Bassett 2015), these still being far better than a random guess (with an average correct acceptance/rejection rate of 80% for the currently used WRA; Gordon et al. 2008). However, given the urgent need to account for climate change in weed management prioritisation, risk assessments must be adapted to account for potential effects of climate change (Beaumont et al. 2014). As scientific knowledge on invasions and interactive factors of global change progresses, weed prioritisation schemes, such as WRA, should be updated. Roger et al. (2015) have produced such a screening tool for Australia in which potential distributions under future climates are considered when screening plants for weediness (www.weedfutures.net). Creating such a tool or adapting existing WRA schemes for New Zealand should be prioritised. Furthermore, future climate needs to be incorporated into other existing weed management prioritising schemes such as regional pest management plans and DOC weed management programmes, even if this is (initially) as simple as including a climate change factor to the predicted maximum extent of invaded land.

Improving predictions of future distribution

SDMs are a useful tool for predicting which alien species may become a problem under climate change. Although the application of SDMs to climate change and invasive species has been criticised (Sinclair et al. 2010), SDMs are the easiest, fastest and cheapest way of assessing potential invasion risk. Furthermore, Araújo and Peterson (2012) suggested that criticism of SDMs has often been misplaced, resulting from confusion between what the models actually show versus what people want them to show. For example, predictions of potential distributions of invasive species should be considered as risk maps, with overprediction (precautionary principle) being a desirable property (Jiménez-Valverde et al. 2011). However, given this critique, and as highlighted in Sheppard (2013c), careful model building and evaluation is still essential.

Recent research advances have developed models that allow more accurate predictions, for example by integrating dispersal (e.g. Smolik et al. 2010), incorporating biotic interactions (Kissling et al. 2012) or using hierarchical Bayesian frameworks to statistically estimate both the environmental response of demographic rates and spatiotemporal population dynamics from species distribution data to predict range dynamics (Pagel & Schurr 2012). Despite being very promising tools for global change research, such models are complex and data- and computing power-intensive, which is why user-friendly correlative SDMs are still needed for urgent management decisions. Although the number of SDM studies has greatly increased in the scientific literature, there is little evidence that their results are used to assist conservation decisions (Guisan et al. 2013). Yet, considering conservation management under global change, a more practical tool for managers is urgently needed. Using ensemble-modelling techniques to reduce uncertainty, SDMs can be applied to many species leading to the identification of invasion hotspots, enabling cost-effective management decisions such as simultaneously preventing establishment and spread of numerous alien plants (O'Donnell et al. 2012). In Australia, potential distributions of large groups of alien plants under climate change have been assessed both for 'sleeper weeds' (Scott et al. 2008) and 'weeds of national significance' (O'Donnell et al. 2012) mostly resulting in predicted reductions in weed distributions (O'Donnell et al. 2012; Gallagher et al. 2013; Roger et al. 2015). However, considering Australia's already hot and dry climate their situation is quite different to New Zealand where climate change is likely beneficial for many weeds, thus making such assessments of weed distributions under climate change even more urgent in this country.

To increase confidence in model predictions, Bradley et al. (2010a) suggested that experimental studies should be used to directly evaluate these predictions, an approach that was taken in Sheppard et al. (2014) when assessing potential distributions of the three aforementioned alien subtropical species. The pool of alien species in New Zealand is too large to make it feasible to carry out such a thorough assessment for each and every one of them. However, such studies may be useful to highlight which groups of potential weeds are of concern, such as the woody subtropical ornamentals. In fact, trait-based approaches have extensively been used to predict or explain invasiveness (van Kleunen et al. 2010). However, the traits associated with successful colonisation and spread may be context-dependent, and interactions among climate and other drivers of global change may make a trait-based approach to predict responses to climate change challenging (Caplat et al. 2013). Nonetheless, given the large pool of potential weeds, some sort of 'trait' or 'group' approach needs to be taken in assessing the effects of climate change on alien plant species, as we do not have the resources for empirical research on each species (for SDMs, an archetype approach has been suggested, which models a species cluster based on their environmental responses together; Hui et al. 2013).

