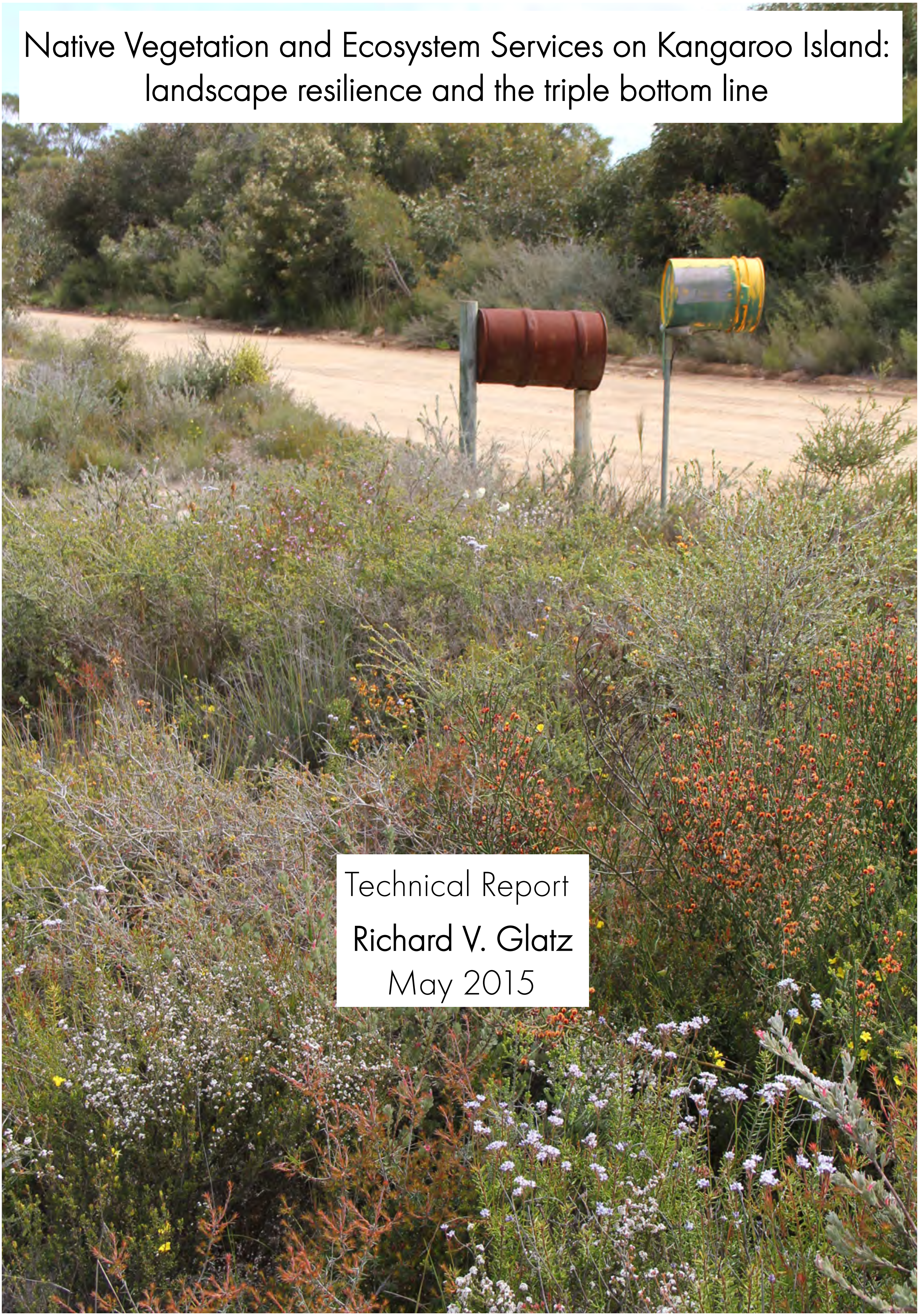
Native Vegetation and Ecosystem Services on Kangaroo Island: landscape resilience and the triple bottom line



Technical Report

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Cover
Kangaroo Island is renowned for some of the most diverse and intact roadside vegetation in Australia, shown here on Three Chain Road, MacGillivray. It plays an important role in supporting biodiversity and leaves an immediate and lasting impression on many visitors. It also supports well-being of residents and is key to contributing to the 'clean & green' image of the island so valued by the primary industries, food and wine, and tourism sectors. When occurring adjacent agricultural production, quality vegetation like this can provide weed/pest management and biosecurity benefits at local and regional scales.

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Abbreviations

BWYV: beet western yellows virus
CaCV: capsicum chlorosis virus
CMV: cucumber mosaic virus
CRC: cooperative research centre
DAFF: Federal Department of Agriculture, Fisheries and Forestry
DEWNR: South Australian Department of Environment, Water and Natural Resources
EPP: emergency plant pest
ES: ecosystem service(s)
ESP: ecosystems services partnership
GM: genetically modified
GRDC: Grains Research and Development Corporation
ha: hectare(s)
INSV: impatiens necrotic spot virus
KI: Kangaroo Island
KINRM: Kangaroo Island Natural Resource Management
NAP: Northern Adelaide Plains
NCCARF: National Climate Change Adaptation Research Facility
NRM: natural resources management
NSW: state of New South Wales
PHA: Plant Health Australia
PLRV: potato leaf roll virus
PMMV: pepper mild mottle virus
PVS: potato virus S
PVX: potato virus X
PVY: potato virus Y
Qld: state of Queensland
SA: state of South Australia
SARDI: South Australian Research and Development Institute
TLCV: tomato leaf curl virus
TMV: tomato mosaic virus
TSWV: tomato spotted wilt virus
TuMV: turnip mosaic virus
TYLCV: tomato yellow leaf curl virus
UK: United Kingdom
WoNS: weed of national significance
WPA: Wilderness Protection Area

Non-technical Summary

Understanding the ecosystem services (ES) provided by natural systems is part of a global trend towards 'complete accounting' of human benefits in order to enhance the beneficial value and the efficiency of ES use so as to mitigate challenges to human health. A primary driver of this trend is the unprecedented rate of increase in global temperatures and the associated difficulties this poses to a range of human activities. This report aims to provide a scientifically informed discussion of ES associated with native vegetation on Kangaroo Island (KI). It is designed to inform the development of the next NRM Plan (2015-2025) which will be characterised by landscape management approaches aimed at maximising the resilience and adaptive capacity of human activity, and the natural systems supporting it.

Conceptualising and valuing ES

The conceptualisation and valuation of ES, as well as mechanisms to directly link them to beneficial outcomes, are key challenges for ES research and the subject of current debate (see Burkhard et al. (2012) for a summary by leading practitioners). Currently ES are generally characterised as complex interactions between:

- basic structural and compositional elements of an ecosystem (e.g., soils, minerals, water, air, biodiversity, human infrastructure, cultural diversity etc.)
- ecosystem processes (e.g., water cycle, photosynthesis, disease epidemiology, carbon cycle, social processes, economic processes etc.)
- human values (e.g. health, adequate resources, recreation, philosophy etc.)

In reality, these three interacting partners may overlap, and may have to be redefined (as well as their interactions) depending upon the ES being considered, the operational scale, the application being undertaken, and/or the stakeholder viewpoint. This presents obvious challenges to land mangers wishing to design landscape management principles based on ES provision. However, significant resources are being invested in this regard globally and there is a range of collaborative networks involved in these endeavours.

ES provided by native vegetation

On Kangaroo Island, ES from the endemic vegetation make three important, but undervalued, contributions to agricultural production.

1. *Agricultural pest management*: native plant species generally support less crop/pasture diseases and invertebrate pests than exotic weeds, which are suppressed by healthy native vegetation. Native plants are also associated with high numbers of invertebrates beneficial to primary production and help support biological control agents. These principles are the subject of recent advice to primary producers from the Grains Research & Development Corporation (GRDC 2014).
2. *Agricultural biosecurity*: good quality native vegetation (with an intact seed-bank) has the capacity to buffer against introduction of new species that pose biosecurity threats. Therefore, it has potential to reduce the area and number of host organisms that can aid the establishment, build-up and spread of a pest/disease; both of these parameters are key influences of the severity and persistence of outbreaks. Native vegetation also supports native biocontrol agents of important pests that are yet to establish
3. *Pollination*: native vegetation plays an important role in providing forage for honeybees (hence also supports the apiary industry), as well as broader habitat requirements of numerous species of native pollinators, which are crucial to native plant species as well as contributing to primary production.

4. *'Clean & green' image*: the impressive native vegetation and rare species contained in numerous public/private conservation regions and in roadside vegetation, are the key contributors to the 'green' image enjoyed by KI producers. In most cases, current production methods are not different to elsewhere.

These four benefits suggest:

- native vegetation is already providing a significant ES to primary production on KI (given a relatively native vegetation coverage of ≈40%)
- there is opportunity to manage the vegetation at a landscape scale to maintain ecosystem resilience and provide co-benefits to primary production to improve economic resilience

Further ES from native vegetation includes:

- *Contributions to landscape adaptive capacity & resilience* - crucial for maximising four levels of diversity (genes, populations, species, ecosystems) that provide ability to adapt and maintain ES under significant change (i.e. resilience). By improving the quality and coverage of native vegetation there is the potential to maximising agricultural flexibility at landscape level and thereby increase production options and resilience of production as a whole.
- *Prevention or mitigation of dryland salinity* – this is one of the most serious forms of landscape degradation as it reduces productive capacity and value of land, as well as causing long-term and significant changes to biodiversity. The primary cause is large-scale removal of deep-rooted perennial vegetation from water-catchments and low-lying areas.
- *Habitat provision*: directly or indirectly supports much of KI's terrestrial biodiversity, which is still relatively poorly understood and of significant commercial value.
- *Tourist/marketing appeal* - KI's natural environment is the key focus for tourists and is the key point of differentiation with other regions. Having abundant native vegetation that contains plants unique to KI gives a 'wild' feel to KI and some locally-common species contribute to a unique KI aesthetic (e.g. KI narrow-leaf mallee arbours, KI conesticks, KI gland flower, round-leaved *Bertya*, KI riceflower, *tateana* subspecies of yacca).
- *Direct social and community benefits* - many obvious benefits associated with physical attributes such as wind-breaks and dust suppression. Mental health and physical well-being is also associated with good quality natural environments. Contributions also to maintaining community structure and producer numbers through providing opportunities for agricultural diversification and adaptive capacity.

Threats to ES associated with native vegetation

1. *Disturbance mechanisms* – these have the capacity to rapidly or incrementally reduce the integrity of the existing native vegetation or its ability to regenerate without species loss or exotic introductions. Includes, clearance, fragmentation, off-target agrichemical impacts, physiochemical changes, inappropriate fire etc.
2. *Weeds/pests/diseases* – one of the main causes of species loss (particularly on islands) and with relevance for current vegetation management and biosecurity. Current resources to tackle these issues are largely insufficient.
3. *Rapid climate change* - well recognised as problematic for species with a low adaption threshold or an inability to migrate (may be exacerbated for an island with a small latitudinal range).

4. *Non-recognition of benefits* – there is currently a significant undervaluing of the broad ES provided by native vegetation, partly because on KI some the problems associated with broad-scale vegetation loss have not impacted as heavily as elsewhere. The full value of ES need to be realised in order to be preserved and extracted through land management.
5. *Increasing economy of scale in agriculture* – requires increasingly large areas for production and increasing mechanisation, therefore usually a trade-off with ability to derive pest management/biodiversity benefits from native vegetation, and with landscape ES more broadly. Also often associated with reduced numbers of resident primary producers.
6. *Insufficient resources for research and/or best practice management* – many areas regarding ES and landscape vegetation management need research to facilitate sound policy and management approaches. Policy itself can be seen as part of this resourcing and should be designed to facilitate research and stakeholder engagement to drive on-ground adaptive management of vegetation delivering targeted ES.

Increasing combined stakeholder ES from native vegetation

The key consideration here is to obtain co-benefits from native vegetation and the associated biota, by actively implementing approaches that maximise ES and thereby leverage stakeholder input either through land area, effort, modified management or funds. This makes economic sense for the island because it has been shown across a range of comparisons that land areas under natural or sustainably managed systems, have greater total ES value than developed or non-sustainable counterparts.

Currently, NRM issues pertaining to conservation and biodiversity are often treated separately from other management issues including those in primary production. A key priority should be the meaningful integration of shared biodiversity and primary production/tourism benefits. One obvious management approach is to aim to produce biodiversity or ecosystems health/functionality outcomes combined with targeted ES delivery to adjacent production systems or niche producers (e.g. pest/weed management, pollination, bee forage).

Maximising beneficial outcomes

A large part of maximising beneficial outcomes of landscape management is taking a scientific approach to dealing with uncertainty regarding how ES are characterised, how ES are provided, the magnitude of benefits, and how human activities modulate their provision. This uncertainty will always be present to some degree and there are four priorities that should be addressed to deal with this:

1. moving to a full adaptive management approach that can engage broad stakeholders and where each step of the iterative process is properly resourced
2. developing mechanisms to integrate with researchers to derive landscape-specific data sets regarding delivery of key ES
3. developing means for tighter integration of Council, State Government and industry, to obtaining funding for research and delivery of on-ground works
4. restructuring of relevant state government departments to tackle adaptive landscape management and ES delivery/accounting

Knowledge gaps and future research

Many knowledge gaps are discussed in the report, ranging from biological questions such as the nature of interactions between organisms and the use of indicator species for monitoring, to the best regulatory mechanisms to facilitate a landscape level ES approach. Additionally, much of the available information is general in nature and KI-specific data are limited. Broad priority areas for future consideration and research are:

- developing integrated quantification, modelling and valuation of ES
- accounting of ES at a landscape scale
- development of a scientifically-based adaptive management approach to ES
- social and economic trade-offs on KI
- interactions between native biota on KI and primary production systems
- determining key biosecurity threats to native vegetation and primary production on KI and developing prophylactic and response plans
- defining a range of biological and physical metrics (including indicator species) that can be used for ongoing and standardised assessment of ES delivery and ecosystems function on KI

Recommendations

Moving towards significant accounting of ES in NRM

- apply latest thinking regarding full accounting of ES to develop adaptive land management models because ES accounting will be a major future driver of economies. This requires an explicit understanding of both individual (land owner) and broadly applicable ES, as well an explicit definition of the associated costs and benefits of native vegetation to these groups.
- develop multi-benefit revegetation models for KI that are designed to deliver biodiversity and production-specific ES
- engage innovative producers to deliver biodiversity- and production-based pilot projects, highlight ES benefits and promote value of current ES delivery
- biosecurity, pest management and other ES should be considered in all matters involving vegetation (e.g. roadside maintenance, construction approval) particularly adjacent agriculture or conservation land
- examine marketing/tourism opportunities based on rare, iconic and endemic KI taxa

Research and data

- leverage scientific expertise: use KI natural systems and iconic status to actively engage researchers to develop proposals and facilitate subsequent projects generating relevant KI-specific data sets.
- develop mechanism to continually develop joint research proposals between the state departments, KI council and KI industry which exploit KI's iconic status and improve leveraging of external NRM funding
- establishment of a KI rainfall transect project to provide long term monitoring of key biological and environmental variables across the gradient
- production of a database of current weed and invertebrate pests, and diseases for key crops
- assessment of beneficial and pest invertebrates on KI's native plant species
- develop a database of pollinating invertebrates and their relationship to crops
- assessment of the impact of various management practices (especially fire) on diverse groups such as invertebrates and microorganisms that effect plant establishment, growth and reproduction (e.g. michorrizal fungi, seed-germination fungi, pollinators)
- assessment of areas of greatest risk for incursion and spread of new organisms
- continued assessment of fire for regeneration purposes
- means to improve DEWNR data sets (e.g. access other national and state databases such as SA museum, Australian Faunal Directory)

- assessment of new primary industries for which KI will have a natural advantage under increasingly warm and arid conditions
- examining means by which KI biota can be used in marketing of agricultural produce
- establishing meaningful thresholds for a range of disturbance processes impacting key ecological communities

Land management

- incorporate weed management into activities that disturb vegetation and/or seed-bank at high frequency (e.g. roadside maintenance, fuel reduction burning) – examine joint funding proposals for this based on ES provision
- refine roadside vegetation management practices to provide removal of encroaching mallee branches (with little biodiversity risk) while leaving the shrub layer and soil undisturbed (to give biodiversity and biosecurity gains)
- similarly, refrain from disturbing roadside vegetation where there is no clear safety, functional or management benefit from doing so (identify such areas to provide cost-savings and improved ecological management)
- examine joint-benefit revegetation/regeneration projects to deliver biodiversity and production benefits
- develop monitoring and response strategies for key pests and diseases threatening KI
- highlight and promote awareness of KI's rare plants (e.g. utilise in marketing and tourism)
- protect diversity across the full range of biological "levels" (e.g. genetic, species, population and community)
- fully investigate use of technologies designed to increase sustainability or input use-efficiency of primary production systems and/or minimise ES-tradeoffs
- set 30% native vegetation target on Dudley and Eastern Plains (currently at ≈27%). Because much of the current coverage is contained in large conserved blocks on limestone, the focus of the increased coverage should be ironstone habitats in multi-use (fragmented) areas. This is designed to not only increase the ES values of the primary production landscape in these degraded regions, but to examine research questions and multi-benefit revegetation/regeneration models, and to drive debate regarding uptake of broader ES accounting on KI.
- examine targeted incentive schemes to deliver vegetation management aimed at tackling key biosecurity and biodiversity challenges
- promote ES benefits by highlighting the costs (lost ES) of poor management of native vegetation in other regions, rather than the poorly defined benefits that are currently received on KI through having maintained the native vegetation. For example, grains and horticultural industry advice about the usefulness of native vegetation has been driven by loss of vegetation in other agricultural regions (e.g. west coast of SA and northern Adelaide plains) and the resultant production problems this has produced.
- investigate innovative methods/models of harnessing volunteers for management of feral plants and animals e.g. streamlined environmental volunteer legislation, tourism opportunities, progress associations

Non-technical Summary References

Burkhard, B., R. de Groot, R. Costanza, R. Seppelt, S. E. Jorgensen and M. Potschin (2012). "Solutions for sustaining natural capital and ecosystem services." Ecological Indicators 21: 1-6.

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Abstract

In recent years there has been a global move towards recognition of services provided to mankind by ecological systems (i.e. ecosystem services; ES), partly driven by the threat to these services posed by a global climate that is now clearly warming at an unprecedented rate (IPCC 2014). Another associated trend is to undertake landscape management to maximise provision of these ES and to maintain adaptive capacity and resilience in natural and farming systems such that their integrity is largely maintained as temperatures increase. Kangaroo Island (KI) is no exception with the new NRM plan (2015-2025) aiming to provide the basis for such an approach on KI.

One of the most obvious and renowned features of KI is the relatively high coverage and quality of its native vegetation, which provides many ES to all sectors of the community. Indeed, the management of native vegetation has long been an important (sometimes controversial) issue for KI, and the current trends towards landscape management and ES accounting, are likely to focus more attention and effort towards management of KI's native vegetation, which displays about 5% endemism.

This report aims to provide information to stakeholders and NRM planners regarding landscape management of native vegetation on KI, in the context of ES delivery and landscape resilience, and from biological, economic and social viewpoints. This information includes discussion relating to:

- conceptualisation and valuation of ES, particularly those associated with native vegetation
- explicit ES types provided by native vegetation
- explicit threats to native vegetation and their resultant effect on ES
- identification of management priorities
- maximising beneficial outcomes
- knowledge gaps and further research

The key ES from native vegetation on KI derive relate to, pest management, biosecurity, biodiversity protection, tourism, marketing, social well-being, physical benefits (e.g. water quality and wind mitigation benefits), and landscape adaptive capacity and resilience to threatening processes.

The main threats to these ES on KI are a range of disturbance processes, climate change, weeds/pests/diseases, non-recognition of benefits, increasing economy of scale of agricultural production (especially broad acre cropping), and inappropriate resourcing and/or legislative framework for research and management.

Based on these discussions, a series of recommendations are presented to facilitate the move towards improved accounting of ES in a landscape management context on KI. Given current approaches, significant effort will likely be required to achieve this and it will require further research, perhaps a refined departmental structure, innovation in conservation and primary production, and an adequately resourced and scientifically validated adaptive management process that can make refinements to on-ground management practices.

Report Framework & Aims

In recent years, mounting scientific evidence regarding the unprecedented rate of climate change (IPCC 2014) has led scientists, regulatory authorities and some industry groups to investigate mechanisms to not only assess the potential for change and related impacts, but to examine means by which landscape-level adaptation/resilience can be achieved. A good example of this is the National Climate Change Adaptation Research Facility at Griffith University, which was established in 2008 (NCCARF 2014). Assessments are often couched in terms of the 'triple bottom line', which focuses on maintaining integrity of economic, social and environmental systems; these systems are overlapping and intrinsically linked in a complex way.

Kangaroo Island (KI) is no exception, with climate change adaptation at the forefront of the next generation of natural resources management (NRM) planning. However, KI has a range of unique challenges and advantages, which require that information developed in a broader (sometimes national) context needs to be synthesised into a context relevant to KI and its specific needs. Indeed, there is little KI-specific information with regards to the adaptive capacity of the landscape in terms of supporting current and future industries, or the significant biodiversity values of KI.

In an NRM plan that seeks to provide economic, social and environmental resilience for KI, the unique challenges/advantages for KI need to be at the forefront of considerations. These include:

- small population (spread over a relatively large area); i.e. low population density
- corresponding small economic base for local government and NRM board
- limited social services and infrastructure
- high economic reliance on few industries (primary production and tourism)
- relatively high export costs
- high number of visiting tourists and corresponding impacts on infrastructure
- very high reliance on agricultural industries common elsewhere (i.e. grain, wool, lamb/beef production, honey)
- need for innovation in agricultural and conservation management practices
- relatively limited value-adding to primary produce (or relevant infrastructure)
- freedom (or reduced incidence) of serious agricultural and environmental pests, most notably rabbits, hares, foxes, European wasp, American and European foulbrood, etc.
- highest level of remnant vegetation of any agricultural region in South Australia (SA) combined with significant native vegetation coexisting with agricultural production
- high biodiversity values and large intact blocks of remnant vegetation (including five Wilderness Protection Areas; WPAs)
- iconic status within Australia and internationally

The specific purpose of this report is to inform the 'climate change ready' NRM Plan 2015-2025 (otherwise referred to as the 'new NRM Plan'), with regard to the value and management of native vegetation on KI. Native vegetation has implications for the main industries on the island, has significant biodiversity values due to its preservation, and is subject to a range of threatening processes.

A key deliverable of the new NRM Plan is that *Principle One* is addressed. This requires stakeholders to:

- *identify priority landscapes for carbon and biodiversity plantings and strategies to build landscape integrity, and*
- *guide adaptation and mitigation actions to address climate change impacts on natural ecosystems.*

Key guiding principles include:

- *adopt a whole of landscape approach to planning and implementation with the aim of restoring and maintaining ecosystem structure and function at various spatial and temporal scales.*
- *build the resilience and adaptive capacity of natural systems to deal with shocks such as climate change.*
- *avoid perverse outcomes such as increased fire risk and negative impacts on water resources or productive agricultural land.*

Therefore, this report aims to investigate ways that native vegetation on KI can be managed such that social, economic and ecological values are maximised whilst augmenting landscape adaptive capacity and resilience. While the ecological, social and tourism-related advantages of the significant island remnant vegetation have been recognised for some time, its value to primary production has largely been overlooked beyond the significant government and private investments made to improve degraded land in agricultural systems (e.g. Landcare programs). Additionally, there has been little assessment of how native vegetation should best be managed with regard to providing pest management and biosecurity benefits to primary production systems. However, this is currently the focus of increasing scientific research elsewhere (supported by some industry groups), particularly in areas where vegetation has largely been removed from landscapes under significant primary production, resulting in obvious management/economic issues for production systems. These include the cotton-growing regions of NSW and Qld, and grain production on the west coast of SA.

