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TROPICAL ECOSYSTEMS hub

Final Report

Pest Adaptation Response Strategies: Process and Metadata

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Australian Government
Department of the Environment

Reef & Rainforest Research Centre

Pest Adaptation Response Strategies: Process and Metadata

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Cover photographs: T. Sydes, CSIRO

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December 2014

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Acronyms Used In This Report

NERP .... National Environmental Research Program
PARS.............Pest Adaptation Response Strategy

Abbreviations Used In This Report

LGA..............Local Government Area
EI.................. Ecoclimatic index
LLD...............long distance dispersal

Acknowledgements

Local Area Pest Management Plans were integral to this work and were developed by Local Governments and stakeholders from across the Wet Tropics region. Special thanks to Matt Birch, Cairns Regional Council for his contribution to the regional pest planning process and presentation. Local Governments participating in this project include Hinchinbrook Shire Council, Cassowary Coast Regional Council, Cairns Regional Council, Tablelands Regional Council, Douglas Shire Council, Mareeba Shire Council and Wujal Wujal Aboriginal Shire Council.

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Cassowary Coast Regional Council, 2014. Local Government Area Pest Management Plan. 2014-18

Douglas Shire Regional Council. Local Government Area Pest Management Plan. 2014-18 (draft)

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Mareeba Shire Council. Local Government Area Pest Management Plan. 2014-18, (in draft)

Hinchinbrook Shire Council. Local Government Area Pest Management Plan. 2013-17

Introduction

Weed managers in Local Government Areas (LGAs) of the Wet Tropics Bioregion have used a spatially-explicit zoned and prioritised approach to pest management planning, interpreting best available information about the current distribution and impacts of species to determine management objectives (Sydes 2012). However, projected changes in the suitability of climate for establishment and growth, and the potential for spread or contraction of species distributions, are likely to have implications for where, when and how many resources may be needed to manage weed invasions in the future (Sydes and Murphy 2014).

Forecast models (climate/habitat/spread) exist most commonly in the realm of risk assessment on a state or continental scale. They are usually presented to on-ground managers as a static, often single 'image', in the form of the ubiquitous climate suitability model, or less commonly, a habitat suitability model. Rarely is the model interrogated in any other process prior to consumption, and even more rarely is it supported by other spatial knowledge (distribution/land-use/assets) or model processes (dispersal/spread). This is certainly the case at a local/regional scale where time and expertise to progress beyond the static image is often not available.

A collaboration between end users and researchers as part of the Tropical Ecosystems Hub of the National Environmental Research Program (NERP) has resulted in the development of a Pest Adaptation Response Strategy (PARS) for priority weed species in the Wet Tropics region. The PARS adds a new layer of intelligence to the process of forecasting and spatially explicit pest management planning, by integrating a sequence of often disconnected model outputs into a single planning support tool.

Important in the design of this approach is the ability to both critique and compliment the current planning tools in place. By considering how a current management plan interacts with future trends in suitable habitat and climate, a profile of risk and a range of appropriate and proactive management responses can be considered. In addition, the PARS provides managers with a future investment forecast, for example, identifying areas that are likely to require a sustained high investment in management over long time-frames or those areas where investment may decrease over time.

Study region and current management planning process

The region of study focused on eight local government areas within the Wet Tropics World Heritage Area. The interpretation of the PARS is based on management objectives determined by individual Pest/Natural Asset Management Advisory Committees facilitated by Local Governments and as such was a requirement for the approach adopted.

Priorities and management objectives for LGA Pest Management Plans were determined in a regionally consistent framework (Local Government Pest Assessment, Prioritisation and Planning Framework) which is an appendix to the Far North Queensland Local Government Regional Pest Management Strategy 2010-15. Approximately 150 stakeholders from across the region were involved in the development of the management plans. These and others will continue to be involved in their implementation and review.

A management zoning approach has been adopted to communicate the management aims of the plans across the whole range of stakeholders that will need to be involved. The zoning approach is a graphics based hierarchy of actions that identifies both the management and biological target for each management area. It identifies five management objectives. The first three are aimed at detecting, preventing and eradicating the target pest from the designated zone and are specifically targeted at managing the seeds and seed bank (or reproductive capacity in animals). The final two identify the options for managing established infestations to reduce their impacts and opportunities for further spread. The pest plan template summarises the key information on each of the priority pests for the local government area pest management plan.

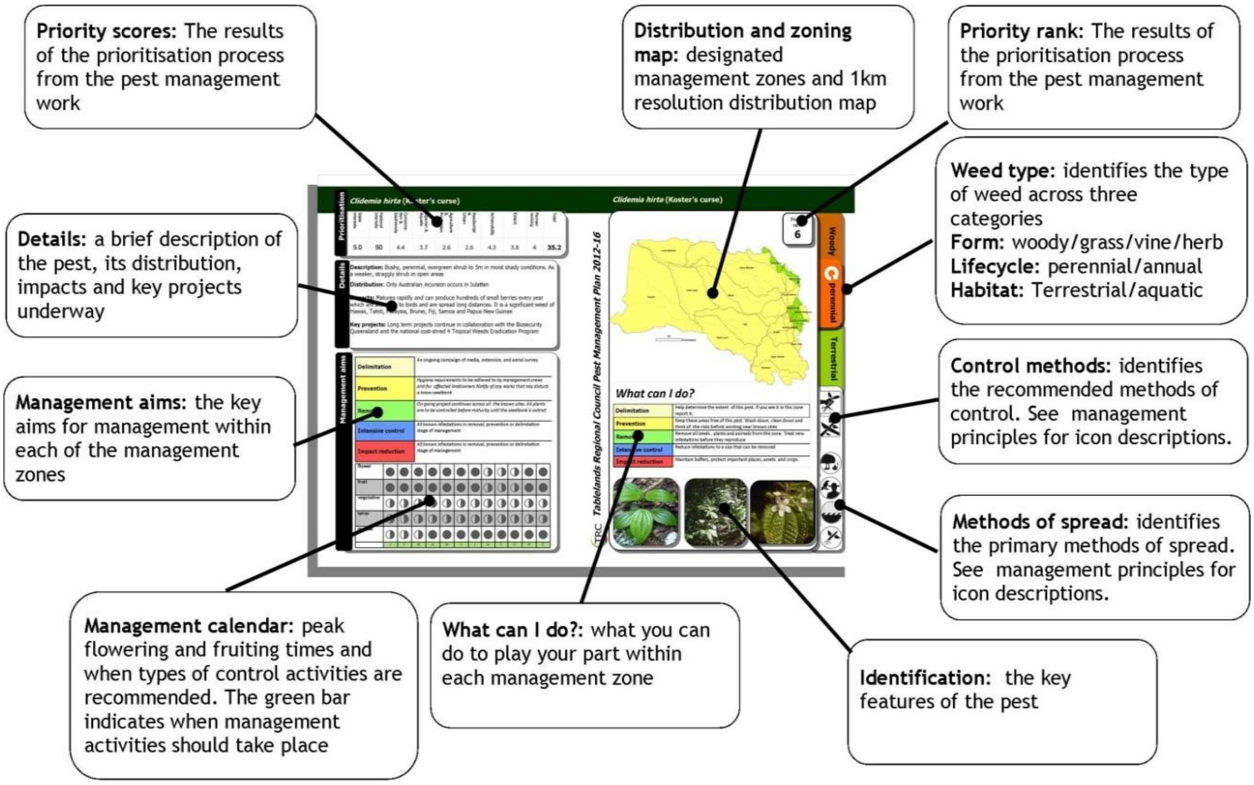


Figure 1: LGA Pest Management Plan format

Modelling future risk

Three widely utilised modeling approaches have been used to project current and future climate suitability (CLIMEX, Sutherst et al. 1999), habitat suitability (MaxEnt, Phillips et al. 2006), and potential spread (MigClim, Engler and Guisan 2009). The mechanics of these models won't be described in detail here – further information is available from the publications noted in the sections below. The general process for modelling will be described and the specific parameters used are available in the data form accompanying each individual PARS (Appendix 2).