Management actions

So what actions should managers take and how can researchers help? McGlone and Walker (2011) recommend: 'prepare a list of weed and pest species likely to become invasive when the climate warms, and a list of at-risk habitats, followed by pre-emptive action (banning, control and removal) with regard to high-risk pests or weeds'. Although biosecurity managers in New Zealand already do most of these actions, the key action not taken to date is the assessment and ranking of weeds under future climate. This involves accounting for warmer and, especially in Northland, Auckland, Gisborne and Hawkes' Bay, possibly drier conditions when assessing invasion risk. Accounting for climate change will undoubtedly change the species that make the 'ban, control, removal' lists.

Surveillance programmes need to include subtropical/tropical alien plants. Citizen science projects have been widely used to aid early detection of alien species elsewhere (Crall et al. 2010) and these could be used more effectively in New Zealand. To be most beneficial, citizen scientists need to be provided with the tools to effectively collect and share data. Quality assurance needs to be considered and various local databases need to be combined into platforms at the national level (Crall et al. 2010). To be useful, the data in citizen science databases such as Naturewatch (http://naturewatch.org.nz/) must be extracted, analysed and used by managers. This is rarely done. Data gathered by more taxa-focussed, agency-run citizen science programmes, such as Weed Spotters (see http://root.ala.org.au/bdrs-core/act-esdd/home.htm), are more likely to be used by managers.

Banning weeds from propagation and sale is one of the most cost-effective means of mitigation (Stanley & Bassett 2015). However, designation of banned species is subject to public consultation, and this can be a major socio-political challenge. Long-term predictions of negative impacts on biodiversity and the need for action are often difficult for the public to grasp, particularly in regard to highly valued species (Simberloff et al. 2013; Stanley & Bassett 2015). It is difficult to convince the public of the importance of early control of potential weeds, because only if both the invasive species and its impact are clearly apparent is there the necessary motivation for action (Simberloff et al. 2013). By adding climate change into the mix, we are asking the public to agree to bans on plants that may become weedy under climate change in what seems like the remote future. As the horticulture industry is pivotal in the propagation and sale of potential invasive plants, increasing their awareness is essential, as they have the capability to prevent many future invasions (Bradley et al. 2012). The human side of invasive weed issues will continue to be one of the biggest challenges weed managers face, and requires some investment in social science and understanding of how to achieve behaviour change.

Conclusions

Although the recommendations in DOC's policy reports by McGlone and Walker (2011) and Christie (2014) show that the problem of exacerbated plant invasions under climate change has at least been recognised, these recommendations have not been implemented. Christie (2014) lists five broad strategies with corresponding actions, of which the ones with relevance to weeds (identification of climate change-induced changes in invasive species, incorporation of climate change adaptation strategies into existing management and research programmes, and raising awareness and understanding of the impacts of climate change) were all described as having 'not yet started'. Even though we are faced with an enormous challenge, we cannot waste any more time before implementing these recommendations. TLAs already have a framework for prioritising and ranking weeds, which includes a cost-benefit model (Stanley & Bassett 2015). There is no need to reinvent the wheel, instead we need to ensure that the cost-benefit model considers risk under climate change. A major problem with addressing climate change is that its effects are usually slow or show a time lag resulting in an invasion debt and therefore go unnoticed, and TLAs face a socio-political battle to ban some of these weeds. Thus, awareness among the public is required to change the short-term perspectives on impacts into mitigation of these two important long-term drivers of global change. Conservation managers, scientists and the general public need to combine their efforts to future-proof weed management for the effects of climate change. It is time to face the challenge!

Acknowledgements

We are grateful to IE Bassett, C Macinnis-Ng, M McGlone and G Perry for helpful comments on drafts of this manuscript.

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Editorial board member: Matt McGlone
Received 24 November 2015; accepted 15 April 2016