In this report, I aim to make initial assessments of:

- qualitative impacts/contributions of KI's native vegetation to the triple bottom line
- ways in which native vegetation on KI contributes to resilience of biodiversity, primary production and related industries
- key threats to broad ecosystem services provided by KI's native vegetation
- mechanisms by which resilience of KI's native vegetation can be maintained to provide combined benefits to economic and environmental (and thereby social) networks on KI, under a rapidly changing climate or other significant challenges

Scientific and regulatory communities are still grappling with these extremely complex issues, and detailed solutions do not yet exist. However, this report makes broad management recommendations on maximising the combined benefits of native vegetation for various stakeholders. It is also intended to highlight issues of importance to KI and principles/evidence regarding ecosystem services related to native vegetation, and to inform the subsequent development of specific NRM recommendations.

Conceptualising and valuing ecosystem services from native vegetation: a global debate with local implications

The concept of the environment supporting human populations is ancient, however, in recent years, there have been increasing attempts to assign a 'value' to 'services' provided to humans by the natural environment; i.e. the value of ecosystem services (ES). Most notably, the Millennium Ecosystems Assessment (MEA; http://www.unep.org/maweb/en/Index.aspx) was set up in 2001 in order to asses the consequences of ecosystems changes to human health and to develop a scientific underpinning for actions to maintain these services in a rapidly changing world (MEA 2005b). Other initiatives have included the Intergovernmental Platform on Biodiversity and Ecosystem Services (http://ipbes.net), The Economics of Ecosystems and Biodiversity (http://www.teebweb.org), the Ecosystems Services Partnership (ESP; http://www.es-partnership.org/esp) and the Wealth Accounting and the Valuation of Ecosystem Services partnership (WAVES; https://www.wavespartnership.org/en).

The MEA published a list of ES under four categories (MEA 2005a) and these have generally been upheld when examined by other authors subsequently. In agreement with the MEA's broad definition of ES, Wallace 2012 published a more concise version of the list (Table 1). The MEA examined 24 ES globally and concluded that 15 had degraded in the last 50 years, including capture fisheries, water supply, waste treatment, natural hazard protection, regulation of air quality and erosion, and multiple cultural services. Only four services were found to have improved, these being, crops, livestock, aquaculture and recently, carbon sequestration (MEA 2005a). A recent estimation of the global value of ES lost due to land use between 1997 and 2011 was $US4.3-20.2 trilllion p.a. (Costanza, de Groot et al. 2014). These global trends may not be reflected on KI and different issues may be relevant, however, it is worth recognizing that they are of widespread occurrence and that KI is not immune from processes leading to ES degradation.

While the definition of ES a being 'benefits provided to humanity by the environment' is generally accepted (Wallace 2007, Fisher, Turner et al. 2009), the classification of the services themselves, the way environmental components and processes interact to produce them, and how these concepts should be defined and considered in the development of management plans, are still the subject of significant debate (Wallace 2007, Costanza 2008, Fisher, Turner et al. 2009, Burkhard, de Groot et al. 2012, Wallace 2012, Adams 2014, Costanza, de Groot et al. 2014, Mace 2014).

A criticism of the MEA-based classification (Table 1) has been that listed ES (also expressed as 'benefits' or 'products') do not differentiate between environmental processes and the ES they provide, which equate to 'means' and 'ends' from a management perspective (Wallace 2007). Further, there should be an understanding of how compositional elements of the environment, which may be inherent (e.g. air, water, minerals) or socio-cultural (e.g. domestic stock, roads, buildings), influence environmental processes (which also may include social and economic influences) (Fig 1). Costanza (2008) argued that viewing the processes as a means to an end (which is an ES) is conceptually flawed because they are all means to achieve the greater goal of human well-being and that it may be more use to characterise ES by spatial associations, or by the excludability/accessibility and level of effect on those who do not benefit from an ES. Constanza concluded that the complexity of the systems means that multiple classification systems are needed, which take into account feedback mechanisms and should be tailored to particular applications.

Table 1. Categorisation of ecosystem services. Simplified from MEA (2005b) by Wallace (2007).

Type of service	Service/Benefit
Provisioning services	Food Fibre Genetic resources Bio-chemicals, natural medicines, etc. Ornamental resources Fresh water
Regulating services	Climate regulation Air quality regulation Water regulation Erosion regulation Disease regulation Pest regulation Pollination
Cultural services	Cultural diversity Spiritual and religious values Recreation and ecotourism Aesthetic values Knowledge systems Educational values
Supporting services	Soil formation Photosynthesis Primary production Nutrient cycling Water cycling

In terms of management, human values are a primary concern because they impact on existing compositional elements and processes in an ecosystem, as well as establishing/influencing management of both to enhance the desired ES (Wallace 2012) (Fig 1). Figure 1attempts to compartmentalise the compositional elements, process and human values into a simple model of their interaction in capturing ES and the evolution of new values and changed ecosystem status. An inescapable conclusion from such a model is that human values are at the heart of all other elements from a management perspective. This is indirectly asserted by one of the 'key messages' from the MEA's biodiversity synthesis (MEA 2005a) which stated that '*Science can help ensure that decisions are made with the best available information, but ultimately the future of biodiversity will be determined by society.*' This highlights the dual needs for stakeholder education and inclusion.

A key challenge for environmental managers on KI is to understand the role and value of native vegetation on KI, which is likely to be significant as it covers ≈40% of the land, more than any other agricultural region is SA. Sixty five percent of this native vegetation is protected under public and private agreements (Neagle 2002, KINRM Board 2009). Wallace (2007) suggested an approach to clarifying targets for management whereby desired ES are linked to discrete compositional elements and environmental processes they derive from. This allows managers to clearly separate the processes that should be managed for the ends (ES) that are desired (but not managed in themselves). Figure 2 provides an example as a simplified flow diagram of how five ES are linked to photosynthesis and pollination processes that produce vegetation in native and primary production systems (Wallace 2007). In theory this appears be a sound approach, however, our rudimentary scientific understanding of the complexity and degree of various interactions, prevents them from being defined with confidence in many cases. A simple example is pollination, a process may be performed by abiotic and biotic elements. The various biotic pollinators may have different environmental requirements and may target different plants, plant species may be pollinated in different ways, and it is not clear how much of the value of a given ES (e.g. recreation in natural environments in Fig 2) is attributable to pollination.

Another consideration is that the definition of what an element/service/process is and how they interact, may change with application, scale and/or viewpoint (even when defining the same ES). Therefore multiple classification systems may be needed to deal with this complexity as suggested by Costanza (2008). Fisher, Turner et al. (2009) make the important point that the classification of ES is essentially a decision making tool and that ES classification schemes should have clear and robust ES definitions as well as reflecting the decision-making context in which they reside and characteristics of the associated environment.

Later in the report, I attempt to discuss some the ecosystem processes and ES that native vegetation contributes to on KI, some threats to these ES and also how native vegetation can contribute to landscape resilience.

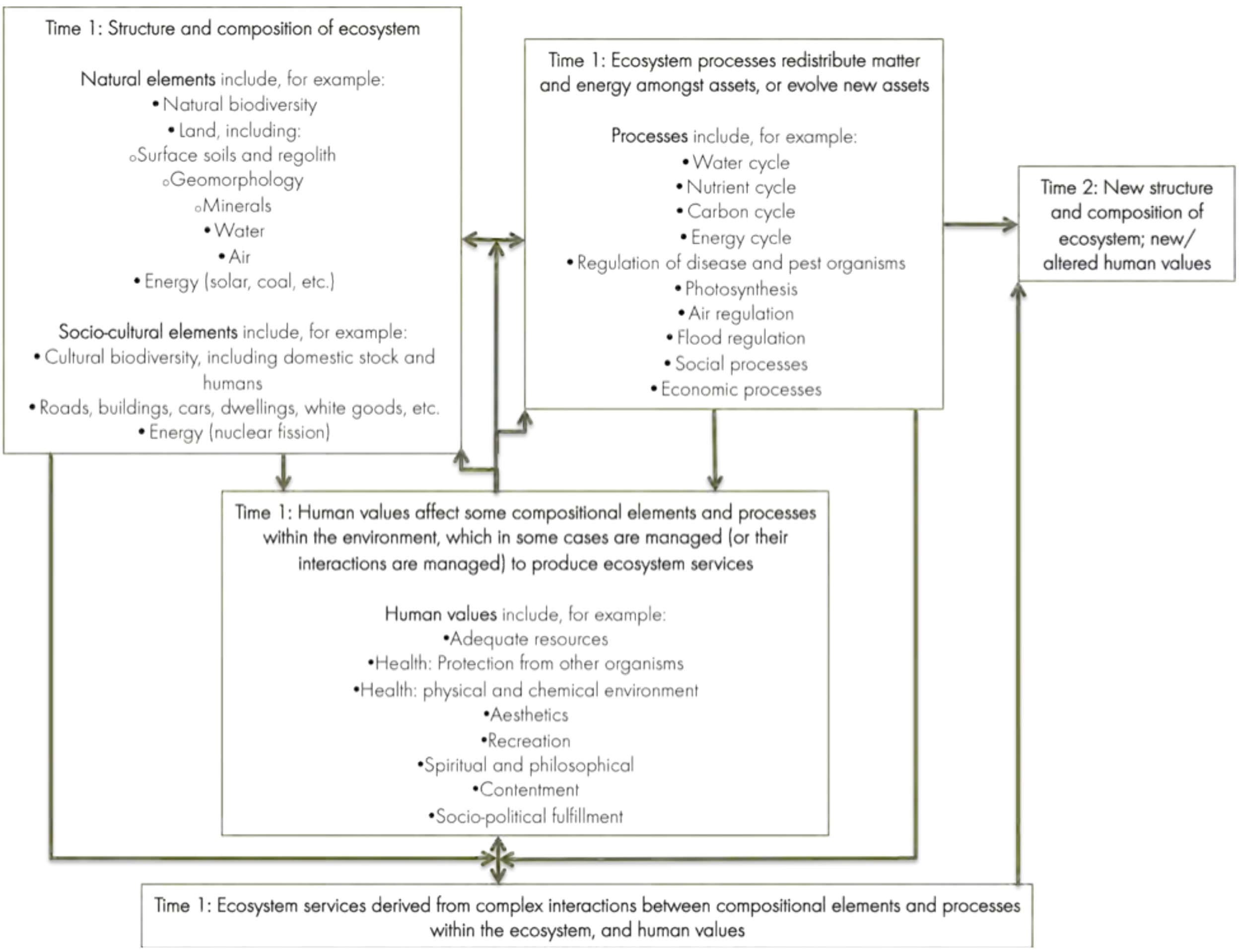

Figure 1. Simplified model of provision of ecosystem services through interactions between structural/compositional elements of an ecosystem, the ecosystem process they underpin, and human values which can impact on the services themselves as well as the ecosystem elements and processes. Arrows represent influence but do not specifiy the type or degree of influence. Over time environmental processes and altered human values lead to a new set of circumstances (e.g. deriving a new service increases social capital of the underpinning elements and processes). Compiled and modified from Wallace (2007 and 2012). Costanza (2008), suggested that the divisions between structure/composition, process and ES in the above model are in realilty not well defined and vary according to application of the model.

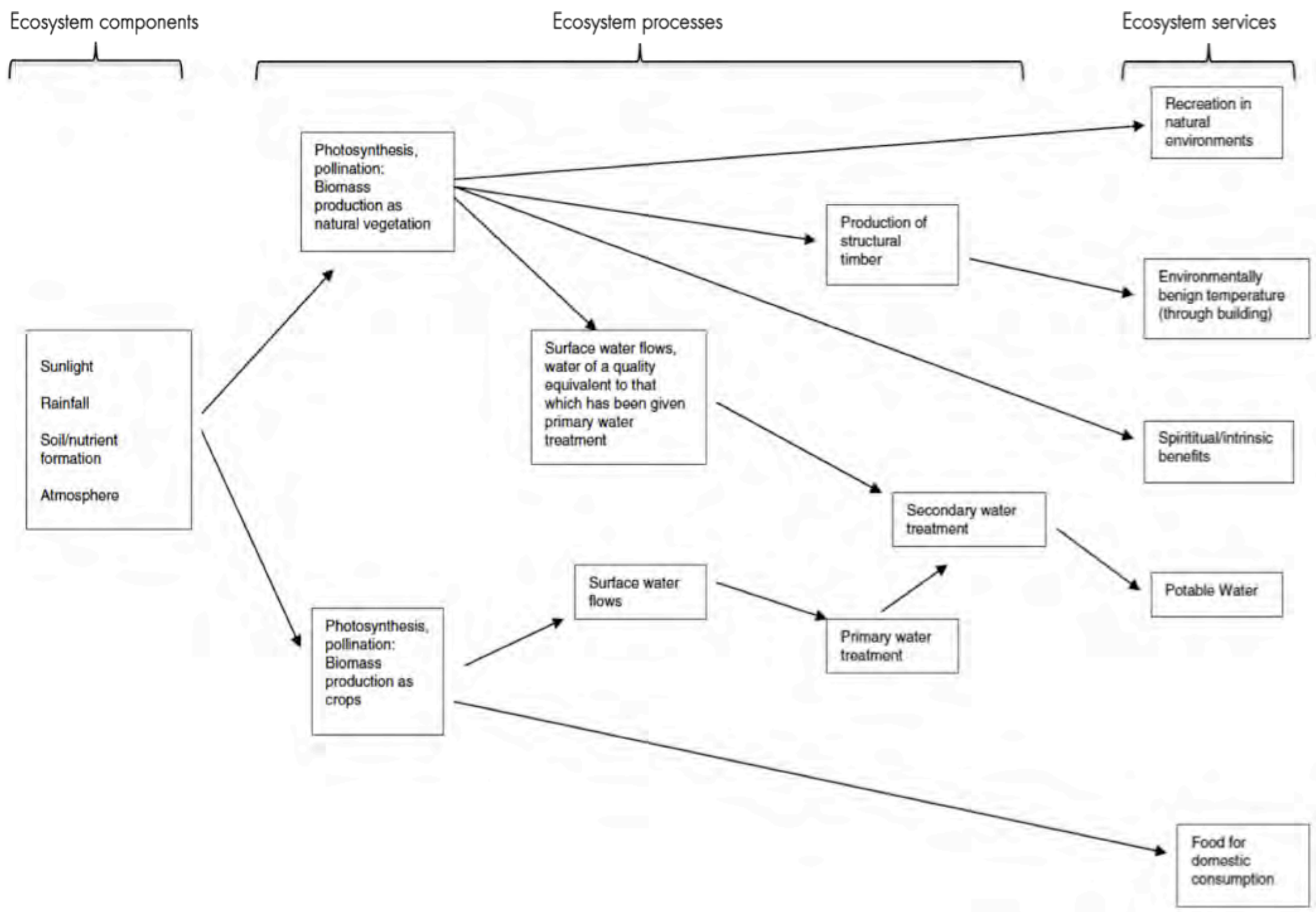

Figure 2. Simplified flow diagram of linkage between basic ecosystem elements, the processes they underpin (here exemplified by photosynthesis and pollination), and the services they provide (adapted from Wallace (2007). If the interacting parts that produce various services can be accurately identified, quatified and their relationships understood, then this form of ES characterisation may be a useful decision making tool in NRM, for landscape management to maximise/preserve ES delivery. However, defintion of what is a element/service/process, and how they interact, may change with application, scale and/or viewpoint, and therefore multiple classification systems may be needed for the same ES.

There is currently not a reliable way to ascribe monetary values to complex ES and the value is unlikely to be constant (MEA 2005a, Costanza, de Groot et al. 2014). A standardised method for economically valuing ES from native vegetation has yet to be developed due to the complexity of the ecosystems themselves, their interaction with human well-being, different views about what ES encompasses, and varying management contexts that use ES classifications. For example, a recent paper cited problems with capturing intangible (non-monetary) benefits and the definition of stakeholder groups as major problems in determining the real value of ES (Brooks, Smith et al. 2014). Even for the relatively targeted assignment of ES to native vegetation on KI, there are significant difficulties in producing meaningful economic values. For example, the value of ES to different stakeholder groups is different and their quantitative relationship unknown e.g. pest management services provided to primary producers versus intangible benefits to tourism). Also the perceived value amongst individuals within a stakeholder group can vary significantly and the benefits/costs will also vary.

There is also a range of other problems, e.g:

- ES that are an inherent part of the landscape are seen by many as being the *status quo* and their economic value is often not considered

- often there is no equivalent service with which to compare a given ES e.g. prevention of weed establishment. Therefore values are often based on indirect measures and involve estimates of the level of connectedness between these measures and the ES
- ES are often not apparent (or at least, less quantifiable) until they are lost. Indeed, the MEA was set up due to broad-scale degradation of ecosystems in developing countries and the concern that ES associated with human well-being were being degraded (MEA 2005b)
- the scientific understanding of the ES provided may be poor
- different ES interact with each other in complex ways and there is limited understanding of how given management practices act in a cumulative way or at sites distant to their implementation
- there may be a range of trade-offs to consider e.g. an accepted cultural/business practice seen as socially beneficial, could have detrimental effects environmentally
- it is difficult to value prophylactic effects and their value depends on events that may or may not occur
- there is no broad agreement about landscape attributes that correlate with well-being
- stakeholders often have a mindset where dealing with current issues has inherently more value that potential future problems
- the conceptualisation of ES by those that are resident on a given property is often very different to those seeking to manage the ES more broadly
- some ES may not relate to economics, or do so in such a convoluted way as to be indeterminable e.g. scientific value of intact and unique ecosystems

The debate is ongoing regarding approaches to conceptualising ES themselves i.e. what they encompass and how they are categorised, and ascribing values to ES. However, it is clear that ES are significant and globally they are believed to easily outstrip gross domestic product i.e., they are of far more value than the economies they underpin (Costanza, de Groot et al. 2014). It has also been argued that in using the MEA-derived classification presented in Table 1, supporting services (e.g. soil) and regulating services (e.g. pollination) are generally grossly undervalued (Bommarco, Kleijn et al. 2013).

For the purposes of NRM planning on KI with limited resources, it could be argued that we should simply identify/define the potential services, attempt to understand their relative impacts, and aim generally to maintain environmental quality and resilience, rather than expending effort to produce values with low statistical confidence. Indeed, there is an argument that the definition of environmental parameters in economic terms is fundamentally flawed (Monbiot 2014), at least in some cases (Adams 2014, Mace 2014). However, there are dangers to non-assignment of economic values (see Mace 2014) and good practical reasons to frame the relative ES values in economic terms, including:

- many ES are not valued by the community until they are lost and so defining an economic value can highlight the ES and aid in its protection/exploitation
- industry, community & government routinely use economic metrics and therefore require such a characterisation for ease of communication and comparison
- facilitates a move towards full cost : benefit accounting and ability to calculate trade-offs, both of which are important to increase the robustness and efficiency of decision making at a landscape level
- most proactive management decisions in the commercial world (including primary production) are undertaken due to economic imperatives

Other considerations are that placing economic values on ES for differing applications may require use of different economic metrics, may need to be calculated over different spatial scales and/or may require differing degrees of accuracy (Table 2) (Costanza 2008, Costanza, Kubiszewski et al. 2011, Zhang, Holzapfel et al. 2013). For example, in terms of raising awareness and demonstrating concepts about ES, total values and low precision may be sufficient and the spatial scale of calculation matches that of the target audience. In contrast, a full cost accounting application might require a range of economic metrics, high precision and be calculated at regional scales (or greater). A good discussion on full cost accounting, valuing intangible benefits and methods for valuation can be found in Kaval and Baskaran (2013). These issues are key in terms of maximising ES benefits across stakeholder groups (see later).

Table 2. Contrast of (theoretical) economic metrics, spatial scales of calculation, and precision, required to economically value ecosystem services for a range of applications (Costanza 2008).

Use of valuation	Appropriate values	Appropriate spatial scales	Precision needed
Raising awareness and interest	Total values; macro aggregates	Regional to global	Low
National income and well-being accounts	Total values by sector; macro aggregates	National	Medium
Specific policy analyses	Changes by policy	Multiple depending on policy	Medium to high
Urban and regional land use planning	Changes by land use scenario	Regional	Low to medium
Payment for ecosystem services	Changes by actions due payment	Multiple depending on system	Medium to high
Full cost accounting	Total values by business, product, or activity; changes by business, product, or activity	Regional to global, given the scale of international corporations	Medium to high
Common asset trusts	Totals to assess capital; changes to assess income and loss	Regional to global	Medium

One clear upshot of the issues I discuss below, is that management practices that are undertaken at a defined site can impact on the broader landscape and effect operations of adjacent and more distant sites, and potentially of many other people on KI. This is one of the key reasons that many regulatory bodies and other NRM-related groups, are taking a 'landscape' approach to NRM.

Ecosystems Services from Native Vegetation

Agricultural Pest, Weed and Disease Management

There are four general principles that suggest that intact native vegetation has significant benefits related to management of invertebrate pests, weeds and crop diseases in primary production systems:

1) Relatedness of crops and weeds and their association with invertebrates: crop plants are generally exotic species and the invertebrate pests that attack them are usually also exotic (Table 3). Crop plants and weeds are also often in the same plant families and so harbour similar invertebrate pests and diseases such as viruses (and the disease vectors). Some of these plant families are rare in native vegetation (see examples in Table 3) as are some key plant viruses.
2) Beneficial invertebrates such as parasitoid wasps and predators are known to be associated with (and supported by) native vegetation (Table 4) and most invertebrate pests and plant viruses are unlikely to be common in native vegetation.
3) Importance of climatic or regional adaptation: plant diseases, weeds and invertebrate pests have a higher chance of establishing and competing in new regions with similar climatic conditions to their

natural range. In such regions, they have also have an increased chance of interacting with each other and with crops to increase pest pressure and pest reservoirs on land adjacent to crops. For KI, relates mainly to South African and the Mediterranean regions, from which many of our pests derive. A recent discovery highlights such an interaction on KI: an important invertebrate pest for KI grains and pasture crops (red-legged earth mite, RLEM: *Halotydeus destructor*) being supported by bridal creeper, *Asparagus asparagoides* (pers. obs. 2014; Figure 3). Bridal creeper is a 'weed of national significance' (WoNS) and a serious environmental and roadside weed on KI. These pest species both originate from South Africa, and while the observation of RLEM on other South African weeds has been reported (Ridsdill-Smith, Hoffmann et al. 2008, GRDC 2014), its presence on bridal creeper has not. This one example highlights the volatile nature of interactions in disturbed areas between exotic species from similar climatic regions, and links to the following principle that,

4) intact native vegetation buffers against changes to species composition, especially introduction of new plants. In agriculture this may be beneficial in inhibiting establishment of weed species (or adjacent volunteer crop species) that carry diseases or infest productive land. This is also important adjacent to primary production as abnormally high nutrient levels (compared to native soils) can drive healthy populations of exotics.