Climate suitability modelling

CLIMEX (Sutherst & Maywald 1985; Sutherst et al. 2007) is a modelling package that enables users to model the climatic potential distribution of organisms based primarily on their current distribution, through taking into consideration climate response information from other knowledge domains if this is available. It is the most suitable climate modelling package for this analysis because it supports model-fitting to global plant distributions, includes a climate change scenario mechanism, and provides insight into the plant's ecological response to climate (Kriticos and Randall 2001). The Compare Locations module in CLIMEX models climatic suitability for a species, rather than habitat similarity (Kriticos et al. 2007, Sutherst et al. 2007). CLIMEX uses biologically relevant functions to relate species climate suitability to raw climate data.

CLIMEX is a dynamic bioclimatic model that integrates the weekly responses of a population to climate using a series of annual indices. CLIMEX uses an annual growth index (GIA) to describe the potential for population growth as a function of soil moisture and temperature during favourable conditions, and up to eight stress indices (cold, wet, hot, dry, cold-wet, cold-dry, hot-wet and hot-dry) to determine the probability that the population can survive unfavourable conditions (Table 1). The growth and stress indices are calculated weekly and are then combined into an overall annual index of climatic suitability, the Ecoclimatic Index (EI), which gives an overall measure of the potential of a given location to support a permanent population of the species. The Ecoclimatic Index (EI), ranges from 0 for locations at which the species is not able to persist to 100 for locations that are optimal for the species year round.

CLIMEX relies on a database of climatic variables of long-term monthly precipitation totals, averages of minimum and maximum temperatures, and averages of relative humidity at 09:00 and 15:00 hours. The historical climate dataset used for these analyses was the CliMond dataset (www.climond.org), with a spatial resolution of 10', using station records centered on 1975 (Kriticos et al. 2012).

The impacts of climate change on the potential for each species to grow or pose an invasion risk were explored using a climate scenario model for 2070 taken from the CliMond dataset (Kriticos et al. 2012). The selected climate datasets were developed using the A1B emission scenario applied to the CSIRO Mk 3.0 global climate model.

Table 1: Climex parameters, definitions and units

Climex parameter			**Unit**
Temperature index	Lower threshold Lower optimum threshold Upper optimum threshold Upper threshold	DVO DV1 DV2 DV3	°C °C °C °C
Moisture index	Lower soil moisture threshold Lower optimum soil moisture threshold Upper optimum soil moisture threshold Upper soil moisture threshold	SM0 SM1 SM2 SM3	
Cold stress	Cold-stress temperature threshold Cold-stress accumulation rate Cold-stress DD threshold Cold-stress DD rate Cold-stress temperature threshold Cold-stress temperature rate	TTCS THCS DTCS DHCS TTCSA THCSA	°C Week-1 DD °C
Heat stress	Heat-stress temperature threshold Heat-stress accumulation rate Heat-stress DD threshold Heat-stress DD rate	TTHS THHS DTHS DHHS	°C Week-1 DD
Dry stress	Dry-stress threshold soil moisture Dry-stress accumulation rate	SMDS HDS	 Week-1
Wet stress	Wet-stress threshold soil moisture Wet-stress accumulation rate	SMWS HWS	 Week-1
Cold-dry stress	Cold-dry DD threshold Cold-dry moisture threshold Cold-dry stress accumulation rate	DTCD MTCD PCD	DD Week-1
Cold-wet stress	Cold-wet DD threshold Cold-wet moisture threshold Cold-wet stress accumulation rate	DTCW MTCW PCW	DD Week-1
Hot-dry stress	Hot-dry temperature threshold Hot-dry moisture threshold Hot-dry stress accumulation rate	TTHD MTHD PHD	°C Week-1
Hot-wet stress	Hot-wet temperature threshold Hot-wet moisture threshold Hot-wet stress accumulation rate	TTHW MTHW PHW	°C Week-1
DD accumulation above DVCS DD accumulation above DVHS DD per generation	Cold-stress DD temperature threshold Heat-stress DD temperature threshold Degree-day threshold. (minimum annual total number of degree days above DV0 needed for population persistence	DVCS DVHS PDD	°C °C °C days

For each species, we used parameters sets that were either published or which we have developed. The parameters sets used for individual species are available in the data form which accompanies each PARS.

Models were run for current and future climate scenarios and then the future EI value (range between 0 – 100) was subtracted from the current EI value to calculate how climate suitability might change over time. Areas with values less than -5 were considered declining in climate suitability, values between -5 and 5 were considered stable, and areas with values greater than 5 were considered to have improving climate suitability.

Habitat suitability modelling

Habitat suitability models were generated using MaxEnt (Phillips et al. 2006, Phillips and Dudik 2008). MaxEnt is a presence-only distribution modelling algorithm based on the principle of maximum entropy, that builds statistical relationships between where a species occurs and the available environment (aka background). In short, MaxEnt takes a list of species presence locations as input, often called presence-only data, as well as a set of environmental predictors (e.g. vegetation type, land use, elevation) across a user-defined landscape that is divided into grid cells. From this landscape, MaxEnt extracts a sample of background locations that it contrasts against the presence locations. Presence is unknown at background locations (Merow et al. 2013). The model expresses the suitability of each grid cell as a function of the environmental variables at that grid cell. A high value at a particular grid cell indicates that the grid cell is predicted to have suitable conditions for that species. The computed model is a probability distribution (i.e. ranging from 0 – 1) over all the grid cells.

This type of modelling is quite difficult for invasive species, particularly those with only limited current distributions in Australia. Where distributions are limited building a relationship between where the species occurs and environment can result in misleading, constrained potential habitat suitability. Therefore, for species with limited distributions, we restricted environment layers to those that were less influenced by the specifics of the location where the species occurred but rather were reflective of the types of habitats that the species was likely to occur in. Thus layers of foliage projective cover and broad vegetation group were used in all habitat suitability models, and other layers including elevation and slope were only used for species that were widespread throughout the region.

Habitat suitability and current climate suitability were re-scaled on a range of 0-50 and added together. Depending on the score, suitability was classified as:

Score	Suitability classification
0[1]	Unsuitable
1 - 5	Low
6 – 25	Favourable
> 25	Highly favourable

1 – a score of 0 in the climate suitability model alone also resulted in an unsuitable classification

The source and further details about each of the layers is given in Table 1 of Appendix A.

Spread modelling

The MIGCLIM model (Engler and Guisan 2009) is a cellular automaton designed to implement dispersal constraints into projections of species distributions under environmental change; it can equally well be used to simulate dispersal in stable environments such as when modeling potential spread of invasive species (Engler et al. 2012).

MIGCLIM couples the predictive distribution maps (generated via the climate and habitat suitability modelling above) representing a species habitat suitability with a cell-based model that simulates dispersal, colonization, growth and extinction of the species in the landscape. A number of specific parameters can be defined, such as dispersal distance, barriers to dispersal, landscape fragmentation, stochastic long- distance dispersal (LDD) or increase in reproductive potential over time (Engler and Guisan 2009).

For each species the following inputs were used to run MIGCLIM (details for each species are given in their respective data form):

- A habitat suitability layer. This was generated from the combined output of the climate suitability and habitat suitability layers as described above.
- The known distribution of the species. Distribution data was compiled from a number of sources including herbarium records, local government databases, and expert knowledge. It is important to note that some infestations may not currently be active.
- Parameters for dispersal. MIGCLIM takes a vector of values indicating the probability of a source cell to disperse propagules as a function of distance (in cell units). Long distance dispersal events are randomly generated with user defined frequency within a user defined distance range (min, max). Long-distance dispersal events aim at representing non-standard ways of propagule dispersal e.g. seed dispersed by vehicles or other anthropogenic means.
- Parameters for propagule production potential. The probability of a source cell to produce propagules as a function of time since the cell became colonized. This is specified via 2 parameters: initial maturity age and a vector indicating the probability of propagule production for each age between initial and full maturity. This parameter can be used as a proxy for population growth in the cell, or for instance to reflect that a species might need several years before starting to produce propagules, and even more time to reach its full reproductive potential. The time unit is a dispersal step, which will usually represent one year.

Very briefly, the process for MIGCLIM is:
1. In each time step look at each location in a landscape (defined by cells in the model) and check: (1) is the species currently absent from the cell, and (2) does the cell represent suitable habitat?
2. If YES, the number of potential source cells within the dispersal kernels maximum dispersal distance is computed.
    - Source cells are occupied cells that can act as propagule sources
3. If (2) is greater than 0, the target cell becomes occupied with the combined probability of:
    a) The distance between the target and source cell (given by the dispersal kernel)
    b) Time since the source cell became occupied (propagule production and initial maturity age parameters), and
    c) The suitability (or invasibility) of the cell
4. Long-distance dispersal (LLD) events are generated from source cells in a random direction and at a random distance between the min and max of the long-distance dispersal parameter. If the cell reached by the LLD is suitable it becomes colonised.

We ran the MIGCLIM models (100 times) over a 50 year time period and at a 100 m grid cell resolution. The probability of spread to a region was scored on a scale of 1 – 6 as per below.

Score	Probability of spread within x years
1	0 – 10 years
2	11 - 20 years
3	21 – 30 years
4	31 – 40 years
5	41 – 50 years
6	> 50 years

Dispersal parameters were estimated from a number of sources depending on information available. Information on dispersal curves for fleshy fruited species was sourced from the literature or from data collected by the CSIRO project team. Where no specific dispersal data was known, dispersal parameters were generated using information about a species' mode of dispersal, seed size, release height (for wind dispersed species) and terminal velocity (when known, for wind dispersed species). The R package dispeRsal (Tamme et al. 2013) was run to calculate maximum dispersal distances for species.

Deriving the risk and future investment profile

The risk of future invasion (high, moderate, low) over 50 years was determined as a function of habitat suitability, climate change and probability of spread. The details of this are shown in Table 2 in Appendix A. In short, areas with unsuitable habitat, low probability of spread and regardless of climate change always have low risk. Areas with moderate to high habitat suitability and any probability of spread, particularly if climate is improving have moderate to high risk.

The future investment profile for each management unit in each LGA across the region was derived from the risk profile and current management objectives using a categorical matrix. Thus, if for example, the current management objective is 'removal' (eradication) and the risk is 'moderate' then the investment outlook is 'stable' i.e be prepared to sustain current investments to minimize impacts (third column, second row). If the current management objective is 'intensive control' and the risk is 'high' the investment outlook is 'high', i.e. be prepared to increase investment to minimize impacts (fourth column, third row).

Table 2: Investment outlook is derived from the current management objective and the risk profile

Management objectives:
DEL = Delimitation; PRE = Prevention, REM = Eradication, INT = intensive control, IMP = impact reduction, ALE = alert, NMO = No management objective, NSH = Not suitable habitat
Letters in brackets indicate the risk profile: (L) = low, (M) = moderate, (H) = high

PARS RISK (stage three) Immediate risk Management outlook/effort (0-10 years)	MANAGEMENT OBJECTIVE							
RISK high Stable low	DEL(L)	PRE(L)	REM(L)	INT(L)	IMP(L)	ALE(L)	NMO(L)	NSH(L)
	DEL(M)	PRE(M)	REM(M)	INT(M)	IMP(M)	ALE(M)	NMO(M)	NSH(M)
	DEL(H)	PRE(H)	REM(H)	INT(H)	IMP(H)	ALE(H)	NMO(H)	NSH(H)

A case study species – Brillantaisia lamium

Brillantaisia lamium is a large herb native to central and western Africa. It occurs in north and south-eastern Queensland. It is a listed 'sleeper weed' but is not currently declared under Queensland legislation. Brillantaisia can form dense stands along waterways and can cause serious impacts to riparian habitat and other native vegetation.

Figure 2: Brillantaisia lamium habit and flower

Current management objectives

Brillantaisia is distributed across three local government planning areas (Figure 3) and currently has sub-basin management objectives across the PARS region comprising prevention (23%), eradication (1%), intensive control (3%) and impact reduction (1%). An alert is identified across 45% of the region, no management objective is allocated in 9% and 17% of the region is identified as not suitable habitat.

An impact profile by sector (conservation and biodiversity, riparian and aquatic, agriculture and production, urban and residential) for Brillantaisia was summarised from the LGA Pest Management Plans. Distribution of the species outside the region is also noted in this section. Thus, Brillantaisia is expected to have the greatest impact on aquatic systems and water resources followed by biodiversity and conservation, with lesser impacts on urban and agricultural systems.