Figure 3. Red-legged earth mite (*Halotydeus destructor*) is an important pest of pasture and grains crops on Kangaroo Island and elsewhere. It was recently discovered feeding on bridal creeper (*Asparagus asparagoides*) adjacent pasture (MacGillivray, June 2014). Both pest species originate from South Africa. Bridal creeper (WoNS species) is common in disturbed roadside vegetation on parts of Kangaroo Island and its presence adjacent to agriculture likely reduces the efficiency of RLEM control measures in crops. Bridal creeper populations are inhibited by dense, undisturbed native vegetation.

Table 3: Two example plant families containing numerous crop plants and weeds. The crop viruses and pest invertebrates (some virus vectors) they support in Australia are listed. Many of the crop viruses and pests are associated with multiple crop and weed species. Both the Brasicaceae and Solanaceae are relatively poorly represented in native vegetation on KI (~1% and ~0.5% of plant taxa, respectively), suggesting that native vegetation has the potential to reduce incidene of both pests and crop viruses when located adjacent to primary production. Thrips and aphids vector most of these viruses. These invertebrate vectors are far more common on weeds than native vegetation, wheras beneficial insects are common in native vegetation (Schellhorn, Glatz et al. 2010, Wood, Siekmann et al. 2010, GRDC 2014).

Plant Family	Crops	Weeds	Viruses	Pest Invertebrates	Comments
Brassicaceae	Canola Cabbage Cauliflower Broccoli Brussels Sprouts Kale Bok Choi Radish Turnip	Lincoln Weed Skeleton Weed Wild Radish Wild Mustard Volunteer Canola	BWYV TSWV TMV TLCV TYLCV TuMV	Diamondback moth Cabbage white butterfly Green peach aphid[V] Turnip aphid[V] Cabbage aphid[V] Western flower thrips[V] Red-legged earth mite Balaustium mite Rutherglen bug[N]	BWYV also infects a range of other crop plants on KI (e.g. pulses, legumes such as lucerne). Outbreak in 2014 in Lower North and Mid North regions of SA linked to weeds supporting BWYV and green peach aphid (both are rare in native vegetation)
Solanaceae	Potato Tomato Capsicum Eggplant Chili	Silver leaf nightshade Blackberry nightshade Apple of Sodom	TSWV INSV CaCV CMV PMMV PVX* PVY* PLRV PVS*	Western flower thrips[V] Tomato thrips[V] Melon thrips[V] Red-legged earth mite Balaustium mite European Earwigs Green vegetable bug Brown shield bug[N]	TSWV is able to infect at least 1090 plant species from 84 families, many of which are weeds.

Abbreviations - BWYV: beet western yellows virus; CaCV: capsicum chlorosis virus; CMV: cucumber mosaic virus; INSV: impatiens necrotic spot virus; PLRV: potato leaf roll virus; PMMV: pepper mild mottle virus; PVS/PVX/PVY potato viruses S, X and Y; TLCV: tomato leaf curl virus; TMV: tomato mosaic virus; TSWV: tomato spotted wilt virus; TuMV: turnip mosaic virus; TYLCV: tomato yellow leaf curl virus.

[V]crop-virus vector

[N]native pest but of relatively minor concern in listed crops

*not known to be present and therefore of biosecurity concern for KI

Compiled from Persley, Thomas et al. (2006), Persley, Sharman et al. (2007), Persly and Gambley (2010), Gillam and Urban (2014).

The underlying numerical relationships between populations of a pest species and a beneficial species that is a predator or parasitoid (a parasite that kills its host) of the pest, have been extensively modelled and are quite well characterised. A simple, generic model of these relationships is that of 'delayed density dependence' (Figure 4). In simple terms this means that beneficial populations in a primary production system will respond to pests after an initial lag period, leading to a rise in the beneficial population and a consequent reduction in the pest population and a sustained reduction in the pest population over time.

Table 4. Key agriculturally beneficial arthropods commonly associated with native vegetation on Kangaroo Island and their benefical roles.

Broad group	Key beneficial groups on KI	Example species occurring on KI (or likely to)	Role
Mantodea (preying mantids)	Most species	*Orthodera ministralis* (green garden mantid) *Archimantis* spp.	General predation of arthropods
Hemiptera (true bugs)	• Reduviudae (assassin bugs) • Miridae (predatory species only) • Pentatomidae (predatory species only) • Lygaeidae (predatory species only) • Cimicoidea (cimicoid bugs) • Stenocephalidae (stenocephalid bugs) • Enicocephalidae (enicocephalid bugs)	*Nabis kinbergii* (Pacific damsel bug) *Dicranocephalus* spp. *Oechalia schellenbergii* (spined predatory bug) *Geocoris sp.* (big eyed bug)	• General predation of arthropods • *Nabis* known to consume aphids & diamondback moth larvae
Thysanoptera (thrips)	Thripidae (predatory species only) Aeolothripidae	*Haplothrips victoriensis* *Scolothrips* sp.	Predate on pest thrips, mites, other small invertebrates & invertebrate eggs
Neuroptera (lacewings)	• Hemerobiidae (brown lacewings) • Chrysopidae (green lacewings) • Coniopterigidae (dusty wings) • Several other families	*Micromus tasmaniae* (common brown lacewing) *Chrysoperla* sp. (green lacewing) *Mallada signatus* (green lacewing)	• General predation of arthropods • *Micromus* known as key beneficial predator of aphids • *Chrysoperla* & *Mallada* commonly found in agricultural systems
Coleoptera (beetles)	• Carabidae (ground/tiger beetles) • Staphylinidae (rove beetles) • Cantharidae (soldier beetles) • Cleridae (clerid beetles) • Melyridae (melyrid beetles) • Coccinellidae (ladybirds)	*Chauligonathus sp.* *Dicaronolaius spp.* *Cryptolaemus montrouzieri* (mealybug ladybird) *Hippodamia variegata* (white-collared ladybird) *Coccinella transversalis* (transverse ladybird) *Harmonia conformis* (large spotted ladybird) *Diomus notescens* (two-spotted ladybird) *Cleobora mellyi* (southern ladybird) *Orcus australasiae* (orange-spotted ladybird)	• General predation of arthropods; some ladybirds target aphids • Many species may be non-specific pollinators when flower feeding.

Table 4 continued

Diptera (flies)	• Nemestrinidae (nemestrinid flies) • Therevidae (therevid flies) • Asilidae (robber flies) • Bombyliidae (bee flies) • Empididae (empidid flies) • Dolichopodidae (long-legged flies) • Syrphidae (hover flies) • Tachinidae	*Cerdistus* spp. *Bathypogon* spp. *Mauropteron pelago* *Neoaratus hercules* *Simosyrphus grandicornis* (common hoverfly) *Carcelia* sp. *Trichopoda* sp.	• Parasitic or general predation of arthropods; • Bee flies predatory as adults, parasitic as larvae. • Some hover fly larvae predatory on communal bugs such as aphids & whitefly. • Many species visiting flowers & may provide pollination (e.g. hover flies)
Hymenoptera (wasps, ants & bees)	• Ichneumonidae (ichneumon wasps) • Braconidae (braconid wasps) • Scelionidae (scelionid wasps) • Chalicidoidea (chalcidid wasps, many families) • Colletidae (short-tongued bees) • Halictidae (halictid bees) • Apoidea (bees; honeybee & ≈100 species of native bee)	*Netelia* spp. (parasitoids of noctuid moth larvae) *Microplitis demolitor* (parasitoid of *Helicoverpa* moths) *Ichneumon* sp. (parasitoid of noctuid pupae) *Heteropelma* sp. (parasitoid of noctuid moth larvae) *Lissopimpla* sp. (parasitoid of noctuid moth larvae) *Aphelinus* spp. (parasitoids of aphids) *Aphidius* spp. (parasitoids of aphids) *Cotesia glomeratum* (parasitoid of cabbage white butterfly) *Cotesia rubecula* (parasitoid of cabbage white butterfly) *Apanteles ippeus* (parasitoid of diamondback moth) *Diadegma semiclausum* (parasitoid of diamondback moth) *Trichogramma* spp. (parasitise noctuid moth eggs) *Hemiptarenus varicornis* (parasitoid of leafmining flies) *Apis mellifera* (European honeybee) *Amegilla chlorocyanea* (blue-banded bee)	• Many species are specific parasites & often used as biocontrol agents. They attack eggs, larvae & adults of other insects. • Many wasps & bees will visit flowers providing pollination.
Arachnida (spiders. scorpions etc.)	• Many spiders • Pseudoscorpions • Predatory mites		General predation on other arthropods with predatory mites generally attacking other mites

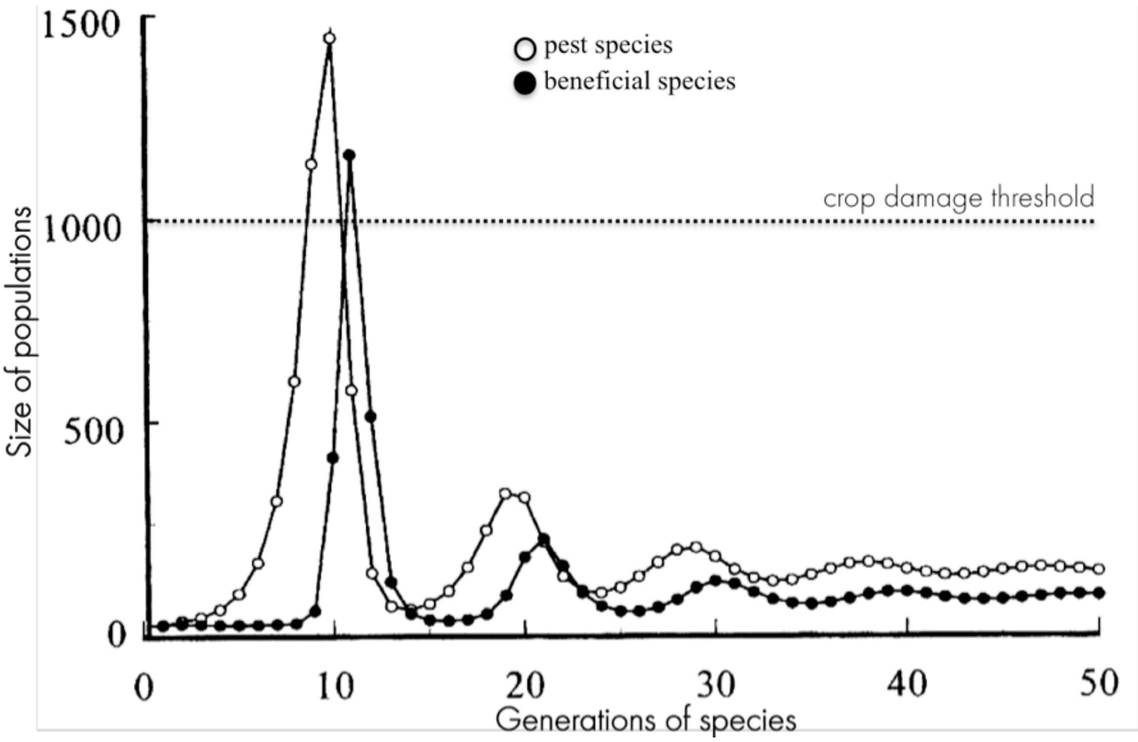

Figure 4. Generic delayed density dependent relationship (using a negative binomial distribution model) between a pest species (white circles) and a beneficial species (black circles) that is either a predator or parasitoid attacking the pest (adapted from Hassell (2000)). The model shows that pest populations can be significantly reduced by the presence of these beneficial species. The model relies on numerous assumptions and is altered by a range of biological and physical variables associated with different pest/beneficial species interactions, however, the underlying principle of delayed density dependence is robust. The level that the pest population can achieve and the speed at which a beneficial species provides pest control are closely related to the starting population levels and how favorable the environment is for each. Both of these important factors may be influenced by the presence of native vegetation and its proximity to crops, and in some cases beneficial species may aid to prevent pest populations from exceeding the crop damage threshold. The model shows the situation in a natural context where generations of coexistence lead to more stable populations of both species, whereas a typical annual cropping system would "reset" the model after harvest.

Thus, native vegetation can be manipulated to aid in reducing pest/disease population peaks (or reduce cost/collateral damage of controls) through either inhibition of pest numbers, earlier provision of beneficials, and/or increased provision of beneficials. These may occur through:

- native vegetation inhibiting establishment or reducing weed populations
- providing resources for beneficial insects (e.g. shelter, nectar, hosts); known as "conservation biological control"
- reduction of pest reservoirs (or prevention of near-crop establishment)
- addition of beneficials into crops early in, or ahead of, pest pressure
- inhibiting movement of pests by fragmenting exotic host weed populations

Each of these processes will act to increase the starting population of beneficials and/or lower the initial pest populations. Both of these effects have potential as part of an integrated pest management system aimed at early establishment of beneficial invertebrates within the crop, reducing the ultimate size of pest populations and aiding in keeping pest numbers below the threshold of acceptable crop damage (Fig 4).

While these general principles have been known for some time, and the benefits of landscape engineering to provide agricultural ES postulated in the scientific community, there has been limited direct scientific evidence about the effectiveness of using native vegetation in specific agricultural pest management scenarios (Landis, Wratten et al. 2000, Gurr, Scarratt et al. 2004, Zehnder, Gurr et al. 2007, Schellhorn, Bianchi et al. 2014). Further, explicit economic advantages have not been easy to define due to the biological complexity and variability of even agricultural systems. However, increasing pest problems in areas with little native vegetation and reduced efficacy of standard control practices (e.g. insecticide resistance), have led some primary industry bodies to investigate the value of native vegetation. Most notably, this has occurred in mid north and western SA where significant losses of canola crops through insecticide-resistance in diamondback moth and green peach aphid, and the aphid-vectored plant virus BWYV (Table 2), have highlighted these issues. Indeed, weed 'bridges' caused by high rainfall was cited as a key reason for the BWYV outbreak in 2014 (Kimber, DeGraaf et al. 2014).

With regard to crop viruses (that can cause significant losses and be difficult to control), a common part of integrated management is weed control. This is because weeds are often reservoirs for the crop viruses and for thrips/aphids, which are their primary vectors (Persley, Sharman et al. 2007, Persly and Gambley 2010, Wood, Glatz et al. 2011) (Table 2). A 1997 study conducted in Perth reported that TSWV was detected in 16 out of 45exotic weeds tested but was found in only one of 42 Australian species tested (Latham and Jones 1997). An example of research on this problem was conducted on the Northern Adelaide Plains (NAP) by SARDI, and funded by government and industry groups (Wood, Glatz et al. 2011, Wood, Glatz et al. 2011). The role of weeds in supporting tospoviruses such as TWSV and CaCV, and the thrips that vector them (see Table 2), had led horticulturalists in the region to manage the viral disease by maintaining bare earth around their crops using herbicide. Research showed that native vegetation was useful as a weed control option because it was competitive, adapted to local conditions and did not contain the crop viruses. Also, significantly less thrips vectors were found on the native plant species used but beneficial insects were abundant, including a parasitoid wasp that attacked the key thrips pest (western flower thrips; *Frankliniella occidentalis*). Furthermore, it was shown that risk of exotic plants in harbouring the thrips vectors (which are exotic) was higher than for native plants, and that pest thrips populations were lower when further from the crop (Schellhorn, Glatz et al. 2010). This work led to the production of guides to revegetation and local insects relevant to vegetable growers on the NAP (SARDI 2009a and 2009b).

A recent factsheet produced by the Grains Research & Development Council (GRDC) and CSIRO, which listed problem weeds and the invertebrate pests they support, as well as native plants and the beneficial species on them (GRDC 2014). Additionally they advised growers that native vegetation would in general provide pest-management-related ES to producers and that the level of the ES would likely be increased when vegetation was closer to crops because arrival of beneficial species was quicker. As mentioned above, higher starting populations of beneficial species, will produce greater dampening of the peak pest populations (and potentially the duration of population levels above the crop damage threshold; see Fig 4).

This advice to growers suggests that the grains industry accepts scientific research indicating that a landscape with significant native vegetation mixed with production systems is a good model for (economic) production goals. Presumably industry leaders would consider that in hindsight a superior land management approach would have better preserved the native vegetation near agriculture in the study regions. Thus, it is realised that there is a pest-management ES provided by native vegetation that can impact economic outcomes and thus has an economic value. This ES is still available to many producers on KI and minimising its reduction should be an aim of producers and governments at all levels.

It should be noted that I have presented general principles highlighted by some specific examples, but that there are exceptions to these principles. For example, some pest invertebrates are native (Table1) and occur in native vegetation and/or weeds. However, species that control these native pests (such as highly specific parasitoid wasps) are also naturally present and can mitigate them to some degree unlike many exotic pests) Therefore, it is important to undertake research with regard to requirements of different crops and their management systems. For example, there is no database that defines invertebrate and plant species that are important to KI in terms of being pests, disease reservoirs and beneficial to production. Indeed, a recent report from a regional species assessment project (phase 1) underway in DEWNR takes into account only one invertebrate on KI (Gillam and Urban 2014). Nevertheless, there are obvious potential shared production and biodiversity benefits that could be realised through revegetation programs that target pest management objectives in primary production. It could be argued that many of these issues have not become as serious on KI due to the fact that a lot of native vegetation still exists near agriculture, however, this also means that historically there has not been a good recognition of these benefits on KI and indeed, management practices such as roadside maintenance and fuel-reduction burning ignore these issues and may reduce their efficiency. For example, the current roadside management plans discuss the cost of removing/maintaining roadside vegetation but do not account for any production effects (Kangaroo Island Council 2006).

Similarly, fire management protocols related to fuel reduction discuss asset protection but do not account for beneficial effects of native vegetation on primary production or the reduction of asset values through disturbance, weed introduction and loss of beneficial species from treated areas although some of these concerns are mentioned from a biodiversity perspective (DEWNR 2009, KIDBPC 2009). With regard to shared benefits (or shared problems), fire adapted weeds provide obvious cause for concern. For example, Gorse (which has a very limited KI distribution) is a serious weed of natural systems and agriculture, and reduces the value of agricultural land (DAFF 2006). Additionally, it is highly flammable and seeds are viable for many years in soil. Thus, if introduced to areas that are consistently burnt, Gorse has the potential to cause significant impacts with insufficient resources for its control. For example, it is now a common plant in dense native vegetation in Kyeema CP on the Fleurieu Peninsula after several fires there (pers. obs).

There have been preliminary investigations into the use of controlled burns for biodiversity purposes on KI. These have primarily aimed at regeneration of rare plant species existing in seed-banks of isolated patches of mallee that are considered "senescent" due to long periods without fire resulting in highly reduced plant diversity in the understory and poor condition of the remaining trees. This research has not investigated the effect on organisms related to the adjacent production systems, however, the use of targeted fires may have utility in agricultural weed/pest management and provision of agriculturally beneficial organisms (or in some cases may be detrimental to production). Considering just these two management practices as examples i.e., management of fire and roadside vegetation which are both beset by insufficient resourcing, highlights potential for improving them with regard to the structure of their administration and/or obtaining dual production and ecological benefits.

In this section, I have provided several specific examples to highlight the contributions that native vegetation makes to agricultural pest management. However, there are many more examples in literature and the manipulation of native vegetation to provide agricultural ES is in its infancy, particularly at a landscape scale. The effect of KI flora species for use in pest management on current and potential KI production systems has not been examined in detail and warrants further study.

The issues discussed here under pest management, also have relevance for biosecurity (below).

Agricultural Biosecurity

Pest management and biosecurity issues are similar at a biological level and are mainly differentiated by whether a given organism already exists in the landscape (pest management) or could be introduced there and spread (biosecurity). KI is currently free of a range of serious mainland pests including rabbits/hares, foxes, European wasp, European honeybee (*Apis mellifera*) bacterial diseases European and American foulbrood (Gellard 2005, Glatz 2015). Because of the absence of some obvious and high-profile pest species and being an island, KI biosecurity has been a focus of PIRSA and the various incarnations of DEWNR for some time and departmental plans/legislation have been produced in this regard (Gellard 2005). However, this has primarily focused on the management of entry points for new pests and on-farm biosecurity and there has been little work on several important areas such as:

- identifying key threatening pests (particularly invertebrates and microorganisms) for KI under predicted climatic parameters
- identifying landscape ES that pertain to introduction and spread of newly introduced species
- identifying management practices that maximise these services and will aid in preventing an incursion, or limiting its spread and severity at a landscape level

Intact native vegetation buffers changes to species (especially plant) composition, as mentioned above. Therefore, it is likely the best (free) passive defence in resisting the spread (and hence economic impact on production) of new introductions of exotic pests, weeds and diseases. This is because models of pest/disease spread show that important factors include:

- potential suitable area available
- suitability of climatic conditions
- number and interconnectedness of susceptible host organisms e.g. weeds and crops supporting a disease or invertebrate pest,
- presence/abundance of vectors (including humans)
- presence/degree of competing factors such as control measures.

Biosecurity is particularly important in the context of rapid climate change as presumably KI will be subject to a different suite of potential pests/diseases as conditions alter and the land area that is buffered against this will likely be proportional to the inhibitive capacity of the landscape, particularly for adjacent production systems. This is particularly so for 'cold blooded' organisms such as insects because most aspects of their biology (notably development rates) are regulated by temperature. The Plant Biosecurity CRC (http://www.crcplantbiosecurity.com.au/) has conducted projects aimed at modelling risk of potential invasive species. For example, the risk of exotic insects and plants entering Australia was analysed using quantitative self-organising maps of pest species assemblages internationally, based on impact metrics (Paini, Worner et al. 2010, Morin, Paini et al. 2013). These studies both commented that current data sets in this area are beset by subjectivity (particularly regarding relative impacts of specific taxa) but that their approach had some merit in adding objectivity to what is currently a largely consultative process. For weeds in particular, it was suggested that analysing characteristics of invasiveness could be a superior approach in minimising subjectivity (Morin, Paini et al. 2013). It should be realised that this type of research is still examining different models for agreement with current data sets to assess the usefulness of various approaches, and predictive models of this kind are not yet in widespread managerial use. However, it is useful to be aware of developments in this area, and to attempt to engage with relevant researchers to analyse data sets relevant to KI. Determining the most likely and/or most damaging incursions for KI, will help to prioritise landscape attributes to be managed for biosecurity outcomes although the underlying principle of reduction of disturbed, non-managed areas are likely to be important in most cases. The plant biosecurity CRC is also investigating a range of technologies for real-time biosecurity monitoring as well developing biosecurity networks for information sharing and diagnostics.

The value of intact native vegetation in providing biosecurity-related ES to agricultural production systems was recently acknowledged by the KINRM board who endorsed a recommendation from its Biosecurity Advisory Committee stating that "degradation/clearance of native vegetation adjacent to primary production is a Key Threatening Process for agricultural biosecurity on KI" (KINRM Board 2014). Given that resources available to control new outbreaks will be insufficient to significantly reduce their population size and rate of spread, the presence of intact native vegetation should be seen as an insurance against the occurrence or severity of such incursions and could conceivably be worth many millions of dollars in that regard. A further consideration is that biosecurity incursions may not occur in adjacent mainland areas, in which case there could be prohibitions placed on KI exports and/or sales, which would have significant impact on affected industries. There are numerous examples of this such as several fruit fly species on mainland SA, the discovery of which results in establishment of exclusion zones from which fruit and vegetables cannot be exported.