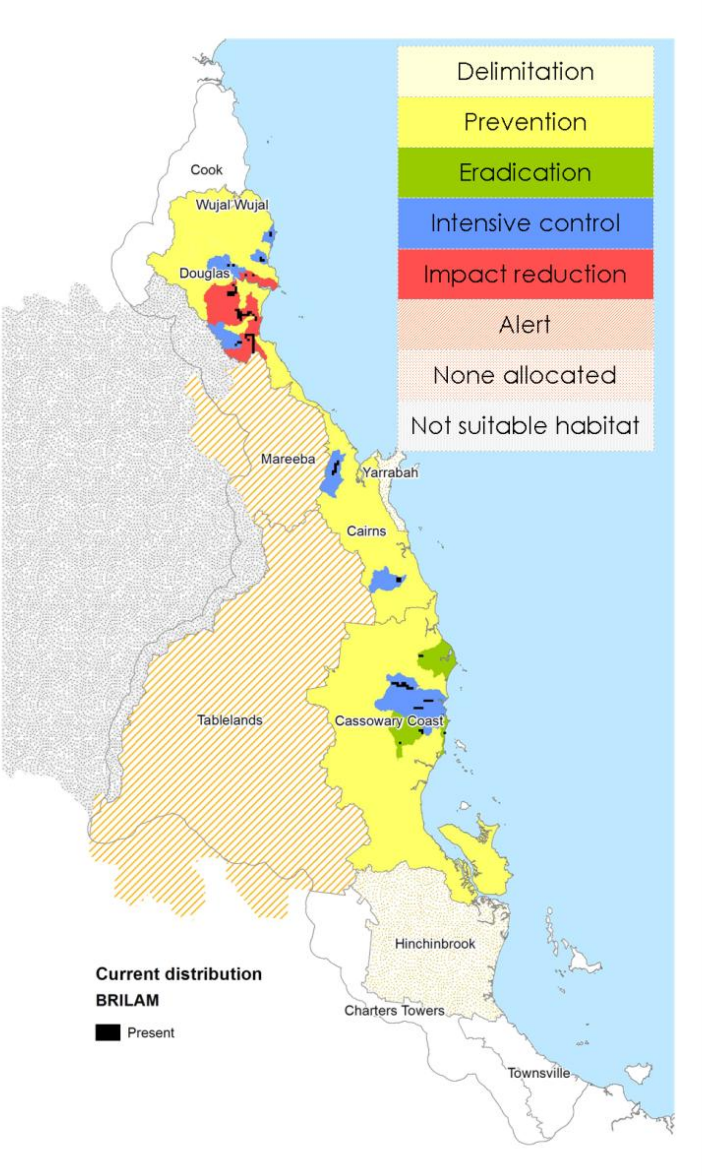


Figure 3: Current management objectives for Brillantaisia

Climate suitability

Climate modelling for Brillantaisia indicates highly favourable climate across the eastern part of the region in both current (Figure 4a) and future climates (Figure 4b). Climate suitability is increasing around Cairns and decreasing or remaining stable over the remainder of the region (Figure 4c).

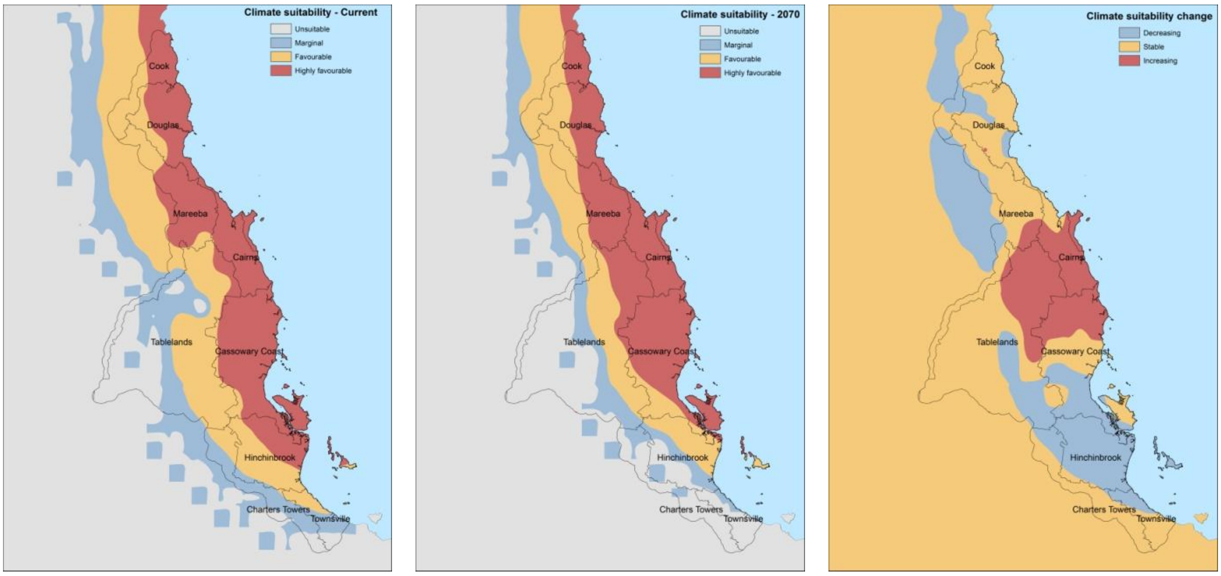


Figure 4: Climate suitability modelling for Brillantaisia

Habitat suitability

The habitat suitability modelling reflects a combination of climate suitability and habitat suitability (Figure 5). In this case habitat suitability was modeled using parameters of broad vegetation group, population density, foliage projective cover and elevation. Most of the region is highly favourable habitat for Brillantaisia.

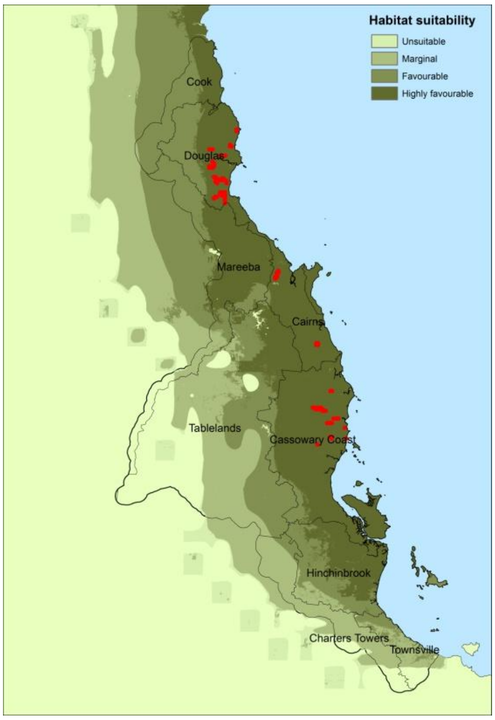


Figure 5: Habitat suitability and current distribution for Brillantaisia. Red dots indicate the current distribution

Spread modelling

The dispersal parameters used for the Brillantaisia spread model reflect a limited capacity to disperse; while the species is wind-dispersed it has no significant seed adaptation allowing it to travel longer distances (e.g. explosively released, long pappus) and its maximum release height is relatively low (approx 2 metres). Thus the dispersal curve reflected a 100% probability of dispersal within 1 grid cell (100 m) and a 10% probability of dispersal within 2 grid cells (100 m – 200 m). The model included a long-distance dispersal parameter reflecting a 1% probably that a given cell (at full propagule production) would produce a seed that travelled between 300 m and 1 km to reflect the potential for secondary dispersal via water, vehicles etc. Propagule production was assumed to occur within one year.

The results of spread modelling are presented in two ways. Figure 6a shows the potential timing of spread (over 50 years) from places where the species is known to occur or have occurred. Figure 6b indicates the probability of spread over the same time period. The reason that both figures are shown is that the type of modelling used here is stochastic, or random, meaning that the results are determined by probability distributions. Normally with stochastic models many runs (i.e. >=100) are completed and results are averaged or compiled together so that random results in any one run of the model are not given undue importance. We ran MigClim 100 times; on average, differences in year of spread into any given grid cell between the 100 runs of the model was very small (<1 years). Therefore we chose one random run out of the 100 to give an indication of the potential timeframe over which spread may occur (Figure 6a). We also summed all 100 runs to generate a probability that spread would occur into a given cell within 50 years (Figure 6b).