Not only can native vegetation act as a passive aid to biosecurity through reducing the area and hosts allowing establishment and spread of a given pest, but there is potential for it to host natural biological control agents for serious pests that are yet to occur. For example, research on the NAP showed that native saltbush species were supporting parasitoid wasps that were attacking small native flies mining in their leaves (Wood, Siekmann et al. 2010). One wasp in particular, *Hemiptarsenus varicornis*, is a known biological control agent for an Emergency Plant Pest (EPP) as declared by Plant Health Australia (PHA 2014). This pest, which is a fly known as the vegetable leaf-miner (*Liriomyza sativae*), causes serious losses in vegetables and ornamentals by mining in their leaves and has become increasingly difficult to control by insecticides in other countries (Murphy and LaSalle 1999, Rauf, Shepard et al. 2000, Salvo and Valladares 2007). Furthermore, the pest flies would not likely mine the saltbush leaves. Therefore, these saltbushes provide the capability of producing prophylactic populations of *H. varicornis* (and other wasp species also) near relevant crops (Murphy and LaSalle 1999, Wood, Siekmann et al. 2010). Also, the saltbushes supported native biodiversity including useful insects, were less likely to support other key vegetable pests such as thrips virus-vectors (Table 3) and required little post-establishment management (SARDI 2009, Schellhorn, Glatz et al. 2010, Wood, Glatz et al. 2011).

Management practices for biosecurity applications are necessarily prophylactic and therefore their value is difficult to assess as they attempt to encompass measures of risk; they are akin to an insurance policy in that their real value is determined by the occurrence of future events. However, the majority of people do consider it appropriate to use insurance to mitigate risk for major occurrences that are relatively unlikely. This is because the cost of these risk factors far outweighs the insurance cost. Landscape management for biosecurity purposes should be considered similarly in that the cost of altering current management practices (or introducing new practices) to reduce area for pest establishment and spread is likely to be a fraction of the cost of serious incursions under a 'business as usual' scenario. Such incursions could have large impacts and cost KI through ongoing reduced production, control measures, quarantine measures, certification problems etc., and in a worse case scenario could involve increased regulation or banning of inter- or intra-island movement/trading.

Pollination

It is well known that natural ecosystems provide pollination services to crops and that agricultural intensification generally requires trade-offs with these services and with pollination of native plant species (Allen-Wardell, Bernhardt et al. 1998, Kleijn and van Langevelde 2006). The European honeybee is widely recognised for its contribution to the pollination of some agricultural plants. On KI, this relates mainly to broad-leaf pasture, canola, pulses and horticultural production, with cereals being wind pollinated. However, natural ecosystems support a diverse range of native pollinating insects that appear to provide good pollination services, which are less well characterised and generally underestimated. These pollinating insects include many species of flies, wasps and bees (some examples in Table 4), which regularly visit flowers and have the potential to pollinate them. Observations suggest that there are about 100 species of native bee on KI (the only introduced species is the honeybee), which nest either in dead wood or in the ground.

There are two main issues to consider with regard to wild pollinators and native vegetation management:

1) the crop pollination ES that can be derived from native vegetation
2) pollination of native vegetation as an ecosystem function

The degree of 'native pollination' of crops is yet to be fully understood and will vary with crop type, proximity of habitat to crop etc. However, there is clear evidence that there is a pollination ES provided by adjacent native vegetation to a range of crops across different environments and that pollinator density is a key driver of this effect (Blanche, Ludwig et al. 2006, Ricketts, Regetz et al. 2008, Arthur, Li et al. 2010). Importantly for KI, research on temperate Australian canola crops showed that densities of wild honeybees were greater at the margins of crops (compared to the centre) and positively correlated with good quality woody vegetation within 300 metres of crops (Arthur, Li et al. 2010). This study also found that collectively, hover flies and native bees were more abundant visitors than honeybees but were not as strongly associated with the woody vegetation likely due to the native bees being ground nesting. In the UK, nutrition of managed honeybees was positively correlated to the amount of grassland and broadleaf woodland around hives and negatively correlated with the amount of "arable and horticultural farmland" (Donkersley, Rhodes et al. 2014). Furthermore, landscape complexity and bee abundance have been correlated across many cropping systems (Kennedy, Lonsdorf et al. 2013). These findings highlight that different pollinator species have different habitat requirements and respond to landscape management in different ways (Greenleaf and Kremen 2006). Therefore, to inform vegetation management aimed at delivering pollination ES, research is required to tease out the specifics of these variables with regard to production of different crops adjacent to different suites of native plants. Some researchers are attempting to find reliable ways to assess the crop pollination potential afforded by various adjacent vegetation types e.g. see (Ricou, Schneller et al. 2014). Farming systems themselves, also appear to play a role in the efficiency of capturing the available pollination services of wild bees. For example, a large study assessed factors correlated with abundance and diversity of wild bees in 39 crops globally and found that both measures were higher in landscapes comprising more quality habitats and in organic or multi-crop fields (Kennedy, Lonsdorf et al. 2013). In agreement with the Australian canola study cited above, they found that bee diversity in conventionally farmed fields of low diversity were correlated with high quality surrounding landscape. Two key conclusions were that:

1) pollinator resilience will depend on maintenance of high quality habitat around farms
2) that local management practices may help to reduce the pollination trade-offs inherent in agricultural systems that are intensive monocultures

With regard to native plant species it is crucial that diverse pollinator populations are maintained, which essentially requires habitat protection for a broad range of pollinator species, which include birds, mammals and many species of insect. It is important to recognise that while many native plants have quite general pollination requirements (such as Mrytaceae) there are many that require a more defined pollinator suite and in some cases (particularly orchids) pollination may be highly specific. It is important to note that many native plants require vibratory pollination (commonly known as buzz-pollination) and on KI this can only be performed by a subset of native bees and highlights the need to maintain healthy populations of these native pollinators. The European honeybee cannot perform buzz pollination and cannot efficiently pollinate these plants although honeybees may still harvest the pollen these flowers use to attract their natural pollinators.

This also highlights the potential complexity of the biological trade-offs that need to be assessed and managed as part of a landscape-based ES approach. While honeybees are required for sufficient pollination of some exotic crops, they are likely to negatively impact on native ecosystems in numerous ways (Carr 2011, Glatz 2015). It should be considered that southern Australian native plants have coevolved with native pollinators, all of which have quite different biology to the honeybee. For example, no KI bee species forms eusocial colonies or forages throughout the year. A decision framework for formulating trade-offs in managing a species that is both agriculturally useful and ecologically deleterious was investigated for buffel grass (Grechi, Chades et al. 2013) and a similar approach could be useful for management decisions regarding such species on KI.

The health of honeybees is currently topical due to the threat posed by the parasitic Varroa mite (*Varroa destructor*), which has reduced wild populations where it has established. Additionally, the occurrence of 'colony collapse disorder' in the US and Europe has been linked to Varroa introduction although clearly there are also other interacting factors which are not yet understood. It was estimated that economic losses from the introduction of the Varroa mite to Australia would range from AUS$21.3-55.5 million per year (Cook, Thomas et al. 2007). This has focussed increasing attention on maintaining current pollination services and harnessing pollination services provided by species other than the honeybee; landscape management is increasingly seen as having a role to play in this regard. An example of a concerted pollination initiative is *The Integrated Crop Pollination Project* in the USA (ICCP 2015). With regard to biosecurity of honeybees, KI is far better prepared than other Australian regions due to long standing legislation and geographical isolation (Glatz 2015). This is also applies to the Asian honeybee (*Apis cerana*) which has now established around Cairns, Qld.

Salinity

The most serious changes that can occur in a landscape are physiochemcial changes, as they are seen as 'permanent' and generally they completely alter the associated biodiversity and productive capacity of affected land (Pisanu, Rogers et al. 2013). On KI and elsewhere in Australia, salinity is the most serious of such changes, particularly dryland salinity which is caused by significant removal of deep rooted, perennial native vegetation and/or its replacement by shallow rooted, annual plants (most often crops, pastures and weeds). This reduces the amount of water that is taken up by plants which causes the mean level of the water-table (which naturally rises and falls with seasonal rainfall) to rise, leading to the increased deposition of naturally occurring salt in upper layers of the soil or at the surface. This reduces and in many cases destroys productivity and/or existing biodiversity, which is replaced by far fewer species that are salt tolerant. This is most pronounced in low lying areas and has been clearly demonstrated in some parts of KI such as the Eastern Plains where many previously freshwater soaks and lagoons have markedly increased in size and salinity. This has in turn resulted in loss of much of the associated biodiversity in affected areas and marginalised associated agricultural land.

In 2000, it was estimated that almost 10,000ha were effected on KI (NDSP 2000) and this is expected to increase (Pisanu, Rogers et al. 2013). The only solutions that have provided mitigation at landscape level have been large engineering efforts such as drains (such as in south-east SA) and evaporation basins (e.g. Riverland). However, these are expensive to establish and maintain, and are associated with their own environmental problems. Given the small rates base of the KI council and the difficulty in remediating such land, the maintenance or cooperative reestablishment of deep-rooted, perennial native vegetation in such areas is likely to be the best long term solution especially in light of the other benefits discussed here. Technologies such as salt tolerant (perhaps GM) crops will also be important as they could reduce the area of agricultural land that is marginalised without requiring solutions causing further environmental damage or reducing tourist appeal e.g. salt drains and pipelines.

Biodiversity

The biodiversity of KI is better protected than other agricultural regions on mainland Australia, largely due to the significant natural vegetation remaining on a large portion of the island. KI displays quite a high level of plant endemism with ≈46 endemic taxa, representing ≈5% of species (Neagle 2002, Gillam and Urban 2014, Glatz 2015). However, KI also has a lot to lose and has significant challenges with 21% of flora species and 21% of fauna species (only one invertebrate assessed) classed as threatened, and with significant threatened flora in fragmented and degraded areas e.g. roadsides of the Eastern Plains (Pisanu, Rogers et al. 2013, Gillam and Urban 2014). These figures increase to 52% and 59% if 'rare' or 'near threatened' taxa are included. Native vegetation is crucial to broader biodiversity as it provides habitat, indeed clearance/fragmentation of vegetation is often cited as a key issue in species loss. Native vegetation is also important for regulation of ecological processes that maintain biodiversity such as maintaining water quality.

Researchers recently assessed whether certain landscape design principles would likely protect significant native biodiversity under models encompassing a range of future climates and land uses (Doerr, Williams et al. 2013). Interestingly, none of the currently applied principles they modelled were always effective but their 'aspirational' principle of ≈30% vegetation cover was reliable for improving biodiversity outcomes. KI currently exceeds this percentage (suggesting significant ongoing ES in this regard), however, this is principally due to large, intact conservation regions in the south and west of KI. Vegetation cover in the Eastern Plains and Dudley landscape is currently ≈27%, again occurring in the southern coastal belt. Other remnant vegetation in this region exists in long unburnt isolated patches associated with primary production and along roadsides (Pisanu, Rogers et al. 2013). There are already significant threats to biodiversity in these areas due to fragmentation and inappropriate fire regime and the same is true for parts of the north coast, west of Dudley Peninsula.

Biodiversity considerations raise issues of how landscapes are classified because biodiversity is highly variable in a landscape and cannot be traded between areas. Differing biotic communities occur across the landscape due to variables such as soil type, climate, aspect etc. Pisanu, Rogers et al. (2013) attempted to address this by analyzing vegetation cover for different soil types and reported that Dudley Peninsula had only ~16% cover on ironstone soils. These data suggest that with regard to landscape management, biodiversity protection can be achieved in significant parts of the island by protecting the integrity of the existing vegetation. However, in more degraded areas there are significant concerns that may be partly mitigated by targeted, cooperative (inter-stakeholder) revegetation. Elucidating the broad benefits and non-utilitarian values of native vegetation on KI are key aspects to maximizing protection of KI's biodiversity (see Fig 10), partly through realisation of shared benefits across stakeholder groups. However, it is crucial that vegetation management principles such as revegetation, are planned using landscape models that are relevant to local biodiversity and targeted to sustain the maximum biodiversity over the long term, rather than achieving an arbitrary level of average cover when considering the entire landscape. Furthermore, revegetation should target degraded, marginal, surplus and/or non-managed areas near primary production, rather than land currently sustaining primary production.

A recent NCCCARF report (Dunlop, Parris et al. 2013) listed three significant shortcomings to the development of conservation management plans tackling rapid climate change, *viz:*

1. lack of robust means to characterise ecosystem health and human activities in ecological terms
2. poor understanding of how society values biodiversity and other related concepts such as ecosystems and landscapes
3. poor policy mechanisms for definition and implementation of objectives that are ecologically sound and socially endorsed.

The authors also developed a prototype flow chart of questions/answers to help NRM planners set conservation management objectives. The three shortcomings listed above are all significant issues for KI, and as mentioned the island has more to lose than most areas with regard to biodiversity. The NRM board's On-ground works program has for several years applied a process aimed at selecting projects that contribute the most to landscape-level connectivity, patch size, threatened species habitat and site condition (G. Flanagan, pers. comm., 2015). This current approach may therefore provide the basis for a refined model with increased nuance with regard to ES delivery through on-ground works.

Biosecurity is a key consideration with respect to biodiversity conservation. I have mentioned above the need to understand what the major pest threats are likely to be for agriculture under rapidly changing climatic conditions. The same is true for organisms that threaten natural systems. As mentioned, agriculturally relevant invertebrates/viruses are usually largely confined to exotic hosts and generally do not impact the natural ecosystems significantly; thus they are largely an economic issue and not a direct concern in preserving biodiversity. However, introduction of exotic organisms that can thrive in land under native vegetation and are not subject to their normal controls are a major concern as they have the capacity to permanently alter ecosystems that have evolved over millions of years. The honeybee is an interesting example because it is beneficial to production of canola, pulses, fruit and vegetables but is one the most invasive and widespread species known, and is likely to negatively impact natural ecosystems on KI (Paton 1996, Neagle 2002, Goulson 2003, Celebreeze and Paton 2004, Paini and Roberts 2005, Singh, Levitt et al. 2010, Glatz 2015). In 2002 in NSW, invasion of natural ecosystems by honeybees was assessed as a Key Threatening Process to native biodiversity (Carr 2011).

It should be noted that our scientific understanding of our natural ecosystems has large gaps. Besides plants, the organisms that play key roles in maintaining ecosystem function are invertebrates, fungi and microorganisms. These groups also contain the most species diversity on land and in the ocean, however, many of the species are not known (Fig 5) and most are not well understood. KI's biodiversity is no exception and in recent years a range of new invertebrate species have been discovered on KI including an entirely new family of moth (the enigma moth) with an ancient association with *Callitris* (native pine) (Kristensen, Hilton et al. 2015) and a new genus of braconid wasp that parasitises it (unpublished data). This illustrates the scientific value of the intact ecosystems of KI, as well as being an indication of how much there is to learn in terms of ES delivery from native invertebrates, fungi etc. It should be noted that recent publicity surrounding the "KI Enigma moth" has brought global attention to KI and the quality of its ecosystems (e.g. Casey 2015, Hilton and Edwards 2015) which also illustrates the potential economic benefits from improving our understanding and protection of KI's unique natural heritage.

Currently, DEWNR can consider only the species contained in their own database amounting to some plants, birds and other vertebrates (and one insect) (Gillam and Urban 2014), which represent only a small proportion of the existing taxa. This is a scientific shortcoming given that much of the ES delivery and ecosystem functioning rely on taxa that cannot currently be easily assessed such as invertebrates, fungi and microorganisms (plants are also significant contributors). Furthermore, such taxa are likely to contain the best indicators for ecosystem function, validated examples of which are most desirable. This is because they are diverse and can have very specific niches or interactions with other organisms; they both support and rely on native vegetation and so are intricately linked to the population dynamics and overall well-being of plant species. It would be beneficial for DEWNR to investigate ways to tap into other large datasets (some of which are publically available) and ways to incorporate these data into their assessments and management plans. For example, the South Australian Museum contains many records of invertebrates etc. and resides in another state department. A national example is the Australian Faunal Directory (http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/afd/home).

There is significant current research aimed at developing high-throughput molecular assays to assess large numbers of species in environmental samples such as soil samples. This provides an opportunity for KI to link with such research to begin to harness these technological advances by making KI a focus of collaborative research projects that address environmental monitoring, particularly with regard to the assessment of management practices.

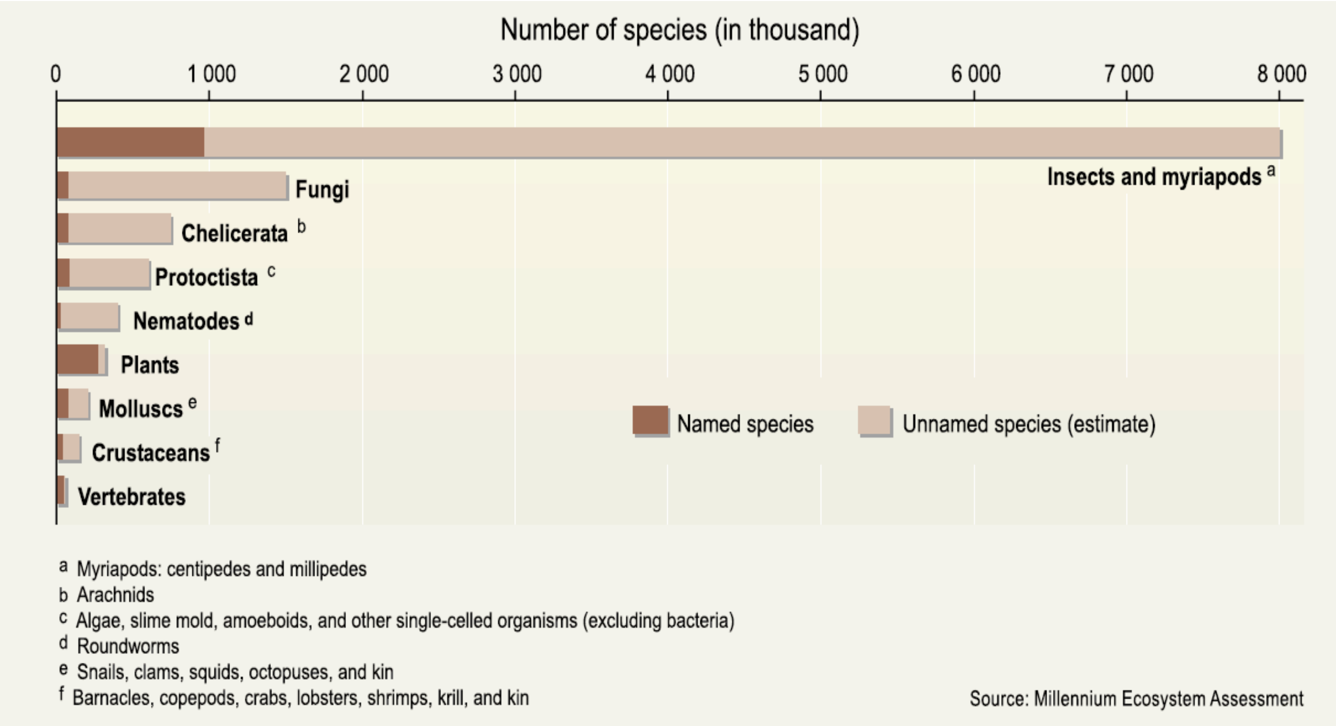

Figure 5. Breakdown of named and unamed species residing in various taxonomic groups (MEA 2005b). Most of the terrestrial biodiversity consists of invertebrates of which many are not known, whereas plants and vertebrates (birds, reptiles and amphibians are not shown) contain relatively few species and are relatively well characterised. In terms of understanding and capturing ES, this is a significant knowledge gap as many of the ES (or basic ecosystem functions) are regulated by invertebrates, fungi and microorganisms.

Another knowledge gap in for biodiversity maximisation is the population genetics of many island species. For example: overall levels of genetic diversity, the level of gene flow across the island, and the degree to which isolated populations are suffering genetic bottlenecks (an effect of population disturbance) are all important questions with regard to the adaptive capacity and resilience of the natural ecosystems (see Fig 6 below). Such information is crucial with regard to maximizing desired outcomes of conservation management decisions. The technology to assess these metrics is available but would again require collaboration with researchers in this field.

It may be an achievable goal to attain 30% native vegetation cover on Dudley Peninsula and & Eastern Plains (as defined by Pisanu, Rogers et al. (2013)) With regard to broad ES and biodiversity benefits, this would best be undertaken by revegetation or regeneration of targeted environmental associations in fragmented areas of these regions rather than increasing the current conservation areas that largely consist of coastal limestone habitats In particular those associations supported by ironstone soils would be preferable. This could be achieved through pilot projects delivering production and biodiversity ES in targeted collaboration with primary producers and council. This would obviously need to considered in the context of fire risk, however given that almost the entire landscape is highly flammable a relatively small increase in native vegetation cover (or improved quality of existing cover) is unlikely to significantly increase fire risk. This risk can be minimised by integrating revegetation/regeneration activities into the fire risk assessment process within the respective fire management plans.

In general, a combination of soil type, plant community and level/type of previous disturbance is intuitively a useful way to target areas for biodiversity related revegetation or regeneration, as the soil directly influences plant biodiversity through physical and chemical properties as well as containing the inherent potential to recover from disturbance through the soil bank.

Tourism & marketing

It is clear that the main draw-card for tourists on KI is the natural environment: the large areas of intact native vegetation, the coastal and marine environment, and the biodiversity they support being the most obvious features. This further contributes to the case that it is in KI's economic interest to maintain the integrity of the remaining ecosystems. KI's roadside vegetation is renowned and provides the ambience and uniqueness that is so important for the islands image as an intact environment that provides healthy ('clean and green') produce.

The abundance of KI endemic plants in some areas gives KI its own aesthetic and although this does not seem to be widely recognised on the island it is immediately obvious and remarkable to visitors who travel to observe the natural environment or have an interest in native plants. Some examples include: KI narrow-leaf mallee arbours, KI conesticks, KI gland-flower, round-leaved *Bertya*, KI riceflower, the *tateana* subspecies of yacca. This unique aesthetic should be promoted where possible in public spaces; this is to be contrasted with planting of exotic ornamentals in public spaces, which gives the appearance of so many rural mainland country areas that have little native vegetation remaining.

Additionally, the remaining native vegetation is crucial to marketing of KI food and wine because it suggests to consumers that the environment is 'pristine' and so the resultant produce is healthy. This is particularly so given that farming systems on KI are not significantly different to elsewhere. Additionally, the proximity of native vegetation to crops gives a 'clean and green' image to consumers as it insinuates care for the environment, integrated management systems and benign management practices. This also strengthens KI's brand in the sense that provenance and quality of food are key concerns for consumers interested in food and wine. Identification of benign/innovative farming systems with KI strengthens these perceptions and provides a talking point for publicity.

Therefore, there is not only an economic advantage provided to KI by native vegetation with regard to tourism and marketing but there exists the opportunity to derive new production, tourism and marketing opportunities from the incorporation on native vegetation into farming systems. Table 6 provides a theoretical example.

Social and Community Benefits

The social benefits of native vegetation are hard to define and somewhat personal. For many, the presence of vegetated landscapes is more about ambiance than commercial ES, biodiversity or ecological values, and the species that exist on the island are not well understood and/or of relatively little personal importance. This does not reduce the importance of these personal feelings however, the lack of appreciation/awareness could be considered a lost opportunity. It has been suggested that in the long term, a lack of appreciation for endemic biodiversity or for it having an intrinsic non-utilitarian values, will reduce the amount of biodiversity that is conserved (Fig 10 below).

A recent study in the USA attributed forest and tree effects to an air quality improvement of 1% (17.4 million tonnes) which accounted for estimated human health benefits of US$6.8 billion (Nowak, Hirabayashi et al. 2014). In the context of native vegetation-related ES on KI, it is interesting that most of this effect occurred in rural areas suggesting that proximity was important. Besides environmental/physical health advantages of native vegetation there is mounting evidence that a close connection with natural systems is related to mental well being, and that a disconnect from natural environments may compromise this (for a literature review see Maller, Townsend et al. (2008). The native biodiversity supported by native vegetation on KI is abundant and visible and the vegetation brings it into the proximity of people, be they local or visiting. This generally gives a feeling of environmental wellbeing, and is sought after by many.

It is noteworthy that a sound environment is cited by many recent immigrants to KI as a key reason for becoming resident, and is also cited as crucially important by most of the community, including those with intergenerational links to KI. Additionally, the natural environment is the focus of many in KI's artistic community. These facts point to native vegetation being important to the 'psyche' of the KI community, however, personal aspects of this are hard to define and there is significant disagreement about how native vegetation should be managed.

Perhaps the greatest social benefits largely flow from the impact of native vegetation on providing ES that facilitate a vibrant community which maintains significant numbers of primary producers that are resident property owners (through maintaining production options value), other businesses that provide support services to the community, and environmental integrity. The native vegetation of KI is able to be utilised for leveraging significant ES and providing marketing opportunities for tourism and KI produce, that captures and exploits KI's unique attributes i.e., natural ecosystems and cultural heritage. A key to maximizing these ES is to understand what is special about KI ecosystems, maintaining these unique aspects and putting them at the forefront of marketing in tourism and primary production. Currently, agricultural production systems and related businesses on KI are similar to those elsewhere and they are not key drivers of tourism compared to the natural environment. However, there are some exceptions to this that utilise unique aspects of the KI environment with value-adding, for example *Eucalyptus* oil production, a boutique spirit distillery, high quality seafood, and to a lesser extent marron farming.

ES associated with physical properties of native vegetation are more obvious and widely understood. Much of the remaining vegetation on farmland is there due to its use as a shelter-belt, primarily for stock shelter or as a crop wind-break, the latter being important for KI given its coastal weather. Indeed, a historical example of landscape management on KI is the numerous plantings of exotic trees (especially *Pinus* spp.) as wind-breaks around dwellings and farm infrastructure. Native species can perform the same function and should be utilised in the future, perhaps designed to produce a range of ES (e.g. combined wind-break and honeybee forage). In summer months, native vegetation also provides shade and breaks dust movement. Given the moderate climate of KI and the relatively low number of days with extreme heat, the placement of vegetation to shade dwellings in summer can largely remove the energy requirements needed to actively cool dwellings.

Some authors have argued that by taking a social ecology perspective to landscape resilience a more nuanced consideration of the dynamics of human-environmental interactions can be achieved leading to improvements in how scientific and biological data are accepted and translated by the community into resilience outcomes (Stokols, Lejano et al. 2013). Regardless of the exact method there may be merit in examining social attitudes to the environment, adaptive capacity, resilience etc., as well as methods of improving understanding of the complexity and science of natural ecosystems, and the complete range of ES they offer and support.

Contributions to landscape adaptive capacity and resilience

In addition to ES, the concept of resilient landscapes has become a focus due to the weight of scientific evidence for rapid warming of the globe (IPCC 2014). In the context of this report I define resilience of a terrestrial landscape as *the capacity of the landscape to continue to provide ecosystem services and support high levels of endemic biodiversity under changing physical, socio-economic and political drivers.* The way in which vegetation contributes to ecosystem resilience was discussed recently by Pisanu, Rogers et al. (2013), where resilience was presented as the capability of an ecosystem to remain below ecosystem-process damage thresholds (as per King and Hobbs (2006)). Standish, Hobbs et al. (2014) reiterated that resilience is related to an ability of an ecosystem to remain within disturbance/damage thresholds and suggested that resilience can be assessed by detecting changes to the functional diversity of the ecosystem, indices of which can act as proxies for resilience if direct measures are not available.

A relatively lower degree of vegetation degradation is associated with damage to biotic interactions that can cause functionality of ecosystem processes to cross a 'biotic' threshold. It was suggested that beyond this biotic damage threshold (which presumably has been exceeded in many areas), manipulations to vegetation are required (beyond removal of degradation processes) to recover original ecosystem integrity. At this time, abiotic interactions may be damaged but still able to recover without significant manipulation, however, once increased degradation causes significant damage to abiotic interactions, an upper threshold of ecosystem process damage is reached. Beyond this upper threshold, ecosystem processes may become non-functional and require manipulation of biotic interactions to reinstate integrity of basic processes. While the above characterisation of resilience was discussed in a context of conserving biodiversity, a similar model could be proposed for the resilience of the ES delivered by biodiversity. Thus, in the context of ES delivery, native vegetation contributes to resilience by supporting ecosystem processes that facilitate ES (or mitigating damage to them). General principles are the same as for pest management and biosecurity; the more 'non-managed' area that is under 'good quality' native vegetation (see below for quality characteristics), the greater the resilience in provision of associated ES and correspondingly less requirement for management to preserve or restore these ES.

It is clear that once native vegetation is lost or compromised, it is often extremely difficult to recover the full benefits and management options are generally reduced. Even with long-term and active restorative management (for which resourcing is unlikely), infestation by exotic species is unlikely to be eliminated. When considering resilience, it is important to understand what attributes constitute 'good quality' native vegetation. These include:

- displaying (or having the capacity to regenerate through soil seed-bank) biodiversity near to the ecosystem it was derived from in an undamaged state,
- having none (or low levels) of exotic infestations,
- generally being dense except through natural attrition through aging,
- having a soil seed-bank that has the capacity to regenerate a high number of naturally occurring species without favouring increase in exotic infestations,
- being of sufficient quality to support diversity at various levels (see Table 5 below).

There are obvious spatial and temporal aspects to these attributes. For example, spatial aspects such as the size of a given patch of vegetation, the soil diversity within it, its interconnectedness/isolation with respect to other patches, surrounding land use etc. all influence its ability to provide ES, adapt to disturbance/change and support landscape level biodiversity. Temporal aspects such as its age, disturbance frequency, and integrity of the seed-bank, can impact similarly. Thus, good quality vegetation is that which has the capacity to support high levels of native biodiversity, has low levels of exotic infestation, can regenerate much if its original biodiversity and contributes to overall genetic, species, population and/or ecosystem diversity (Table 5).

There is an increasing understanding of the way that biodiversity at various scales (including landscape) acts to sustain ecosystem functionality and there is increasing discussion about this in the scientific community (Mokany, Burley et al. 2013, Pasari, Levi et al. 2013). This concept effectively links biodiversity to resilience and suggests that maintaining diversity and population integrity of native plant species (and thereby reliant taxa) is important for maintaining ecosystem functionality. Pollination is an ecosystem function for which this concept is relatively intuitive. With regard to the potential ES that can be derived from native flora and fauna, an important consideration is to level of diversity is therefore likely correlated to the ES options available through adaptive management. In other words, there should be an aim to maximise ES for current conditions and industries but prevent foreclosure management options for new industries, under changing climatic conditions, and also other changes such as those related to legislation, economy, consumer preferences etc.

In recent years, the word biodiversity has achieved widespread use in the general populous; it now has a variety of usages and is commonly used as a proxy for "flora and fauna" without necessarily encompassing diversity. However, it is important to realise that the crux of the concept of biodiversity is diversity (which could also be expressed as 'variation'). In biology, the concepts of diversity and adaptive capacity are closely intertwined, and are the basis for evolution through natural selection.

Further key considerations are that diversity is required at all biological levels (from genes to ecosystems) and that diversity is maintained over a sufficient distribution. With regard to ES provision and landscape adaptive capacity/resilience, these biological levels are important for different reasons (Table 5) and therefore should be inherent in plans aimed to protect and exploit biodiversity. For example, genetic diversity relates to adaptive capacity of organisms, while species diversity relates to interactions producing ecosystem function. These levels are not independent, for example, genetic diversity of a species allows it to adapt and survive to changing conditions thereby making continued contributions to ecosystem function. Simply considering the species richness of a landscape does not allow information from other biological levels to be utilised in NRM planning.

Table 5. The importance of biodiversity (variability) at various biological levels (MEA 2005b).

Level	Importance of diversity/variability	Importance of quantity & distribution
Genes	adaptive variability for production and resilience	local resistance and resilience to environmental change, pathogens, and so on
Populations	different populations retain local adaptation	local provisioning and regulating services, food, fresh water
Species	the ultimate reservoir of adaptive variability, representing option values	community and ecosystem interactions are enabled through co-occurrence of species
Ecosystems	different ecosystems deliver a diversity of roles	the quantity and quality of service delivery depend on distribution and location

If a simplified metric is to be utilised for management decisions then it may be wise (given current knowledge and resourcing) to concentrate on conservation of the highest order unit (ecosystems) because maintaining a diversity of ecosystems in good condition and over sufficient should contribute to preservation of finer-scale diversity. Further, different ecosystems (or vegetation associations) have been defined on KI for some time now (Robinson and Armstrong 1999, Willoughby, Oppermann et al. 2001) so there is existing data that can be used to assess ecosystem units with regard to maximising their diversity.

The way vegetation impacts the landscape is not always obvious and can be surprising in scale of the effect. A well-known example is the contribution of global vegetation to reduction of atmospheric carbon and increase in oxygen levels. In addition to biodiversity within habitats, the extent of vegetation in a landscape can impact on climate across multiple scales. MEA (2005a) suggested that landscape-level vegetation effects can substantially alter climate at a local-regional scale. Land areas >10 kilometres in diameter with lower albedo (solar energy reflection) and higher surface temperature than neighbouring patches, create cells of rising warm/dry air above the patch (convection). This air is replaced by cooler/moister air flowing laterally from adjacent patches (advection). Climate modelling of this effect in WA showed that the replacement of native heath vegetation by wheat would increase regional albedo. This was predicted to increase the level of convection over the native heath (which is dark, more solar-absorptive and therefore warmer) drawing more moist air from the surrounding wheat crops. The net effect was predicted to be a 10% increase in heathland rainfall, and a 30% decrease in rainfall over crops. Regardless of the real effects, this example illustrates the interconnectedness of environmental processes, how accumulative actions can increase the scale of impact, and the need to fully account for ES effects of individual management practices on entire ecosystems.

To summarise, fully accounting for the range of ES supplied by native species may assist us in managing landscapes to maximise their adaptive capacity and resilience. This is important to maintain maximum flexibility to respond to change. In recent years climate change has become a focus that has led to a deeper questioning of ES, however, landscape resilience and adaptive capacity maximises the ability to respond to a whole range of natural and anthropogenic perturbations. For KI, this adaptive capacity will aid in coping with change by:

- aiding in maintaining production levels in current systems, potentially reducing inputs and maintaining community integrity through healthy primary production and tourism sectors,
- providing flexibility to adapt to changing climate with new crops/production systems combined with suppression of new pests (i.e. adaptive capacity of landscapes to a range primary production with desirable attributes,
- maximise economic benefits of natural vegetation that is still abundant (e.g. salinity prevention, tourism, pest suppression etc.),
- maximise future ecotourism opportunities which should involve innovative primary production,
- maintain functional integrity of unique KI ecosystems, their associated biodiversity and the ES they support.

Threats to ecosystem services provided by native vegetation on KI

Threats to native vegetation and associated ES on KI appear to related to four main issues, which are discussed below, *viz*:

- direct vegetation disturbance mechanisms
- rapid climate change
- non-recognition of full benefits (and shared benefits) and trade-offs of ES
- capacity of regulatory bodies to characterise and manage ES adequately i.e., research, resourcing, planning, policy, legislation, implementation

Disturbance Mechanisms

Disturbance of native vegetation can take many forms and act over different spatial and temporal scales. They are not all necessarily detrimental in all cases although most have the capacity to reduce floral biodiversity. Some processes such as clearance and salinity have obvious and broad effects, while other mechanisms such as climate change and inappropriate fire regimes produce changes that may be subtle in that they do not result in obvious loss of floral biodiversity over short time-frames, but likely cause significant (perhaps chronic) changes to ecosystem functioning as exposure increases/changes.

It is intuitive that ES derived from native vegetation will decrease or be qualitatively degraded proportionally with the degree of vegetation degradation at a landscape scale. However, it is also intuitive that impacts on stakeholders will be greater the closer or more tightly linked they are to the source of a disturbance process/event. For NRM purposes, disturbance processes and resultant impacts must be considered at a landscape level because they generally accumulate across increasing area, effects of many processes are inter-property, and it is likely that there is an landscape area threshold above which damage is significantly increased and/or mitigation cost is significantly increased or no longer possible.

A good example of cumulative impacts of deleterious processes and the need for a landscape approach, is well illustrated by Fig 6 which shows how genetic bottlenecks in native plant species can be produced by disturbance caused by ecosystem fragmentation and climate change, leading to reduction in fitness (and hence resilience) across a landscape. This reduction in genetic diversity in turn can reduce the resilience of the landscape and its ability to deliver ES. While this particular scenario relates to plant populations, these effects of population fragmentation and reduced genetic variability are generally applicable to most sexually reproducing organisms (such as pollinating insects).

In an agricultural landscape, disturbance events are relatively common and are often management requirements such as harvest, insecticide use etc.) In such systems, non-crop vegetation is crucial for supplying pest management benefits as part of an integrated approach (see crop wheel in Fig 12). Populations of beneficial organisms that can positively impact on production systems are a function of relative levels of immigration/emigration and births/deaths of beneficials occurring in crop and adjacent non-crop vegetation (Schellhorn, Bianchi et al. 2014). Disturbance processes directly affect these metrics and the provision of beneficial invertebrates to production systems is expected to be more efficient under a scenario of reduced disturbance (Fig 7). This illustrates a general principle that disturbance events to which native vegetation (and supported biota) are not well adapted (e.g. pesticides, clearance), will disrupt dynamics of reproduction and dispersal at a population level and reduce the effect of associated ES in agricultural systems.

The frequency, nature and context (including timing) of vegetation disturbance processes are likely to have significant effects on the degree of undesirable and beneficial outcomes. Fire is a good example (see below). Generally, low frequency disturbance of a given type occurring in areas that are not heavily subjected to subsequent pest pressure and/or other disturbance types are unlikely to cause significant changes to biodiversity and may be beneficial. However, increasing the frequency of disturbance can be problematic as it favours species that are competitive colonisers (a common characteristic of weeds) at the expense of species dominant in the medium to long term and increases the time over which pests can easily establish. Frequent disturbance processes that continually expose the soil seed-bank are likely to be deleterious as they may reduce the restorative capacity of the seed-bank and provide increased opportunity for exotic seed to be introduced (see below). This leads to changes which are extremely difficult to counter, may increase the effects of further disturbance, and are likely to impact over the long term, particularly as resources for successful management of weed incursions over medium to long term are generally inadequate.

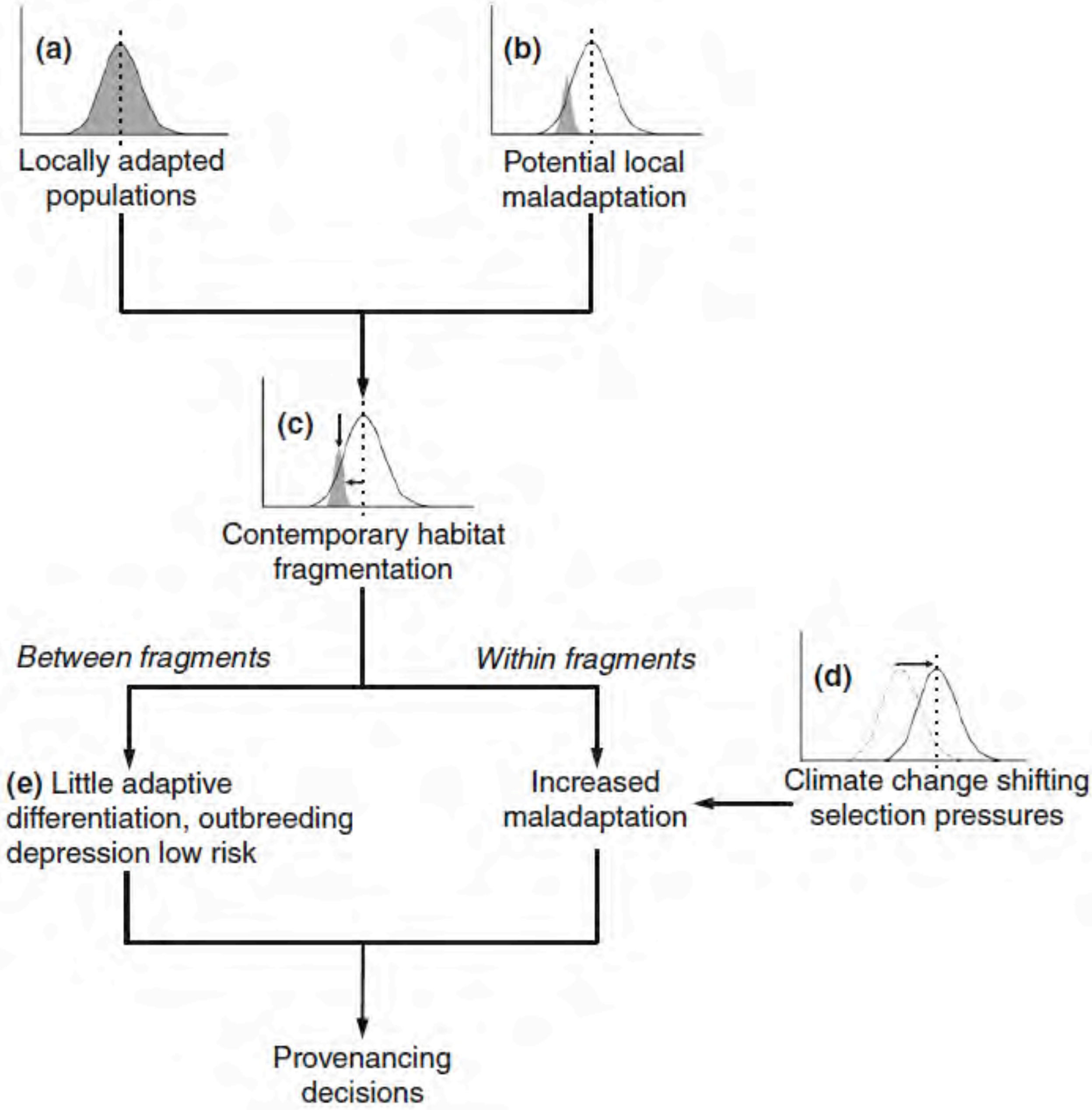

Figure 6. Genetic bottlenecks can be produced by disturbance (in this case clearance/fragmentation) which can cause maladaptation of plants to their environment and can be exacerbated by significant physical or biological selection pressure (in this case due to climate change). Existing plant populations can either be well adapted to local conditions (a) or maladapted due to previous pressures such as historical clearance regimes (b), and maladaptation can be increased due to genetic effects caused by more recent fragmentation (c) reducing the resiliency of the population. When climate change places further selection pressure on these fragmented populations (d) this can lead to increased maladaptation of the population a reduction in the differential adaptive capacity of various fragments (e). Therefore, seed provenancing for revegetation should attempt to maximise adaptive capacity by utilising regional population fragments to attain maximum genetic diversity while reducing potential for outbreeding depression (e) that can be caused by introduction of genetic material adapted to a different region. Here, simplified fitness landscapes indicate the relationship between a landscape's fitness optimum (solid curve with dotted line at the fitness peak), fitness of a local (isolated) population (shaded area), and fitness optimum of the recent past (dotted curve in (d)). Number of genotypes is contained on X-axes and Y-axes represent fitness levels. From Breed, Stead et al. (2012).

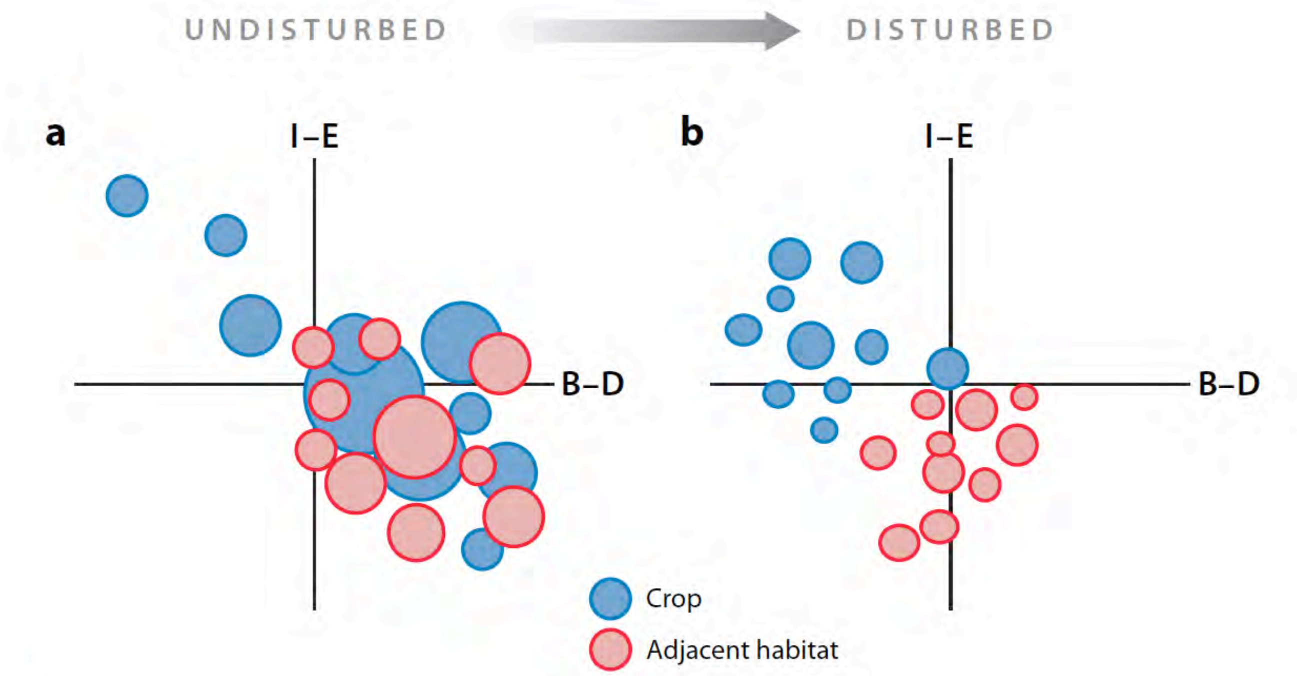

Figure 7. Theoretical relationship between disturbance and pest management ES provided by native vegetation; disturbance reduces beneficial invertebrates supplied by native vegetation into production systems. Populations are a function of the difference between births (B) and deaths (D) at a given site, and immigration (I) and emmigration (E) of an invertebrate population. The size of each circle represents number of beneficial arthropods in a sampling event (i.e. the potential ES in native vegetation, and the supplied ES in crop vegetation). An ideal landscape for providing ES through beneficial invertebrates (a) shows increasing populations in crops and native vegetation (i.e. net population increases B>D, and export of invertebrates and E>I) due to local processes. Disturbance events (b) such as insecticides cause high mortality (D>B) in crops and these populations require immigration from native vegetation (I>E) for in-crop survival. The disturbance has caused in-crop population units to shrink and cluster in the top left and have effectively become sinks for beneficals. Disturbance such as insecticide can also reduce beneficial populations in native vegetation through mortaility which is indicated here by smaller circles that have moved left on the B-D axis (i.e. ratio of births to deaths has decreased). From Schellhorn, Bianchi et al. (2014).