The results of the modelling indicate that, if left unchecked, Brillantaisia could spread rapidly from existing infestations. In particular, Mareeba Shire, which is currently free of Brillantaisia could see spread from infestations north of Cairns and from the southern end of Douglas Shire.

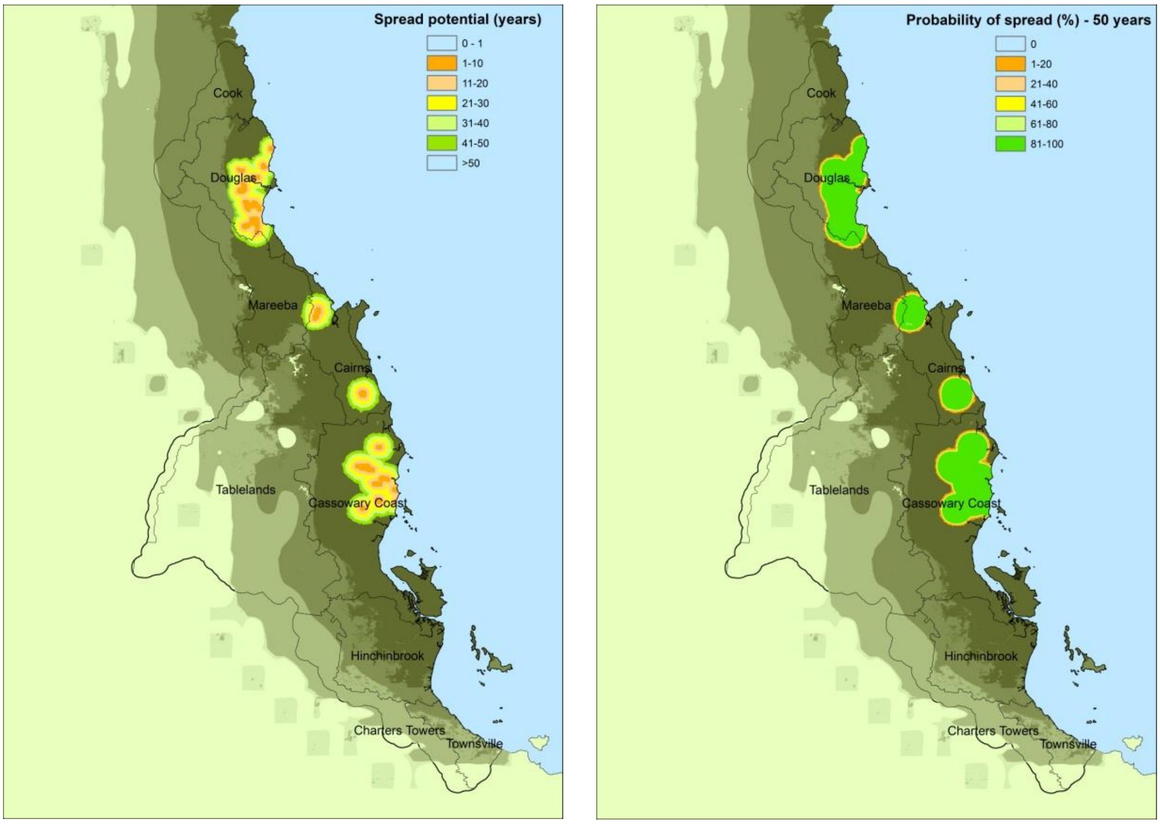


Figure 6: Results of spread modelling

(a) spread potential in years over a 50 year time frame, and (b) the probability of spread after 50 years.

Future risk and management outlook

Considering the climate suitability of the region is high and mostly stable or increasing around existing infestations, and habitat suitability is also favourable the risk profile of the species reflects a high risk in all areas where spread may occur within 10 years (Figure 7). The investment outlook in these areas is generally ‘high’ i.e. be prepared to increase investment. Areas with a high probability of spread surrounding existing infestations and which mostly have a current management objective of ‘prevention’ generally have an investment outlook reflecting a need to sustain current investments, i.e. ‘stable’ (Figure 8).