Clearance/Fragmentation

Clearance has long been recognised as most serious threats to landscape-scale ecosystems because apart from removing most of the biodiversity at the site of clearance, there are a range of potential downstream problems, for example:

- ecosystem fragmentation reduces ecosystem resilience/adaptive capacity adaptation (e.g. through preventing gene-flow)
- physicochemical changes (such as salinity) in prone areas
- increased land for establishment of pests/diseases (in unmanaged areas)
- erosion
- species loss
- reduced ES provision

One point that should be considered in landscape management is that natural (or sustainably managed) systems are generally worth more money per area in total benefits than those that are more highly modified or non-sustainably managed (Fig 8). Thus, the clearance of good quality native vegetation is likely to reduce the total benefits provided to society by the land although benefits to a sub-set of individuals may increase. Although such a study has not been conducted in Australian mallee systems, this phenomenon has been demonstrated across a range of landscape use changes in various countries (Fig 8) and there is no obvious reason to believe that this principle should be different on KI.

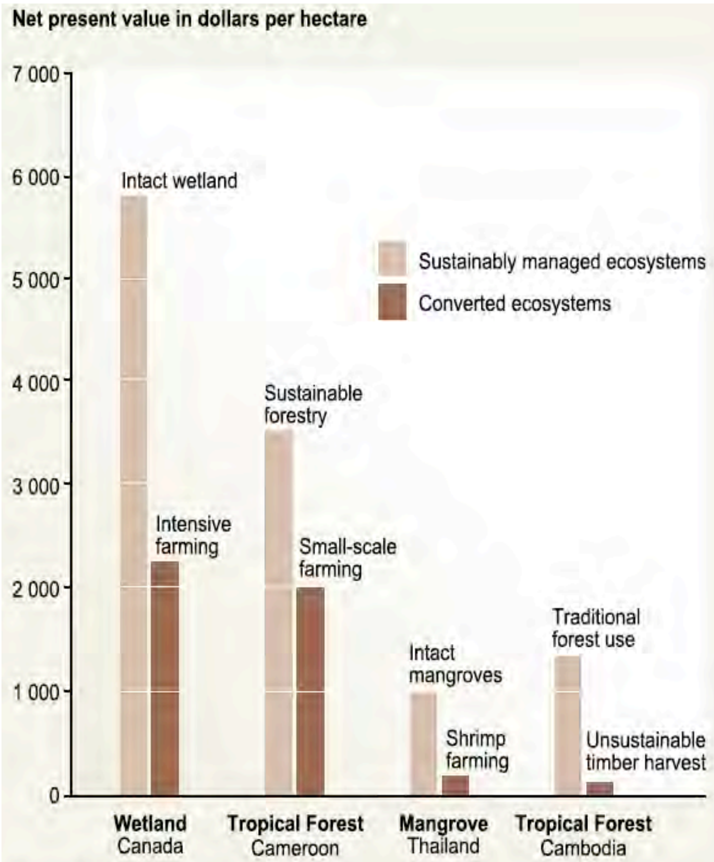

Figure 8. Loss of total economic benefits from conversion of ecosystems from natural or sustainably managed to simplified or unsustainable ecosystems. This correlation is demonstrated for various conversion activities across different ecosystems occurring in Canada, Cameroon, Thailand and Cambodia (MEA 2005a).

Adverse outcomes of widespread clearance have been recognised at a government level for many years and ultimately led to the introduction of the Native Vegetation Act in 1991, which aimed to maintain native vegetation at or above 30% landscape coverage (DEH 1991). This legislation formally protects ~45,000 acres of native vegetation on private land not under state heritage agreements (G. Flanagan, pers. comm., 2015). In 1992, the State moved to increase the level of protection for the highest value ecosystems through introduction of the South Australian Wilderness Protection Act (Government of South Australia 2011); that there are five of the associated Wilderness Protection Areas on KI is a testament to the significant natural heritage values of the island. There is little doubt these pieces of legislation have been beneficial to KI ecosystems, although it should be recognised that most clearance on KI occurred in the years following the soldier settler scheme (largely prior to 1970) (Fig 9).

It should also be recognised that much of the arable land has been highly fragmented and the larger intact areas of the south and west occur on limestone which is of limited use in farming (particularly cropping). Mitigative ES provided by native vegetation (primarily for erosion and riparian management) have also been recognised by some primary producers and delivered to interested parties through programs such as Landcare.

The SA Native Vegetation Act has attracted some controversy on KI with regard to inhibiting the ability of primary producers to effectively manage their properties, many of which contain native vegetation. Additionally, it has been cited by political figures as the primary cause of the severity of large fires on KI in 2007 (Bates 2008, Pengilly 2008), despite a lack of hard evidence that it had any effect and the involvement of other significant drivers such as unprecedented drought conditions, severe and unpredictable local weather characteristics (Peace, Mattner et al. 2011, Peace and Mills 2012), and loss of the majority of the area through back-burning operations.

As Fig 9 shows, the eastern and central parts of KI were fragmented almost to their present level by the late 1960s and in contrast to many other areas, there has been little clearance since then. While the latter fact is remarkable, the clearance pattern means that there are long-standing issues with landscape degradation on non-managed land that is not under protection, particularly on the eastern plains and cleared areas of the Dudley Peninsula. Drivers of this degradation in these areas were recently discussed in Pisanu, Rogers et al. (2013). Because there are a range of ecosystems on KI that are much smaller than the total landmass and generally clumped in distribution, the clearance pattern also means that some ecosystems are in good condition (e.g. *Eucalyptus diversifolia* associations on limestone) but some are now highly fragmented (e.g. *Eucalyptus cneorifolia* associations of Dudley Peninsula) (Robinson and Armstrong 1999, Willoughby, Oppermann et al. 2001, Pisanu, Rogers et al. 2013). Indeed, despite the 40% cover of native vegetation on KI, several floristic associations have been degraded to such a degree that some of the associated plant species are now only (or primarily) found in roadside reserves (e.g. plains of MacGillivray and Haines). Some of these roadsides are weed infested and disturbed at a high frequency. Species restricted to these areas rely on the Native Vegetation Act and Council management considerations rather than intact ecosystems for their protection.

Germination analysis of soil seed-banks from small, long isolated, 'senescent' patches dominated by *E. cneorifolia* revealed that although the seed-bank had not been recently or frequently disturbed and seed of native plants (some rare) were still present and viable, there were invariably exotic species (mainly grasses and daisies) present presumably due to the surrounding land use (Rawson, Davies et al. 2013). The study analysed 10 patches and found the most commonly germinated species (830 individuals) was an exotic weed (*Isolepis marginata*); 26 exotic weeds from10 families were germinated (1176 individuals) while 65 native species from 35 families (1391 individuals) were germinated. Therefore, weedy species were abundant and contained considerable diversity indicating that seed-banks were significantly compromised and that pest-management values of these patches may also have been reduced. Further, while rare plants may be germinated from the seed-bank, the vegetation overall would still require management to prevent further degradation of the seed-bank with respect to the ratio of rare/native seed to exotic seed. This illustrates how fragmentation can impact on areas even though they may not have been subject to frequently disturbance

Off-target effects of agrichemical use

It has long been recognised that there is often off-target environmental damage associated with the use of agrichemicals (particularly herbicides and insecticides) and fertiliser, and this is one reason for the environmental and ES trade-offs associated with agricultural intensification. There has been recognition of this on KI, and has been specifically mentioned in the context of increasing broadacre cropping on the island (Dohle 2013, Pisanu, Rogers et al. 2013) although aerial spraying of insecticide/miticide is used in pasture management.

The effects of herbicide drift on native vegetation are obvious, resulting in death or reduced health of affected individuals. As for most agrichemicals, the area over which there is an effect can be increased by contamination of water-courses. Insecticides are generally indiscriminate and will kill insects that encounter them in sufficient concentration (in some cases effective doses can be very low). Soluble fertilisers by their nature are immediately available to plants, however, they are difficult to apply in sufficient quantities that give significant yield advantages without excess. Being soluble, these nutrients are readily transported by water into water-courses and the margins of agricultural land. Contamination of water-courses with agricultural nutrients is linked to outbreaks of toxic blue-green algae. Nutrient run-off is also often responsible for allowing weed infestations to flourish in roadside vegetation. On KI bridal creeper and bridal veil (WoNS) can outcompete native vegetation at the margins of agricultural land but are far less competitive elsewhere. All of these effects amount to forms of disturbance, the outcomes of which have been discussed in detail above.

Therefore, off-target effects of agrichemicals have the potential to reduce agricultural ES by:

- directly killing beneficial insects such as pollinators, predators and parasites (Table 4)
- directly killing plants that support these beneficial species
- reducing integrity of surrounding vegetation through promoting weed growth
- reducing water quality through contamination and/or promotion of algal blooms

Inappropriate Fire

Fire is a natural and important part of KI ecology with many species displaying evolutionary adaptations to fire and/or requiring it to maintain healthy populations. However, when fire variables move outside of the thresholds to which the biota is adapted there is the potential for species loss or decline. While there is a reasonable understanding of some aspects of fire ecology for some species such as age thresholds, regeneration time, germination requirements etc., we still lack a detailed understanding of how intertwined communities of plants, animals and microorganisms respond to different fire variables, and how their interactions (e.g. pollination) are affected. As a very simple example, several studies examining the effect of fire on fruit production in Proteaceae (an important family for KI) produced different results which were postulated as being due to variation in fire intensity (Penman and Penman 2010).

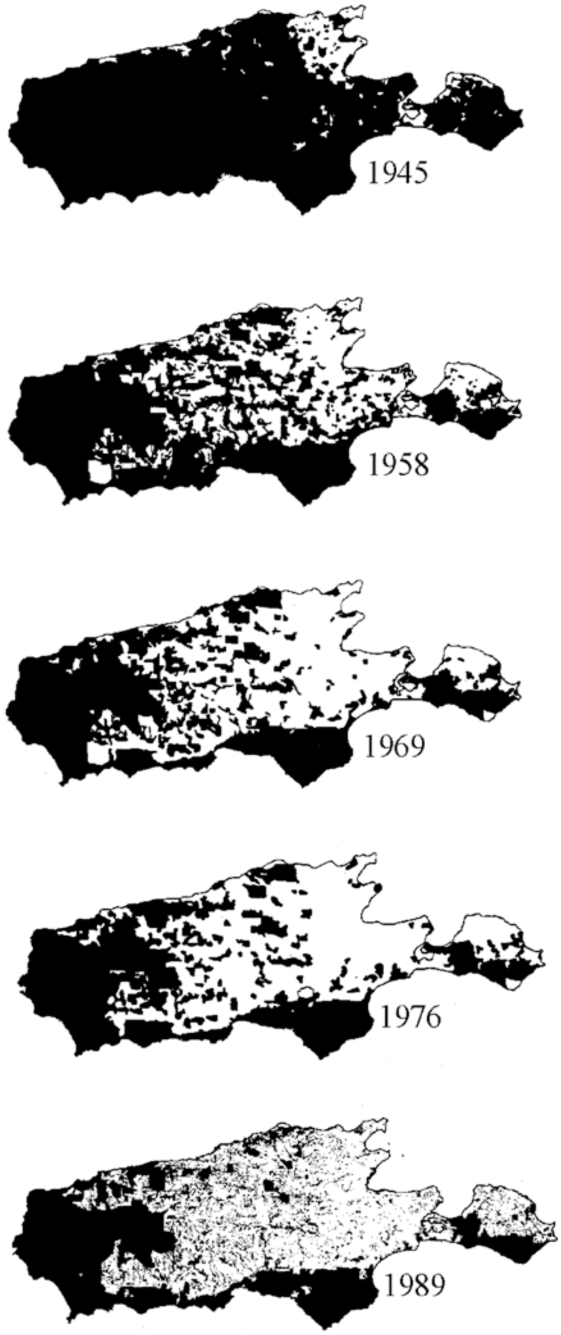

Figure 9. Vegetation coverage on KI at selected time-points between 1945 and 1989 (Robinson and Armstrong 1999). Most clearance was associated with the soldier-settler scheme in the years following World War 2 and clearance rate has significantly decreased since the 1970s. Mallee communities on the limestone soils of the south and west coast and reasonably intact, while plant communities of the east and north are now highly fragmented subject to significant exotic introductions. Improved resolution of vegetation mapping for 1989 allows smaller patches of vegetation to be displayed.

The most obvious concern for native vegetation is fire that is either too frequent (leading to insufficient regeneration) or too infrequent leading to loss of reproductive capacity in the seed-bank. In the highly fragmented areas of the Dudley Peninsula and Eastern Plains there is concern that fragmentation and resultant long-term inhibition of fire has reduced the capacity of the remaining fragments to regenerate some plant species, particularly those that have become rare due to habitat loss. Thus, the KI Eastern Plains Fire Trial was established to investigate fire as a regenerative tool although that program is not currently active. However, its establishment demonstrates concerns about fires that are too infrequent although it should be noted that the upper age threshold for KI ecosystems is not well characterised and is likely to be well beyond 50 years;

several rare insect species on KI are associated with areas that are long unburnt (Glatz, Leijs et al. 2015, Kristensen, Hilton et al. 2015). Lower thresholds are less variable and easier to define, generally relating to seed production. Upper thresholds relate to the regenerative capacity of the seed-bank and/or the visible level of biodiversity present each of which may vary significantly over time depending on environmental factors such as soil, climate, aspect, fire history etc.

In recent years the use of fuel reduction and asset protection burns in public conservation areas, has increased (DEWNR 2009, KIDBPC 2009). While it is realised that this approach requires burning at a frequency that will likely reduce biodiversity within the treated areas (KIDBPC 2009), fire managers regard it as an appropriate tactic for reducing intensity and spread of large fires to reduce the area being burnt in single large events. The merits of the approach are still being debated in the science community (Penman, Christie et al. 2011, Penman, Collins et al. 2013, Enright and Fontaine 2014, Penman, Bradstcok et al. 2014) and fire managers are assessing the effectiveness of fuel reduction burns (A. Howard, pers. comm., 2014). It should be noted however, that two recent studies both suggest that concentrating fuel reduction in close proximity to an asset is more effective and economical than treating larger areas that are further from the assets (Enright and Fontaine 2014, Penman, Bradstcok et al. 2014). It is possible that adverse ecological impacts, relative lack of effect, and/or cost of large prophylactic fuel reduction burns within conservation regions may well see them reduced.

Other ecological concerns potentially associated with fuel reduction burning in high value conservation areas include:

- weed introduction or spread: potentially resulting from construction of fire breaks and/or prior seed-bank contamination
- *Phytophthora* introduction or spread: associated particularly with the use of earth moving equipment but also through movement of vehicles and people (also associated with other management such as road maintenance)
- erosion: this is associated with most processes that remove vegetation. In a study of prescribed burns in the Mount Lofty Ranges, researchers found only minor erosion and suggested that fire intensity was a bigger factor than slope (Morris, Bradstock et al. 2014).

It is clear that further research needs to be conducted and that consideration needs to be given to the use of fire as a biodiversity management and asset protection tool. In that light, the prescribed burn zones are very useful for research purposes and should be utilised to understand the effects on fire on KI ecology and provision of ES.

Physiochemcial changes

The primary physiochemical threat to native vegetation is salinity, which was discussed in detail with regard to the ES provided by native vegetation (see above). Dryland salinity is usually exacerbated by the loss of deep rooted native species, and resultant saline conditions produce long term changes to associated plant communities characterised by species replacement and much reduced diversity (Pisanu, Rogers et al. 2013). Another physiochemical threat discussed above is the change in soil nutrients often found at the margins of primary production or in contaminated water-courses. Soil acidity and non-wetting soils are also physiochemical issues but are largely problematic for agricultural production rather than native vegetation, and are generally treated with lime and clay, respectively.

Weeds, pests and diseases

Biodiversity threats associated with weeds, pests and diseases have long been recognised. It is of note that the MEA biodiversity synthesis listed invasive alien species as the main cause of island extinctions over the past 20 years and the second leading cause in freshwater habitats (MEA 2005a). KI has15 wetlands considered to be nationally significant in the Directory of Important Wetlands in Australia and New Zealand Environment Conservation Council (Neagle 2002).

With regard to native vegetation, there are three main concerns regarding disease (1) the disease itself (usually a microorganism), (2) disease vectors (often insects) and (3) loss or disruption of species that underpin plant reproduction and ecology e.g. pollinators, fungal associations etc. *Phytophthora* is a well-known and established pathogen on KI, which apart from infecting native species, now requires significant management effort that impacts on most activities in affected areas. Myrtle rust (*Puccinia psidii s.l.*) is a current and obvious threat that is not yet present on KI and has been declared a Category 1 EPP by PHA (PHA 2014). It was first detected in Australia in 2010 at a nursery on the central coast of NSW and has now spread along the coast to Qld and Victoria (Pegg, Giblin et al. 2014). Myrtle rust infects many members of the plant family Myrtaceae, which on KI contains the native genera *Eucalyptus, Melaleuca, Callistemon, Leptospermum and Calytrix*, among others. In Qld alone, 48 myrtaceous plant species are considered highly or extremely susceptible; this information is not known for KI. Of further concern is that like all rusts, the spores are easily spread by wind, water and animal vectors (particularly insects) and rust diseases are notoriously difficult to contain; a good model for this on KI is bridal creeper rust (biocontrol agent) which is now present across most of KI due to human-aided spread and wind.

This example highlights the importance of a well-resourced, strong and effective biosecurity program for KI in terms of direct agricultural production and environmental benefits, and for broader economic reasons such as tourism appeal of the island. This is particularly so given that insufficient resources are available to eradicate or significantly control a new exotic outbreak, particularly a microorganism or insect. Additionally, myrtle rust highlights the need to prioritise key biosecurity concerns, assess (ahead of possible incursions) the nature and scope of their threats to KI biodiversity and industry, understand their routes of entry, and design appropriate monitoring and eradication/containment protocols.

Rapid climate change

There is much discussion about the ways that rapid climatic changes will impact plant and animal species. The most common concern is the ability of many species to adapt to new conditions and/or alter their range (usually by changing latitude or altitude) to reduce the climatic differential. Those with limited adaptive capacity (a low adaptation threshold) are likely to become extinct or undergo reductions in population size or range. Because KI is a relatively small, landmass with limited latitudinal or altitudinal span, there is concern that the opportunities for a given KI species to alter its range are relatively few and natural migration of other species to the island may also be limited. As discussed above, high levels of biodiversity are associated with multi-functionality and resilience of ecosystems and therefore climate change may cause reductions in ES through reducing biodiversity. A further concern is that increased temperature will change taxonomic and developmental profiles of diseases and insects that impact on native plants (herbivores, pollinators, disease vectors etc.), which will cause changes to the dynamics of the associated interactions in ways that are not easy to predict. For example, it has been postulated that drier conditions could increase susceptibility to existing diseases such as *Phytophthora,* through drought stress on susceptible plants (Singh, Davey et al. 2010). Other climate-associated changes such as aridity and/or reduction in available ground water are possible threats to native plant biodiversity (Barron, Froend et al. 2014).

Modelling is currently under way to try and understand which areas of KI are likely to act as 'climate refugia' i.e. where the highest level of biodiversity will likely to be preserved under a various climate scenarios. The purpose of this is to provide information to facilitate management of native vegetation to minimise species loss. This is a common approach to predicting and minimising biodiversity loss, however, there is still significant scientific shortcomings in our understanding of how to assess refuge quality at the species and community levels. It was suggested that these need to be overcome for refugia of this type to be truly useful management targets for conservation activities mitigating climate change (Reside, Welbergen et al. 2014). These authors listed key properties of refugia that promote the persistence of species under climate change, *viz*:

- spatially available to species under threat
- capacity to buffer the species from climate change
- capacity to sustain long term population viability and evolutionary processes
- capacity to minimise deleterious species interactions

They also classified refugia based on the stressors that they mitigate (i.e. thermal, hydric, cyclonic, pyric and biotic refugia) and stated that refugia should provide mitigation against multiple stressors. (James, Vanderwal et al. 2013) recently produced a detailed discussion of climate change refugia for freshwater biodiversity in Australia.

Non-recognition of benefits

One of the most serious threats to native vegetation is simply that its full value is not accounted for and not widely realised amongst landholders and the broader community. Many of the benefits are not realised until they are compromised and resultant problems manifest. For example, as mentioned previously, pest management research related to native vegetation has generally not been conducted until sustainability issues have arisen through economic/management problems such pesticide resistance or disease outbreaks. However, the related research has mainly highlighted problems and suggested solutions that still require research and funding for their implementation. Clearly, it is desirable to learn the lessons from elsewhere and to maintain the current ES that are freely provided as this is a more efficient ecological and economic approach than mitigation. Public acceptance of such an approach is made difficult if local benefits (or the problems faced by others) are not realised and clearly communicated.

The MEA Biodiversity Synthesis (MEA 2005a) suggested that the level of biodiversity that will be conserved is proportional to the level of benefits that are considered/accepted by the community and political leaders (Fig 10). Current trends and policies represent a trade-off between economic development/agricultural production and biodiversity conservation, and will likely lead to significant biodiversity losses. However, understanding of the role of biodiversity in providing ES is likely to increase its protection for utilitarian reasons associated with the ES. Understanding of the contribution to landscape resilience, modifying thresholds and maximising management option values for current and future systems, increases the utilitarian values further and thus subsequent biodiversity conservation. The MEA suggested that recognition of non-utilitarian values (e.g. intrinsic values) would be required to preserve the maximum biodiversity. Burkhard, de Groot et al. (2012) concurred that low levels of shared knowledge about how ecosystems function and how they support human well-being, are key limiting factors for sustaining natural capital. They stated that this could be tackled by targeted education campaigns and clear dissemination of successes and failures, that these should be aimed at elected officials as well as the public, and delivered through collaboration between the public, private industry, and government entities.