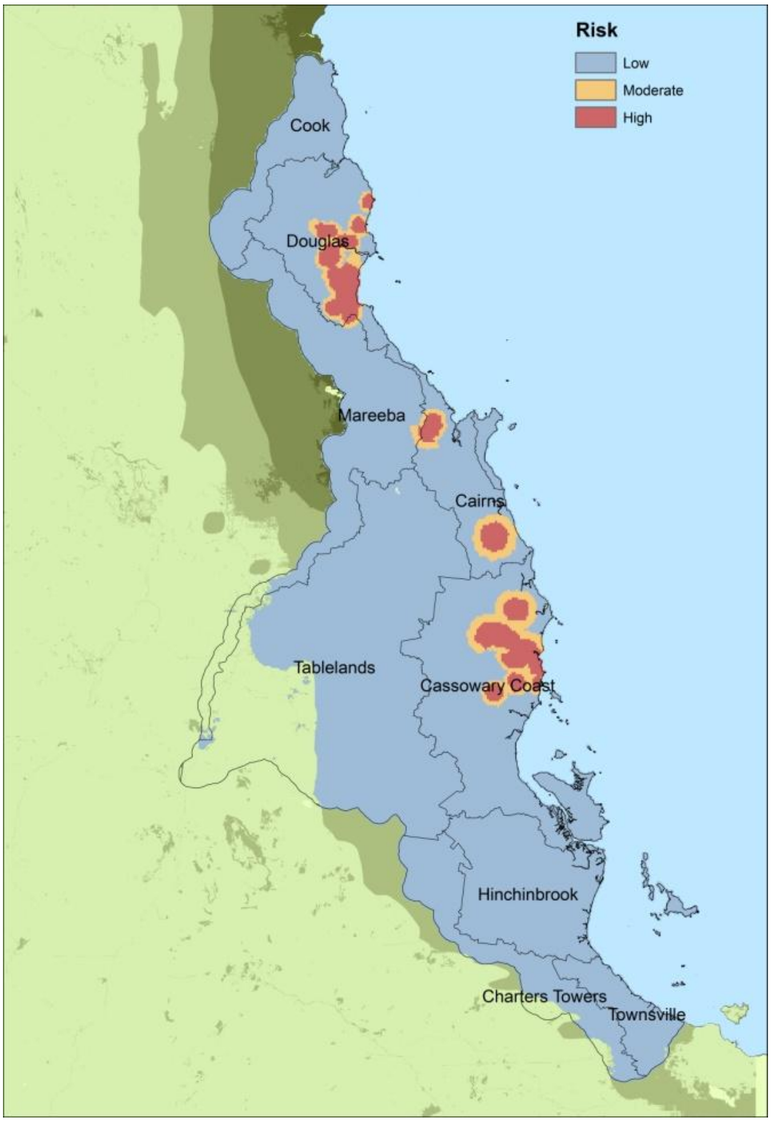


Figure 7: Risk of invasion over a 50 year time-frame

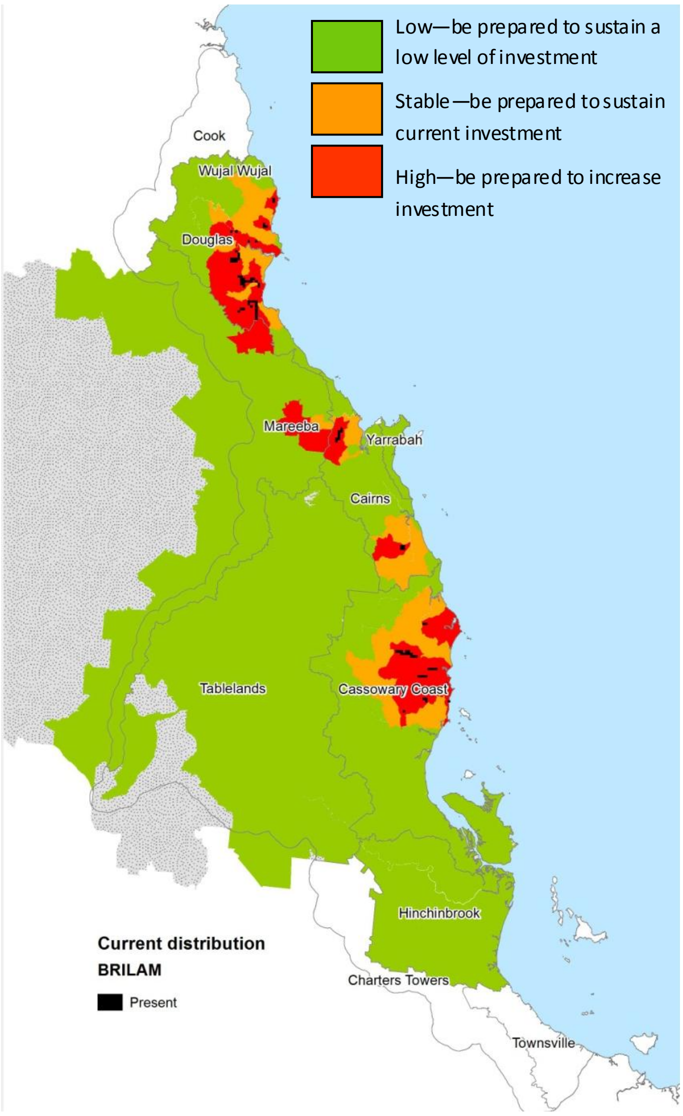
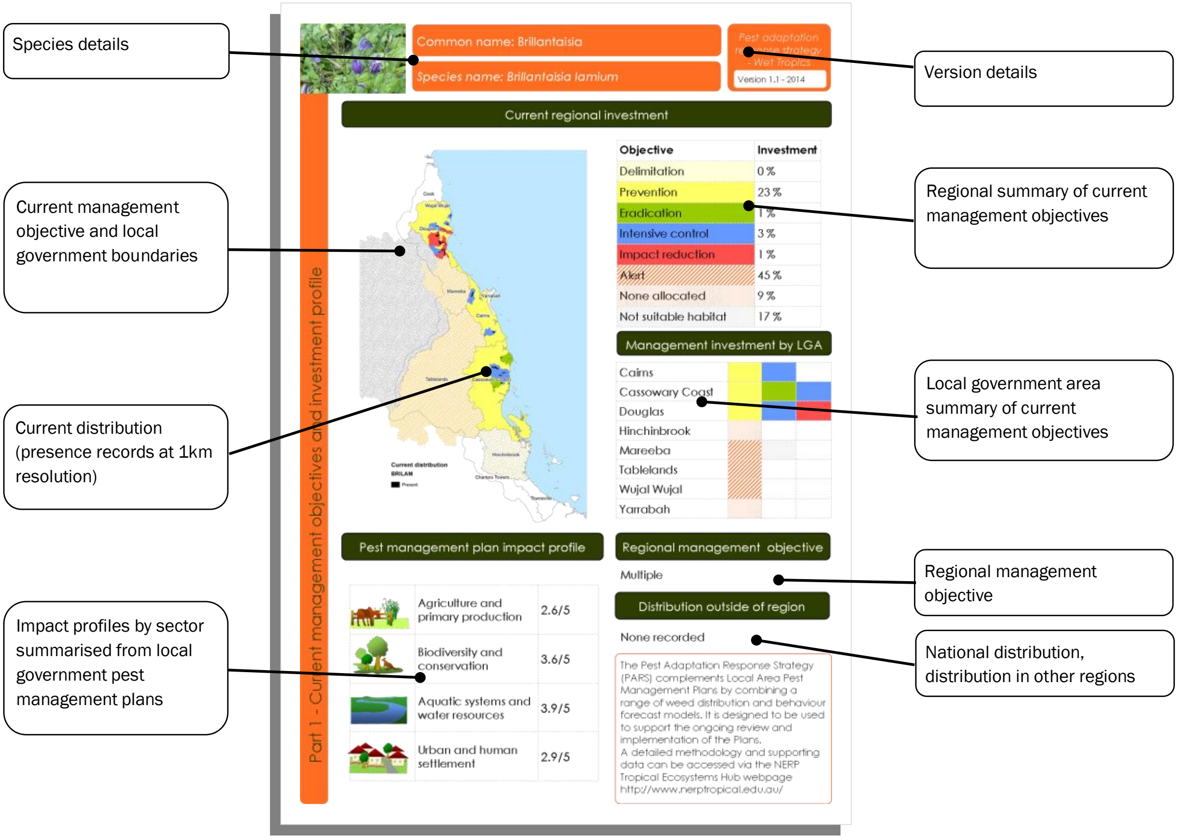
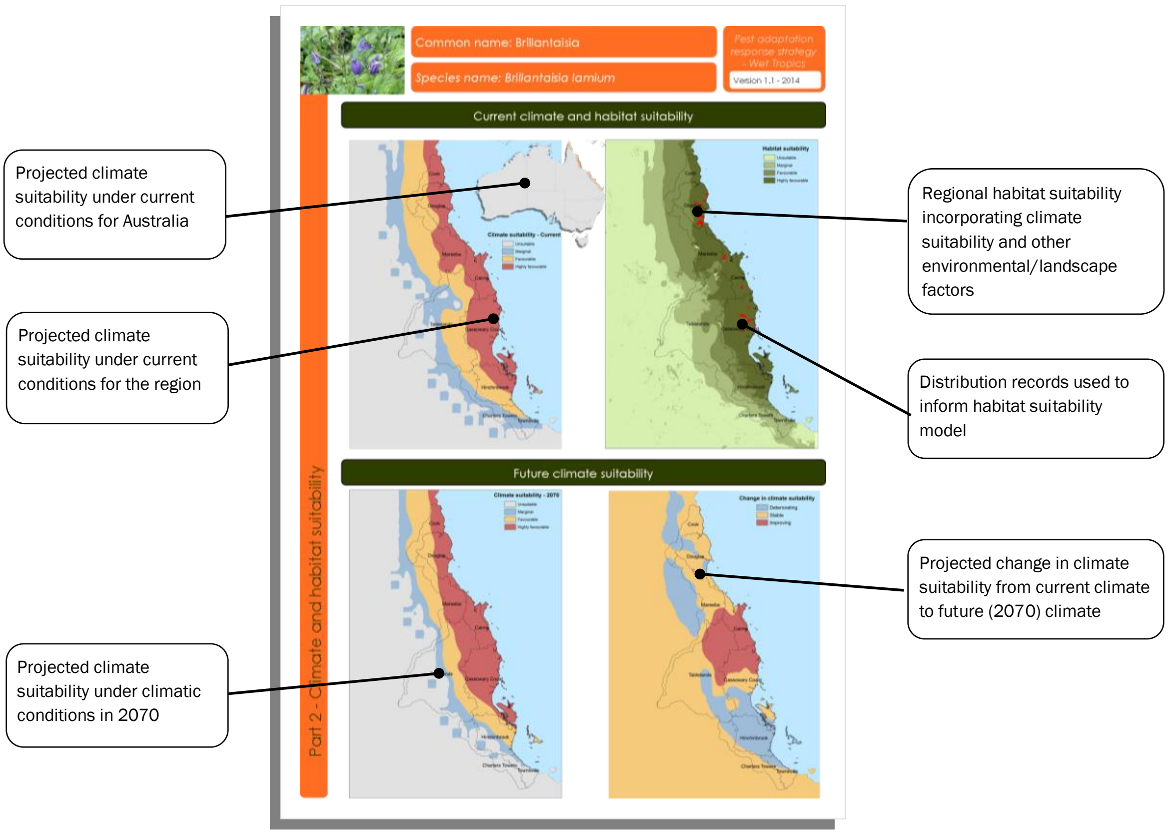


Figure 8: Investment outlook for Brillantaisia

The PARS layout

The following four figures (Figure 9) show the PARS layout with commentary, incorporating all of the above figures. Appendix 2 contains the Data Form for Brillantaisia which outlines all the model parameters used.


Species details
Common name: Brillantaisia
Species name: Brillantaisia lamium
Version details
Current regional investment
Current management objective and local government boundaries
Regional summary of current management objectives
Objective
Investment
Delimitation
0 %
Prevention
23 %
Eradication
1 %
Intensive control
3 %
Impact reduction
1 %
Alert
45 %
None allocated
9 %
Not suitable habitat
17 %
Management investment by LGA
Cairns
Cassowary Coast
Douglas
Hinchinbrook
Mareeba
Tablelands
Wujal Wujal
Yarrabah
Local government area summary of current management objectives
Current distribution (presence records at 1km resolution)
Part 1 - Current management objectives and investment profile
Pest management plan impact profile
Agriculture and primary production
2.6/5
Biodiversity and conservation
3.6/5
Aquatic systems and water resources
3.9/5
Urban and human settlement
2.9/5
Impact profiles by sector summarised from local government pest management plans
Regional management objective
Multiple
Regional management objective
Distribution outside of region
None recorded
National distribution, distribution in other regions
The Pest Adaptation Response Strategy (PARS) complements Local Area Pest Management Plans by combining a range of weed distribution and behaviour forecast models. It is designed to be used to support the ongoing review and implementation of the Plans.
A detailed methodology and supporting data can be accessed via the NERP Tropical Ecosystems Hub webpage
http://www.nerptropical.edu.au/


Common name: Brillantaisia
Species name: Brillantaisia lamium
Version 1.1 - 2014
Current climate and habitat suitability
Projected climate suitability under current conditions for Australia
Regional habitat suitability incorporating climate suitability and other environmental/landscape factors
Projected climate suitability under current conditions for the region
Distribution records used to inform habitat suitability model
Future climate suitability
Projected change in climate suitability from current climate to future (2070) climate
Projected climate suitability under climatic conditions in 2070
Part 2 - Climate and habitat suitability

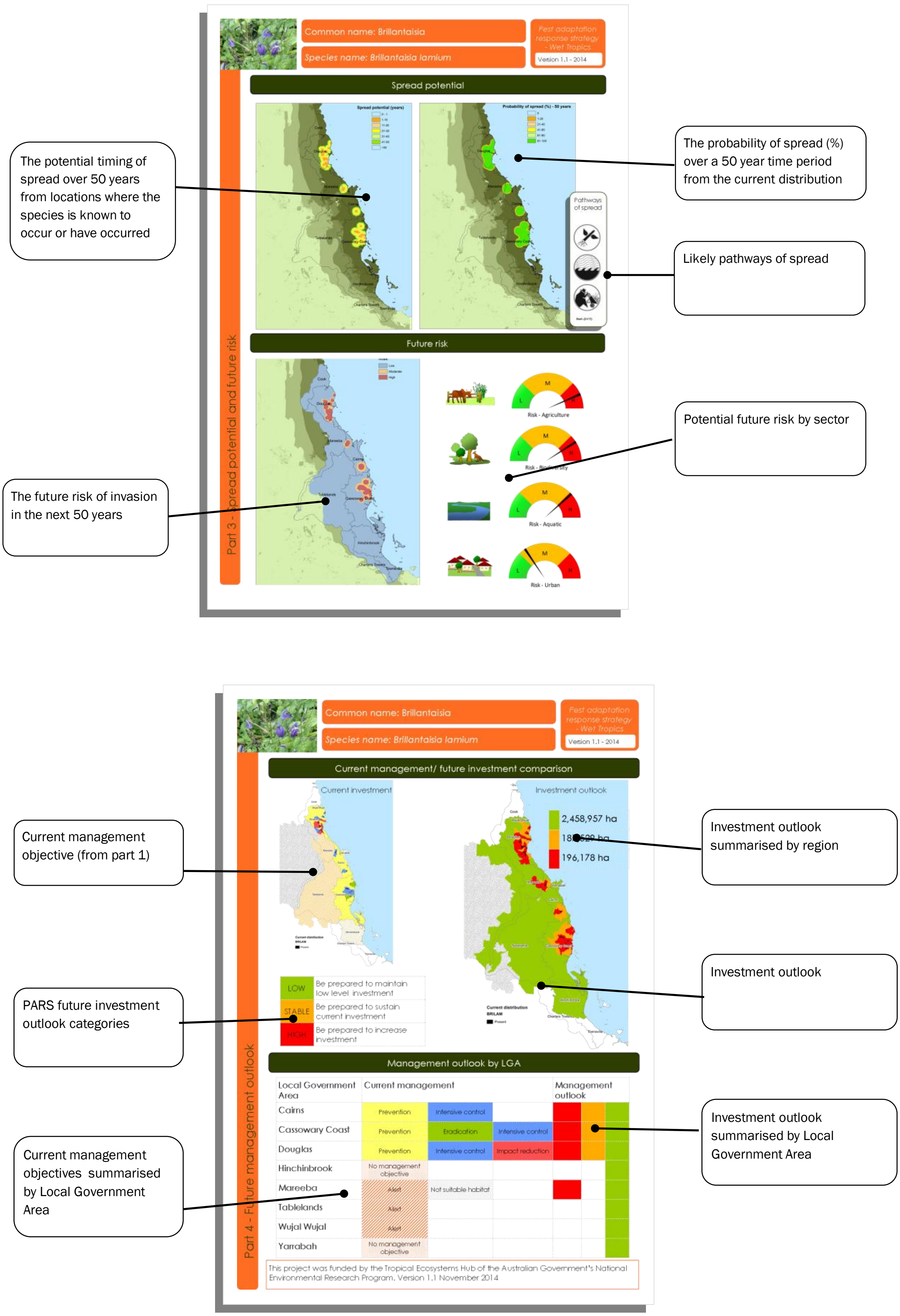


Figure 9: The PARS layout with commentary

Summary

PARS have so far been developed for a number of high priority weeds of the Wet Tropics region. It is intended that more species will be added to this list as priority dictates. Completed PARS and the accompanying data files can be viewed at the FNQROC website.