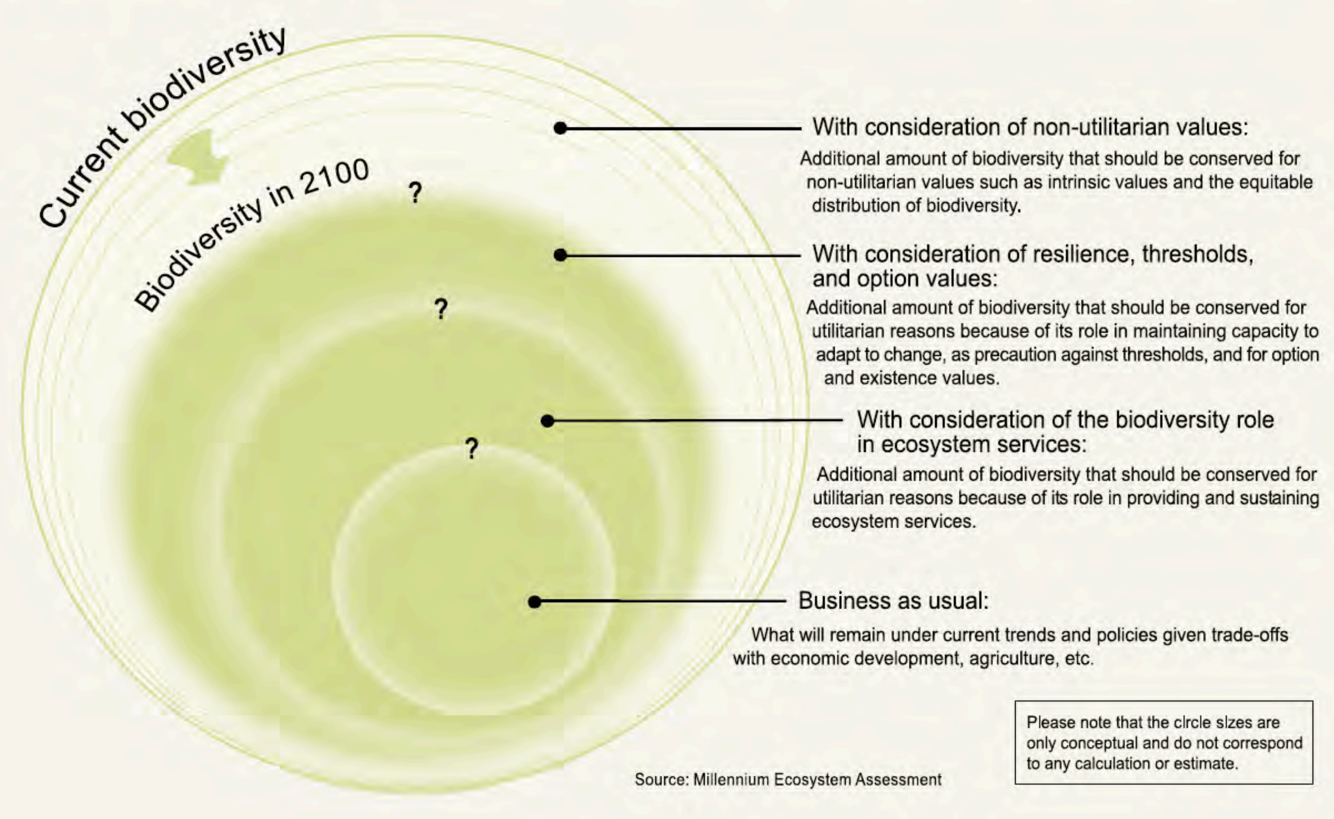

Figure 10. Theoretical global biodiversity conservation scenarios were described based simply on consideration of under-exploited utilitarian values and non-utilitarian values producing changes to current biodiversity trade-offs (MEA 2005a). In a KI context, the outer circle represents total KI biodiversity and inner circles represent the level of biodiversity preserved under various value frameworks; question marks represent uncertainties over boundaries (and hence relative sizes of inner circles). This suggests that understanding and capturing the full benefits provided by biodiversity will lead to improved conservation outcomes.

Increasing economy-of-scale in agricultural production

There has long been a trend in agricultural production, towards increasing economy of scale and a reduction in the number of farm owners and family farming enterprises (Newby 1980). In terms of social structure and public services such a trend is unlikely to benefit the community of KI as economic benefits able to be derived from KI's landmass will be spread between fewer people. The population size is small and already struggles to generate funds to maintain services, and develop infrastructure for residents and visitors alike.

Increasing economies of scale also result in ecological trade-offs through the use of larger land parcels combined with increased scale of mechanisation. For example, on KI it has been suggested that reduction/removal of 'isolated paddock trees' and roadside vegetation be permitted on the basis of facilitating use of larger farm machinery. In the case of isolated trees, vegetation removal requires an offset by the landholder (G. Flanagan, pers. comm., 2015) although these offsets are associated with area/number of trees cleared and not with biodiversity measures or ES provision. Apart from the loss of broad ES in converting more native vegetation to farmland (Fig 8) increasing scale of individual farms decreases the need to reduce overall inputs, increase production intensity, improve production efficiency, increase value of crops grown and increase value-adding which are all desirable for the sustainability and competitiveness of the agricultural sector in Australia. These desirable production attributes are particularly important for KI as they help to maintain producer numbers, overcome transport costs, provide new tourism opportunities (without increasing land area under farming) and aim to exploit the natural advantages producers on KI have (which currently encompass reduced pest pressure and significant ES related to native vegetation cover in excess of mainland producers).

As alluded to above, desirable trends for production on KI include:

- increased intensity of production i.e. more from the same area
- reduced chemical inputs leading to production cost reductions, farmer and public health benefits, reduced off-target effects, reduced disturbance effects (see Fig 7), reduced environmental concerns, extended life-time of chemical use (through reduced resistance)
- increase in profitability through higher value crops, intensification, value-adding
- further integration of production and tourist opportunities
- development of niche products that target KI's natural advantages (including climate) and unique characteristic
- maintenance of the number of producers that are resident and property owners
- increased integrated management plans that recognise and utilise ES provided by native biodiversity

Presently, ≈60% of KI is under agricultural production (230,370 ha), with sheep production being the main activity followed by cropping (mainly cereals, pulses and canola) and then beef production (Dohle 2013, Pisanu, Rogers et al. 2013). In the 20 years following 1991, land under cropping increased by almost 250% from 8,000 to about 19,000 ha and includes mixed cropping/grazing enterprises (Dohle 2013). Cropping-related management practices generally involve the greatest ES trade-off and therefore a significant continuation of this trend should be carefully considered. A judicious increase and diversification in the amount of cropping land under horticultural production would likely reduce this trade-off and could contribute to most of these desirable trends on KI, primarily because they are highly intensive systems with good potential for high value produce and value-adding and a reduced requirement for economy of scale. This would also be of benefit to the island community as it would maintain producer numbers in the long term, increasing the diversity and availability of local produce (hence self sufficiency), and increase tourism opportunities.

As far as possible it would seem sensible from an ES perspective, to minimise the amount of conversion of land under native vegetation to primary production or further degrade the existing native vegetation . This is because of the clear ecological and other trade-offs associated with this conversion (e.g. see Fig 8) that is universally recognised by groups involved in ES science. Furthermore, this would ensure that KI would retain its desirable mean native vegetation coverage of ≈40%. The pending EPBC listing of endangered *E. cneorifolia* communities in KI is therefore likely to produce ES benefits over the long term.

Inappropriate resourcing and legislative framework for research and/or best-practice management

ES as they pertain to landscape management approaches, are a relatively new consideration that government policy will need to keep up with. There are several resourcing and management factors that have the potential to reduce the effectiveness attempts to increase ES pertaining to native vegetation.

1. insufficient resourcing and/or political will to undertake ES accounting, track ES fluxes and/or support the capabilities required to provide meaningful iteration within an adaptive management framework. Financial pressures and political priorities have produced a situation where even basic functions such as control of exotic species or biosecurity monitoring are severely under-resourced with regard to achieving their goals. Without a significant increase in the political will to make real impacts at a landscape level it is difficult to see how the scientific knowledge and refinement of landscape management practices will occur and/or produce the desired outcomes. A good example is the Eastern Plains Fire Trial which was the only

biodiversity-related fire research being conducted on KI; continuation of this program has stalled due to lack of external funding.

2. insufficient internal scientific capacity and research: there are significant knowledge gaps in many of the areas being discussed here (see below) and a corresponding lack of in-house scientific capacity to produce the required data sets or modelling specific to KI. Even relatively longstanding management issues such as response of biological communities to fire variables, value and type of age-class mosaics, definition and use of upper and lower age thresholds, use of vegetation corridors etc. are still being debated at a scientific level.

3. competing goals of local and state government. In many issues surrounding land management, the primary focus of KI council and state government is different, and may be competing in some cases. The most obvious examples are roadside management practices where the main concern of council are liability and infrastructure issues, which are generally at odds with biodiversity and biosecurity concerns of DEWNR and owners of heritage agreements. For example, small heritage grants can be obtained by landowners to prevent weed infestation at the periphery of heritage agreements while adjacent road reserves are managed by local government in a manner that encourages weed invasion. It is of note however, that council has kept significant vegetation on some three chain roads which has provided biodiversity benefits, particularly when located within highly fragmented land (Kangaroo Island Council 2006, Gillam and Urban 2014).

4. policy and red tape as a disincentive to good management practices. The complexity (and other vagaries) of legislating land management practices across landscapes with increased nuance means there is a high chance of discouraging participation in appropriate management, and thereby reducing efficiency of ES accounting and delivery, simply through the design of the legislative framework. While protecting biodiversity and broad ES, legislation has to facilitate:
   - flexibility in land owners undertaking on-ground works
   - efficient cooperation between local and state government
   - expedited assessment of management options
   - expedited translation of research and management feedback into refined management practices
   - encouragement, finical or otherwise, of land owners to undertake practices that preserve or increase broad ES
   - timely assessment and uptake of appropriate technologies

Increasing combined stakeholder benefits of ecosystem services from native vegetation

As alluded to above, apart from many scientific shortcomings, key factors that threaten the loss of ES relate to awareness and/or understanding in that full benefits are not well understood by individual stakeholders, and the shared benefits (common ground) have not been well defined.

The three key 'forces' on KI are tourism, primary production and biodiversity. Each of these shares some common ground with regard to shared benefits (conceptualised in Fig 11 left especially between the biodiversity and each of the others and with less common ground between primary production and the environment which are generally seen as having little shared value. In order to find more common ground attempts should be made to develop management tactics and collaborations that allow dual benefits to be realised in an adaptive management context.

For example, to facilitate biodiversity outcomes, native vegetation management could consider production outcomes where possible. This could be as simple as revegetation supplied on farmland to provide biodiverse windbreaks, or more nuanced such as revegetation or burning of degraded land near agriculture for supply of beneficial invertebrates specific to a given crop. By understanding shared benefits, making them explicit, and managing native vegetation to harness them in an adaptive process, the shared benefits between primary production and biodiversity could be increased (Fig 11). This should provide additional benefits such as the leverage of private effort to achieve these mutual goals and reduce the cost of their delivery e.g. producers could agree to manage weeds in such a planting in return for the planting being supplied. By managing landscapes to maintain their adaptive capacity and option values choices regarding new crops and production systems will be maximised under a rapidly changing climate, especially those for which KI has a natural advantage. In conjunction with increased value-adding, the development of niche products, and innovation, these new production systems will link to new tourism and biodiversity opportunities again increasing shared benefits. Given the current shortcomings in our ability to fully account for the degree and flow of ES, and the effect of various management and legislative processes on them, this is largely a theoretical concept that still requires scientific underpinning, and a relevant and efficient legislative framework. Suggestions to address with these shortcomings are discussed below.

The overarching aims in minimising the levels of clearance and landscape disturbance caused by management practices are capturing and maximising native vegetation-based ES for multiple stakeholder groups, and involve the broader community in this effort. This makes economic as well as ecological sense, given the MEA data showing that increase in sustainability equates to increase in total economic value (Fig 8). Therefore, if highly disturbed/degraded land (e.g. roadsides, agricultural margins, 'wasteland') can be managed more sustainably from a biodiversity perspective, its value to the community should increase. In order for government and the community to achieve this, a clear management structure needs be applied which can iteratively assess needs and outcomes for different stakeholders, and account for a significant proportion of ES provision. Apart from an efficient and relevant management structure, two crucial elements are required: (1) clear management priorities, and (2) means to maximise beneficial outcomes.

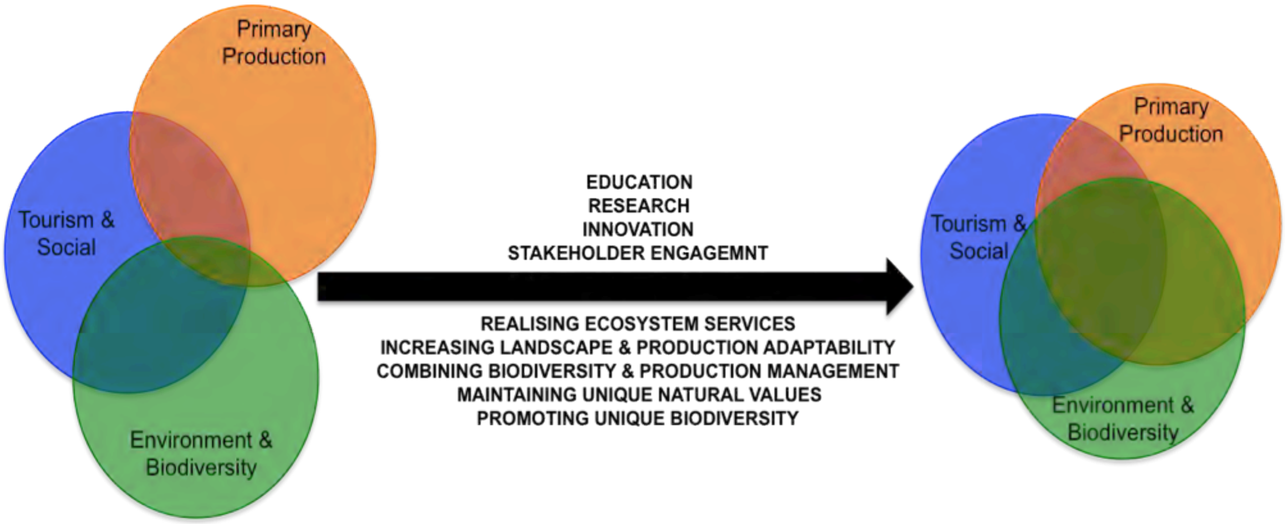

Figure 11. Theoretical model of current (left) and potential shared benefits (economic and ecological) (right) between primary production, tourism and environment sectors on KI, derived from a combination of engagement, education, innovation, ecosystem integrity and landscape adaptive capacity, and restructuring landscape management approaches (arrow). The shared benefits of each sector (overalpping sections of circles) can be increased through ES accounting and resultant imporvements to landscape management approaches. This is expected to lead to increased efficiancy in ES maintenance/delivery, and improved biodiveraity outcomes, through leverage of effort from stakeholders due to increased understanding and attainment of shared benefits.

The key to capturing broad stakeholder benefits is the engagement of the relevant stakeholders (local, regional, national, and global) in developing and implementing management decisions. This is crucial for the credibility and broad acceptance of legislation that assigns appropriate responsibilities and underpins adherence/enforcement (Burkhard, de Groot et al. 2012).

Identifying management priorities

As part of identifying priorities for landscape management, DEWNR recently produced a landscape assessment for KI, whereby the island was divided into three landscapes (management units) based on contiguous areas sharing similar physical and biological parameters (Pisanu, Rogers et al. 2013). The 'health' of these landscapes was then modelled using ecosystem-function thresholds and their status with regard to key drivers that regulate these functional parameters (e.g. vegetation age classes and fire, respectively). The purpose of this was to identify key drivers of ecosystem degradation and identify related management priorities with respect to biodiversity. The ES research I have discussed suggests that there is a range of ways that landscapes can be defined and there may be merit in different definitions for different landscape management aims.

In terms of vegetation management priorities on KI, a key issue for all landscape managers and legislators is managing native vegetation to deliver ES to agriculture whilst achieving improved biodiversity and/or ecosystem functionality. Engaging innovative producers will be crucial to understand constraints and opportunities of their management systems (e.g. see Fig 12 below), and to deliver pilot projects.

A key to delivering agricultural benefits is to understand the management of cropping systems and the role of different native plant species in regulating pests, beneficials and diseases. KI-specific research is required in this regard. A challenge for NRM planning based on agricultural outcomes is the functional categorisation of the landscape (e.g. Figure 2) with respect to beneficial species, which needs to capture the compositional, temporal and spatial heterogeneity of an agricultural landscape subject to significant disturbance events e.g. pesticides, harvest etc. (Schellhorn, Bianchi et al. 2014). Figure 12 shows an example of an 'agricultural landscape wheel' for temperate Australian cropping systems that represents compositional, temporal and disturbance aspects of vegetation in the landscape (from (Schellhorn, Bianchi et al. 2014). It demonstrates that non-crop vegetation has the ability to supply beneficial insects for multiple crops at the times they are most needed.

One obvious example of a management practice aimed at providing ecological, agricultural and tourism outcomes, is revegetation (or ecological rehabilitation) to supply honeybee forage. Native vegetation is of importance to apiarists because it is key to supplying enough forage to maintain healthy colonies for honey production and crop pollination using managed hives. Beekeepers have long sought access to conservation areas but have usually been denied due to environmental concerns (mentioned above) and/or bad management practices. Against a backdrop of increasing concern about environmental impacts of honeybees, and the threat to honeybee populations posed by introduction of Varroa mite (see Pollination above) and Asian honeybee, one of the apiary industry's key goals is increased access to public lands for foraging purposes.

A potential solution (previously suggested by PIRSA (2007)) is to revegetate private land to supply floral resources for honeybees. As apiarists have a good knowledge of native forage plants and their flowering times, and their own management requirements, there exists an opportunity for custom designed revegetation to maximise honeybee foraging at a given site. Benefits could be extended to include pest-management and pollination outcomes for other adjacent production systems. Table 6 summarises the potential problems and benefits that are encompassed in a theoretical revegetation program aimed at honeybee forage.

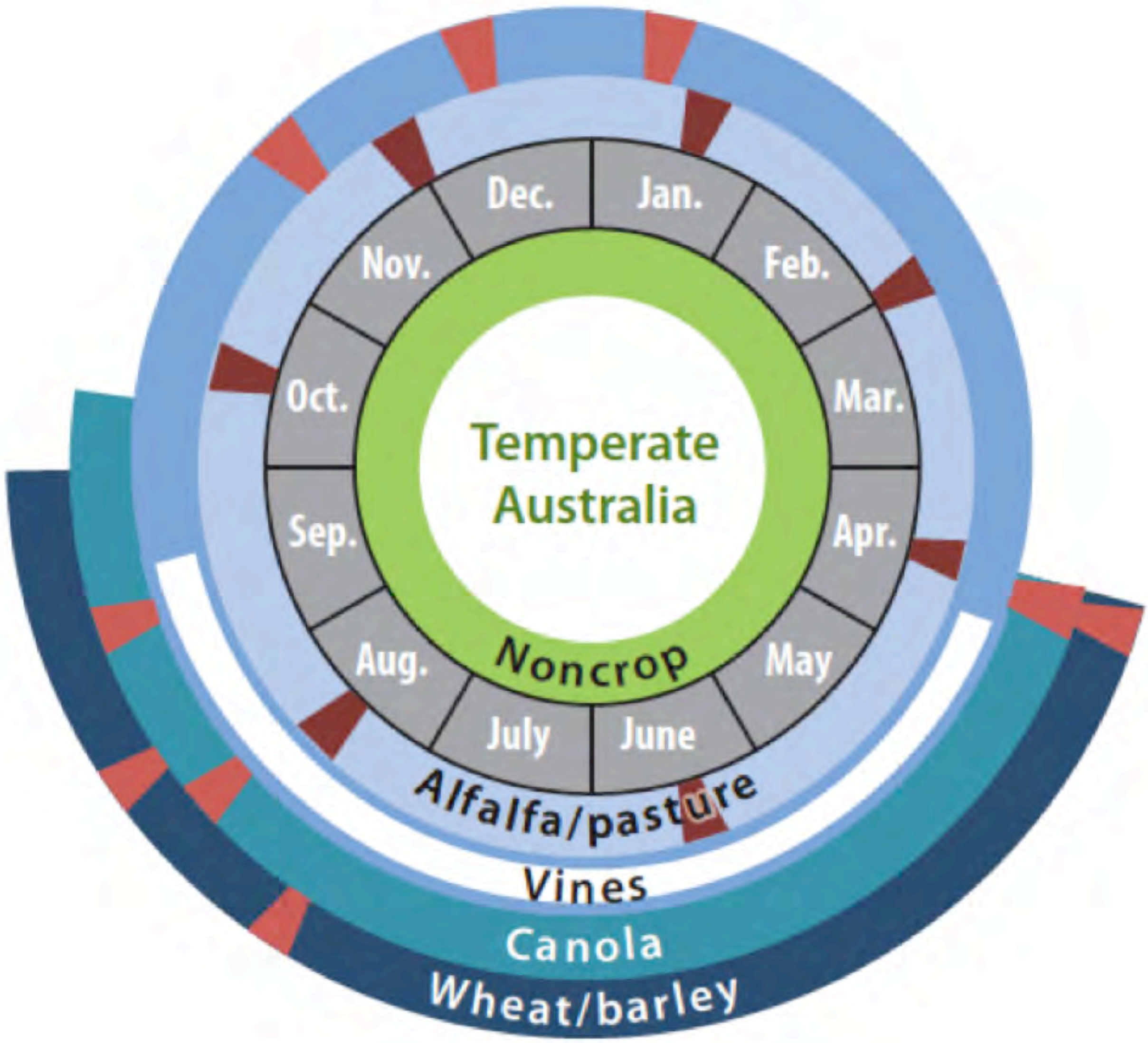

Figure 12. Agricultural landscape wheel for temperate Australia, reflecting temporal (grey circle) and compositional (green and blue circles) heterogeneity, and occurrence of disturbance events by red boxes (insecticides are light red; periodic harvests are dark red). White area within a bar represents leaf-fall in a deciduous habitat. The degree of compositional heterogeneity is represented by the number of circles and temporal heterogeneity by the alignment of circles. The wheel indicates the times that non-crop habitat (green inner bar) are useful for maintaining beneficial species and influencing emmigration/immigration dynamics in production systems. From Schellhorn, Bianchi et al. (2014).

Table 6. Theoretical benefits of a revegetation program conducted in conjunction with primary producers and aimed at delivering production benefits for apiarists. Stakeholder groups (and associated problems addressed by the revegetation program) are listed, along with the deliverables supplied and benefits gained. By maximising stakeholders that can be involved in the planning of the program, certain ES can be targeted and shared benefits identified. Through use of a well designed monitoring and assessment strategy that has a sound scientific basis, the revegetation program can be subsequently optimised for improved performance. In reality stakeholder groups on KI are not discrete and overlap.