Pest management is a learning-by-doing process and there is a growing emphasis placed on our ability to adapt to a dynamic management and planning landscape. Alongside this is an increasing demand for the modelled component of the adaptive cycle of visualising contemporary or future scenarios in the distribution, impact or spread of the target species to better inform 'real' scenarios. Much of our future capacity to respond to pests and weeds will be reliant on our ability to adapt management objectives to suit shifts and changes in environmental conditions; as well as the usual socio-political climate and a continually evolving understanding of invasive species. New opportunities to consider long term trajectories of management programs may assist to better communicate the spatial and temporal scales management actually occurs within.

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APPENDIX 1

Table 1: Spatial layers used in MaxEnt habitat suitability modelling

Layer	Source details	Reference
Elevation	ASTER Global Digital Elevation Model	http://asterweb.jpl.nasa.gov/gdem.asp
Slope	ASTER Global Digital Elevation Model	http://asterweb.jpl.nasa.gov/gdem.asp
Foliage Projective Cover	Foliage Projective Cover 2011 series	https://data.qld.gov.au/dataset/foliage-projective-cover-2011-series
Broad Vegetation Group	Version 1.0 Remnant 2011 Broad Vegetation Groups (BVG) of Queensland, derived from the Regional Ecosystem (RE) mapping.	https://data.qld.gov.au/dataset/remnant-2011-broad-vegetation-groups-of-queensland

Table 2: The risk profile is derived from probability of spread, habitat suitability and climate change layers

Probability of spread (years)	Habitat suitability	Climate change	Risk
<10 years	Unsuitable	Declining	Low
<10 years	Low	Declining	Low
<10 years	Favourable	Declining	High
<10 years	Highly favourable	Declining	High
<10 years	Unsuitable	Stable	Low
<10 years	Low	Stable	Low
<10 years	Favourable	Stable	High
<10 years	Highly favourable	Stable	High
<10 years	Unsuitable	Increasing	Low
<10 years	Low	Increasing	Moderate
<10 years	Favourable	Increasing	High
<10 years	Highly favourable	Increasing	High
11-20 years	Unsuitable	Declining	Low
11-20 years	Low	Declining	Low
11-20 years	Favourable	Declining	Moderate
11-20 years	Highly favourable	Declining	High
11-20 years	Unsuitable	Stable	Low
11-20 years	Low	Stable	Low
11-20 years	Favourable	Stable	Moderate
11-20 years	Highly favourable	Stable	High
11-20 years	Unsuitable	Increasing	Low
11-20 years	Low	Increasing	Moderate
11-20 years	Favourable	Increasing	High
11-20 years	Highly favourable	Increasing	High

Probability of spread (years)	**Habitat suitability**	**Climate change**	**Risk**
21-30 years	Unsuitable	Declining	Low
21-30 years	Low	Declining	Low
21-30 years	Favourable	Declining	Moderate
21-30 years	Highly favourable	Declining	Moderate
21-30 years	Unsuitable	Stable	Low
21-30 years	Low	Stable	Low
21-30 years	Favourable	Stable	Moderate
21-30 years	Highly favourable	Stable	Moderate
21-30 years	Unsuitable	Increasing	Low
21-30 years	Low	Increasing	Low
21-30 years	Favourable	Increasing	High
21-30 years	Highly favourable	Increasing	High
31-40 years	Unsuitable	Declining	Low
31-40 years	Low	Declining	Low
31-40 years	Favourable	Declining	Low
31-40 years	Highly favourable	Declining	Low
31-40 years	Unsuitable	Stable	Low
31-40 years	Low	Stable	Low
31-40 years	Favourable	Stable	Low
31-40 years	Highly favourable	Stable	Low
31-40 years	Unsuitable	Increasing	Low
31-40 years	Low	Increasing	Low
31-40 years	Favourable	Increasing	Moderate
31-40 years	Highly favourable	Increasing	Moderate
41-50 years	Unsuitable	Declining	Low
41-50 years	Low	Declining	Low
41-50 years	Favourable	Declining	Low
41-50 years	Highly favourable	Declining	Low
41-50 years	Unsuitable	Stable	Low
41-50 years	Low	Stable	Low
41-50 years	Favourable	Stable	Low
41-50 years	Highly favourable	Stable	Low
41-50 years	Unsuitable	Increasing	Low
41-50 years	Low	Increasing	Low
41-50 years	Favourable	Increasing	Moderate
41-50 years	Highly favourable	Increasing	Moderate
>50 years	Unsuitable	Declining	Low
>50 years	Low	Declining	Low
>50 years	Favourable	Declining	Low
>50 years	Highly favourable	Declining	Low
>50 years	Unsuitable	Stable	Low

Probability of spread (years)	Habitat suitability	Climate change	Risk
>50 years	Low	Stable	Low
>50 years	Favourable	Stable	Low
>50 years	Highly favourable	Stable	Low
>50 years	Unsuitable	Increasing	Low
>50 years	Low	Increasing	Low
>50 years	Favourable	Increasing	Low
>50 years	Highly favourable	Increasing	Low

APPENDIX 2

PARS Data Form for Brillantaisia lamium

Data Form: *Brillantaisia lamium*

Climex parameters

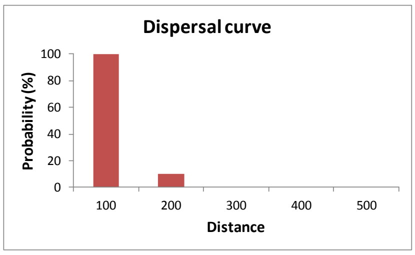
Parameters	Values	
Temperature	DV0	15
	DV1	28
	DV2	33
	DV3	40
Moisture	SM0	0.25
	SM1	0.7
	SM2	1.7
	SM3	3
Cold stress	TTCS	
	THCS	
	DTCS	25
	DHCS	-0.001
	TTCSA	
	THCSA	
Dry stress	SMDS	0.25
	HDS	-0.025
Model time step	MTS	7
DD cold stress temperature threshold	DVCS	15
DD heat stress temperature threshold	DVHS	40
DD per generation	PDD	

Climex source: Revised for RIRDC weeds portal from Scott, J.K., Batchelor, K.L., Ota, N. and Yeoh, P.B. (2008) Modelling climate change impacts on sleeper and alert weeds: final report to Land and Water Australia.
CSIRO Data Access portal

Habitat suitability

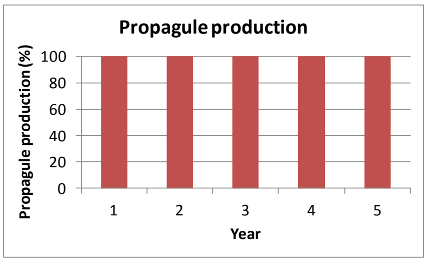
Layers used:
Broad vegetation group
Population density
Foliage projective cover
Elevation

MigClim parameters



Long-distance Dispersal (LDD):
Frequency: 1%
Min distance: 300 m
Max distance: 1 km

Primary dispersal mode: wind
Adaptations: none
Secondary dispersal: water, humans, vegetative



Propagule production occurs within:
1 year