Stakeholder group	Problem(s) addressed	ES-related deliverables	Benefit(s) received
Apiarists	• insufficient forage • hive transport costs • insufficient hives for pollination/honey production • winter &early spring colony vigour	• increased forage plants customised for timing & abundance of flowering	• reduced requirement for access to conservation land • reduced transport needs • increased vigour of colonies in winter/spring • increased pollination & honey production capacity • increased tourism experiences if also operating as a tourism business • improved production efficiency & profitability • improved public perception of apiary management practices
Other Primary Producers	• less than optimal pollination • lack of beneficial invertebrates • nearby crop pest/disease reservoir • invasion of weeds from unmanaged adjacent land • need to use pesticides • strength of economy less than optimal	• pest management benefits perhaps including reduced chemical use • improved pollination • cheaper managed pollination services	• improved production efficiency and/or yield • reduced chemical inputs (cost and health benefits) • increased tourism experiences if also operating as a tourism business • marketing opportunity around innovative, 'green' production & management • improvement to resilience and adaptive capacity of landscape • economy strengthening through production efficiency and tourism opportunities

Tourism Operators	• need for new and novel tourist experiences • need for integrated tourist experiences (farming and natural environment) • strength of economy less than optimal	• novel management practices associated with KI production systems and using KI wildlife (perhaps rare species) • increased vegetation in landscape	• marketing opportunity for KI as place of innovative, 'green' production & management • extra (and integrated) tourism opportunities either through visiting the sites or delivering/maintaining the revegetation • improved tourist amenity outside of conservation areas • economy strengthening through production efficiency and tourism opportunities
Community/ Environment	• degraded natural vegetation and ecosystems • use of agrichemicals • strength of economy less than optimal	• increased native vegetation in landscape • reduced pressure to permit invasive species in conservation areas • reduced use of agrichemicals	• improvements to landscape amenity from native vegetation • improvement to resilience and adaptive capacity of managed landscape • improved biodiversity and conservation values from increased and specified vegetation • reduced managed honeybees in caonservation areas • healthier production landscape and produce (if reduce pesticides) • economy strengthening through production efficiency and tourism opportunities

This is just one example of how a remedial activity for the natural environment could be targeted for delivery to benefit a range of stakeholders and thereby broaden the value and acceptance of the action. The importance in fully understanding the ES that can be delivered and how they relate to various stakeholders and their activities are key goals for the consultation and design stages of the adaptive management process, as they a crucial to integrated delivery of benefits across groups and/or minimising competing outcomes. Another potential example could be the use of primary production landscapes for targeted protection of rare KI species, combined with the right of associated producers to utilise the species (or their conservation activities) in marketing of their products, or a labelling strategy that aims to highlight producers who undertake collaborative remediation/conservation (or subsidies for the same). This could also provide tourism opportunities on-farm. There are endless opportunities in this space and collaboration of stakeholder groups is key to identifying and maximising beneficial outcomes at a landscape level.

A key to driving innovation in farming systems is to engage 'innovators' in the farming community. It is well known that in primary production that there are generally a small percentage of innovators that are quick to take up new practices and technologies, and that the bulk of primary producers will change their approach if benefits are demonstrated by the innovators, but are not highly influenced by benefits espoused by scientists and/or the government. A small percentage will always be resistant to change. Therefore, general uptake of management practices by the broad primary producer community is best facilitated by engaging with the innovators to demonstrate benefits in pilot programs.

Given that there is likely to be insufficient resources to actively drive all desired management outcomes, a key question that will need to be addressed is the relative assignment of resources to restoration/remediation and protection. While protection of high value areas is likely to be simpler and cheaper (mainly requiring control of exotics), the ES provided are not well defined in an economic sense and are broadly distributed (and hence without an obvious advocate). Alternatively, remediation of degraded areas is more complex and likely to require a more active ongoing approach, however, stakeholder benefits may be easier to define and/or capture through the ability to custom-design the resultant landscape. Pisanu, Rogers et al. (2013) stated that it is obvious that biodiversity resources would best be applied to the highly degraded areas of the Eastern Plains and Dudley Peninsula where many of the endangered plant taxa exist. However, there was limited discussion about why this was a better use of limited resources over the long term than protecting high value areas, and there is as yet no consensus in the broad general debate on this question (Wilson, McBride et al. 2006, Rudd 2011). The EDGE group (http://www.edgeofexistence.org/index.php) has produced lists of priority species for conservation based on how evolutionary distinct and globally endangered they are. Regardless of the merit of that particular approach, it highlights the debate in this area and the fact that prioritisation will likely be required due to the scale of the problems and the insufficient resources available for management of all ecosystems and their constituent species.

In degraded areas needing active management, it will be crucial to efficiently define ES and resilience benefits for multiple stakeholders to enable quick decisions, multiple benefits, meaningful participation and prevention of dissatisfaction. The full accounting of ES in remediation situations is a key strategy for prioritizing delivery of on ground works, stakeholder engagement and value adding by stakeholders. For native vegetation management on KI there is a lot to be gained from simply learning the lessons from other regions where little native vegetation remains and associated problems have been manifest in these areas, but may not yet be obvious on KI. Therefore, the prior events from other regions can act as 'case studies' to help define the problems (and the proposed solutions) in economic terms. By combining this with science aimed at elucidating specific aspects of KI landscape attributes and associated ES, KI-specific management solutions can be derived in a meaningful way and act as a sound basis for iteration through the adaptive management process.

Maximising beneficial outcomes

In 2008 the Ecosystem Services Partnership was established to '*enhance communication, coordination and cooperation, and to build a strong network of individuals and organisations*' for '*conceptualisation and application of ecosystem services*'. Against a background of identified emerging needs for scientific development and fostering of applications and environmental management based on ES, participants in a 2011conference organised by ESP released the '*Salzau Message on Sustaining Ecosystem Services and Natural Capital*' (Burkhard, de Groot et al. 2012). This statement, signed by many of the leaders in ES science, listed a series of agreed facts about ES and 'natural capital', which served to underpin their specific recommendations regarding research into ES methods and applications.

Some of these agreed facts related to ensuring beneficial outcomes to multiple stakeholders, *viz*:

- an ES approach helps to identify and quantify ecological and socio-economic trade-offs and synergies on which decision making should be based.
- many ES cannot, and should not, be privately owned and are thus ignored by conventional markets.
- many ES are such that providing benefits to one person does not reduce the amount of benefits available for others. They are "non-rival" and "non-excludable" and therefore best treated as "public goods".
- there will remain enormous uncertainties about how ES are provided, the magnitude of their benefits, and how human activities affect their provision.
- adaptive management/learning is a useful approach that allows one to learn from the system dynamics and manage under this uncertainty.

Encompassing the viewpoints of multiple stakeholders and dealing with ecological and other trade-offs is a key part of ES science and moving towards full accounting. This should take into account the benefits and costs of all stakeholders associated with a given landscape management activity. For example, the incorporation or proximity of native vegetation to production land may provide biodiversity and insect pest management benefits, but may have adverse impacts for some stakeholders such as increasing impacts of sheltered animals such as pigs, goats and native grazers. The complexity of the various biological systems and their interaction with human activity means that these trade-offs must always be managed; this is in fact the primary aim of full accounting. For native vegetation most of the trade-offs are ecological and arise from two sources (Burkhard, de Groot et al. 2012):

1. scarcity and restrictions in the amount of ES that can be provided
2. distribution of the costs and benefits for provisioning the ES

Burkhard et al. (2012) stated that the purpose of ES science is to make these trade-offs explicit and facilitate stakeholder discourse around planning and management, and thus enable sound value judgements by all parties. It also makes explicit the degree to which ES are applicable (i.e. personal vs group vs community). Thus, ES science and full accounting aim to produce robust socio-ecological knowledge for stakeholders and policy makers and produce sets of planning options to resolve as best as possible, social conflicts surrounding ES delivery through landscape management (Burkhard, de Groot et al. 2012).

One tranche of recommendations in the *Salzau Message* related to dealing with uncertainties that will continue to surround many aspects of ES science, using adaptive (or iterative) approaches. They stated that this required constant evaluation of the impact of existing systems and the design of new systems with stakeholder participation as experiments from which to more effectively quantify performance and learn. DEWNR already recoginses the need for an adaptive management approach and so I will not discuss a generic adaptive management framework here; for such a discussion see (Sabine, Schreiber et al. 2004, Pisanu, Rogers et al.

2013). Briefly, adaptive management amounts to using best available knowledge and multiple stakeholder inputs to model a range of management options from which a 'best-bet' approach is chosen and implemented, with monitoring and subsequent evaluation used to improve future outcomes. Haasnoot, Kwakkel et al. (2013) provide an example of a recent approach to making adaptive policy and management decisions when dealing with uncertainty.

One advantage of the early phases of an adaptive management cycle (Sabine, Schreiber et al. 2004) is that it has the capacity to classify and quantify landscape approaches based on multiple stakeholder inputs such that ES goals are clearly defined to allow stakeholders to work towards them. This seems a worthwhile approach and essentially amounts to common sense given the current thinking in ES science. However, the capacity to truly utilise adaptive management to improve landscape resilience/adaptive capacity is limited not only by scientific knowledge in many cases but also the resourcing to drive the interactive process in a meaningful way.

Thus, there are three notes of caution regarding the use of adaptive management as it currently stands:

1. the fact that iterative improvement is inherent in the approach should not be used as an excuse for either a poor starting point or to proceed in the absence of a sound scientific basis.
2. that 'best available knowledge' is not used in an internal (departmental) sense but in an external (scientific) sense. This is crucial as it facilitates the pre-requisite scientific underpinning required for good outcomes in this complex area. Just because a number has been assigned to a given metric does not make it robust or useful.
3. that sufficient resourcing is available to perform required research and consultation to support each phase of the adaptive management process, especially the development of a 'best-bet' plan and the monitoring/assessment required to drive refinement.

It should also be noted that unless trialling the learning (adaptation) process is a goal in itself, that management plans based on poor (or insufficient) information, or poor interpretation of available information, may be worse than the *status quo*. A further consideration is that 'doing nothing' or reducing intervention in the absence of good/sufficient information and/or sufficient expertise, may be legitimate management approaches in many cases. This is particularly so where:

- resource use efficiency has a reasonable prospect of improving in the short/medium term e.g. where a scientific basis is being established,
- the low cost of the approach gives good cost : benefit ratio,
- there is a lag time until drivers of the management decision are impacting significantly,
- a management approach is being applied more broadly than strictly required in attempts to achieve some other efficiency.

Apart from the areas of defining and understanding dynamics of ES (see previously), there are still large knowledge gaps in monitoring and evaluating ecosystem health. Generally, current biological monitoring does not have well defined metrics to assess degradative changes to ecosystem functioning in real time; it is restricted to assessing high-order symptoms of deleterious processes, rather than subtle changes that reflect specific progress of processes. For example, a recent report stated that birds could be used to assess ecosystem health, and linked reduction in numbers of several species to deleterious processes on Dudley Peninsula (Pisanu, Rogers et al. 2013). While they may be indicative of significant/broad scale degradation of ecosystems (which was a correlation used to support the assertion), birds are unlikely to have the functional resolution to be useful indicators of subtle changes to ecosystem processes as they are not very diverse in species number or behaviour and they do not generally have specific associations with other organisms.

A key challenge current NRM planners is the need to deal with complex decisions that often need to be made without a strong scientific underpinning, which limits the ability to monitor outcomes and likely reduces the effectiveness of management tactics (or adverse outcomes may be produced). For KI, it should be an aim to increase interaction between land managers and researchers working in the areas discussed here. There are many scientists in Australia (see numerous references cited) and elsewhere with significant capability that could be applied to KI-specific situations. These researchers seek model systems to test their hypotheses and also need a competitive advantage in funding applications, such as an important region or current issue. KI is attractive in this regard because of:

- the unique multi-use landscape,
- high national and global profile for tourism and biodiversity (iconic status),
- discrete landmass and administration (i.e. one council, KINRM board) but a regional context at state/national level,
- discrete KI-specific data sets already existing ,
- many important questions not specifically addressed here,
- significant natural capital remaining, including biodiversity assets of national importance and scientific value.

Given the current administrative load of and focus of DEWNR, it is not able to conduct research projects, however, it does not need to. Its role should be to use KI's competitive research funding advantages (dot points above) to leverage the research expertise. DEWNR can continue to undertake an administrative role through regional planning, supply of datasets, access to land, input into grant applications, identifying collaborators, gathering regional industry support, supplying in-kind assistance etc. Some suggestions to move towards such a model are:

- develop/prioritise defined and discrete research questions to inform landscape management plans
- produce a database of relevant institutes and researchers (defined by the previous)
- liaise directly with researchers to develop KI-specific funding proposals
- incorporate literature reviews into research projects to leverage information gathering based on defined research goals
- at a state level, consider formal involvement with topic-based national/international research bodies of relevance (some current examples in Australia are NCCARF and Plant Biosecurity CRC)

This approach will allow DEWNR to obtain quality datasets and models and can reduce the effort currently applied to gathering complex information derived elsewhere, and attempting to interpret it in a KI context for management purposes. However, it is likely to require some state funding to achieve it in the short term although the benefits are expected to significantly outweigh this investment because of the leverage of latest knowledge and expertise.

A similar improvement to land management issues is to place effort into working directly with local government in a formal and ongoing way, to identify shared benefits and shared problems in any issue concerning plants. Again, this should be driven through co-development of grant proposals to tackle these issues and address current funding constraints. Given the competitive advantages listed above, targeted grant proposals with regional impact and combined council/DEWNR (and potentially PIRSA) support, would have a high chance of obtaining funding to investigate difficult vegetation management issues.

As alluded to above, the current less-than-optimal attainment of shared benefits (mainly between agriculture and environmental sectors) is partly the result of administrative structures such as the traditional departmental separation of production and conservation activities. The need for a more holistic approach to landscape management has been realised with the remit of the former Department of Environment and Heritage being increased to include NRM (and water). However, NRM is not well defined in this context and this approach has essentially led to a reduction in conservation activities and an increase in expectations that such an NRM-related department must deal with issues pertaining to agricultural production. Therefore, in order to manage the landscape efficiently to maximise shared benefits, biological realities and complexities need to be reflected in the administrative structures of government. In that sense, it would seem beneficial to have a united body dealing with NRM and ES (or simply landscape management), containing sub-units that deal with functional subcategories (e.g. biodiversity, soils, water, biosecurity etc.) at a landscape level, considering both natural and managed systems and associated interactions. Currently, management of NRM and primary production is more disparate.

There are two other strategically important issues with regard to achieving beneficial outcomes at a landscape level. The first is to encourage uptake or increase of production systems where KI has a natural (biological or regional) advantage. This is aimed to reduce overall production costs (reduce inputs and ES trade-offs) and maximise the ES that can be derived from the landscape. As a general principle government and producers should aim to increase production of high quality, high value, high intensity, high efficiency, innovative, high value-added commodities and trend away from greater economies-of-scale which generally ignore efficiency of biological inputs and rely on technological improvements that drive profitability in large-scale production systems. This will act to maintain sufficient numbers of primary producers, increase the value and efficiency of production, and make use of KI's advantages to overcome disadvantages such as export costs.

Secondly, conservation approaches should aim to protect biological communities (rather than individual species), which can be well defined by soil type, plant-species composition and land use history. This is already realised by DEWNR who have moved to protect the remaining *E. cneorifolia* communities (under the federal *Environment Protection and Biodiversity Conservation Act 1999*) that are unique to KI and have been severely fragmented, and therefore often not exposed to fire for long periods. However, because of the high level of degradation of some of the most diverse biological communities on KI such as those of the MacGillivray Plains, there are numerous endangered plant (and probably other reliant) taxa that require attention at the species level because their remaining habitat comprises only roadsides and/or small conservation blocks.

Knowledge Gaps and Future Research

In many areas of biology, there is far a far greater knowledge gap than there is validated scientific knowledge. The very broad area of NRM and ES is no exception. Many of the knowledge gaps have been mentioned under specific sections earlier in this report. While the existence of ES is intuitive and now a broadly accepted concept, ES as a field of study is still in its infancy and the supporting science is gaining in sophistication. A good summary of the current research questions and directions in ES science was provided by Burkhard et al. (2012) on behalf of the ESP; a short summary is provided below in Table 7. Most of these issues have been discussed during the report in a KI-specific context. They also point out that ES research has evolved from introductions and conceptual questions to now focus on more specific and detailed questions regarding methods and applications.

Table 7. Summary of broad research areas and associated research questions in the field of ES science (derived from Burkhard et al. (2012)).

Broad Research Area	Research Questions
Integrated quantification, modeling and valuation of ES	How to measure & evaluate ES?
	How to link ecosystem functions, services & benefits?
	How to explicitly link ES to human well-being?
Accounting for ES at the landscape level	How can the ES approach be applied to landscape analysis?
	How can the ES approach be applied to landscape planning?
	How can the ES approach be applied to landscape management?
Adaptive management of ES	What supporting tools have to be developed to validate the ES approach in adaptive management?
	How can the ES approach be implemented in management and institutions?
Environmental, social & economic trade-offs	How can ES be evaluated from social & economic points of view?
	What instruments should be developed to foster these evaluation strategies?

The following areas of research are recommended to support the movement towards a validated approach to native vegetation-related ES delivery through landscape management on KI:

- developing integrated quantification, modelling and valuation of ES
- significant accounting for ES at a landscape scale
- development of a scientifically-based adaptive management approach to ES
- understanding and characterising social and economic trade-offs on KI
- understanding and characterising interactions between native biota on KI and primary production systems
- determining key biosecurity threats for native vegetation on KI and developing prophylactic and response plans
- defining a range of biological and physical metrics (including indicator species) that can be used for ongoing and standardised assessment of ES delivery and ecosystems function on KI
- adopting all safe technologies that provide a sustainability advantage to production systems and environmental management practices

Among many things, some <u>specific activities and research</u> could include:

- establishment of a KI rainfall transect project to provide long term monitoring of key biological and environmental variables across the gradient
- production of a database of current weed and invertebrate pests, and diseases for key crops
- assessment of beneficial and pest invertebrates on KI's native plant species
- develop a database of pollinating invertebrates and their relationship to crops
- assessment of the impact of various management practices (especially fire) on diverse groups such as invertebrates and microorganisms that effect plant establishment, growth and reproduction (e.g. michorrizal fungi, seed-germination fungi, pollinators)
- assessment of areas of greatest risk for incursion and spread of new organisms
- continued assessment of fire for regeneration purposes

- means to improve DEWNR data sets (e.g. access other national and state databases such as SA museum, Australian Faunal Directory)
- assessment of new primary industries for which KI will have a natural advantage under increasingly warm and arid conditions
- examining means by which KI biota can be used in marketing of agricultural produce
- establishing meaningful thresholds for a range of disturbance processes impacting key ecological communities

As discussed above (see *Maximising Beneficial Outcomes*) the iconic status and high value ecosystems of KI combined with multi-institutional (e.g. council, state, industry, community) grant proposals, should be used to leverage research expertise to produce KI-specific data sets. This will increase the scientific capability being applied to these questions on KI and will increase confidence in parameters used for management decisions.

Conclusions & Recommendations

There is no doubt that a landscape based ES-accounting approach is broadly seen as a useful strategy for maximising current and future ES from the environment, and the approach although virtually in its infancy, is continually being refined and debated. Furthermore, it is now beyond all reasonable doubt that there will be an unprecedented rate of warming of the globe, to a degree that will severely impact some ES that are yet to be well defined. A big part of maintaining ES is to work to improve economic and biological adaptive capacity/resilience of the landscape. Therefore, the new NRM approach of landscape management aimed at adaptive capacity and resilience is to be commended as a sound strategic approach to change and uncertainty.

However, it needs to be recognised that although ES, resilience, adaptive capacity etc. are not new concepts, there still remains a significant knowledge gap in terms of turning these theories into on-ground management providing significant ES benefits, particularly against a cultural background that tends to focus on direct individual benefits and costs of management, rather than the broad spread required for full ES accounting. This largely relates to developing integrated quantification, modelling and valuation of ES across management units.

Moving towards significant accounting of ES in NRM

- apply latest thinking regarding full accounting of ES to develop adaptive land management models because ES accounting will be a major future driver of economies. This requires an explicit understanding of both individual (land owner) and broadly applicable ES, as well an explicit definition of the associated costs and benefits of native vegetation to these groups.
- develop multi-benefit revegetation models for KI that are designed to deliver biodiversity and production-specific ES
- engage innovative producers to deliver biodiversity- and production-based pilot projects, highlight ES benefits and promote value of current ES delivery
- biosecurity, pest management and other ES should be considered in all matters involving vegetation (e.g. roadside maintenance, construction approval) particularly adjacent agriculture or conservation land
- examine marketing/tourism opportunities based on rare, iconic and endemic KI taxa

Research and data

- leverage scientific expertise: use KI natural systems and iconic status to actively engage researchers to develop proposals and facilitate subsequent projects generating relevant KI-specific data sets.
- develop mechanism to continually develop joint research proposals between the state departments, KI council and KI industry which exploit KI's iconic status and improve leveraging of external NRM funding
- establishment of a KI rainfall transect project to provide long term monitoring of key biological and environmental variables across the gradient
- production of a database of current weed and invertebrate pests, and diseases for key crops
- assessment of beneficial and pest invertebrates on KI's native plant species
- develop a database of pollinating invertebrates and their relationship to crops
- assessment of the impact of various management practices (especially fire) on diverse groups such as invertebrates and microorganisms that effect plant establishment, growth and reproduction (e.g. michorrizal fungi, seed-germination fungi, pollinators)

- assessment of areas of greatest risk for incursion and spread of new organisms
- continued assessment of fire for regeneration purposes
- means to improve DEWNR data sets (e.g. access other national and state databases such as SA museum, Australian Faunal Directory)
- assessment of new primary industries for which KI will have a natural advantage under increasingly warm and arid conditions
- examining means by which KI biota can be used in marketing of agricultural produce
- establishing meaningful thresholds for a range of disturbance processes impacting key ecological communities

Land management

- incorporate weed management into activities that disturb vegetation and/or seed-bank at high frequency (e.g. roadside maintenance, fuel reduction burning) – examine joint funding proposals for this based on ES provision
- refine roadside vegetation management practices to provide removal of encroaching mallee branches (with little biodiversity risk) while leaving the shrub layer and soil undisturbed (to give biodiversity and biosecurity gains)
- similarly, refrain from disturbing roadside vegetation where there is no clear safety, functional or management benefit from doing so (identify such areas to provide cost-savings and improved ecological management)
- examine joint-benefit revegetation/regeneration projects to deliver biodiversity and production benefits
- develop monitoring and response strategies for key pests and diseases threatening KI
- highlight and promote awareness of KI's rare plants (e.g. utilise in marketing and tourism)
- protect diversity across the full range of biological "levels" (e.g. genetic, species, population and community)
- fully investigate use of technologies designed to increase sustainability or input use-efficiency of primary production systems and/or minimise ES-tradeoffs
- set 30% native vegetation target on Dudley and Eastern Plains (currently at ≈27%). Because much of the current coverage is contained in large conserved blocks on limestone, the focus of the increased coverage should be ironstone habitats in multi-use (fragmented) areas. This is designed to not only increase the ES values of the primary production landscape in these degraded regions, but to examine research questions and multi-benefit revegetation/regeneration models, and to drive debate regarding uptake of broader ES accounting on KI.
- examine targeted incentive schemes to deliver vegetation management aimed at tackling key biosecurity and biodiversity challenges
- promote ES benefits by highlighting the costs (lost ES) of poor management of native vegetation in other regions, rather than the poorly defined benefits that are currently received on KI through having maintained the native vegetation. For example, grains and horticultural industry advice about the usefulness of native vegetation has been driven by loss of vegetation in other agricultural regions (e.g. west coast of SA and northern Adelaide plains) and the resultant production problems this has produced.
- investigate innovative methods/models of harnessing volunteers for management of feral plants and animals e.g. streamlined environmental volunteer legislation, tourism opportunities, progress associations

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