Invasive Plant Species in Port of Brisbane

Weed Monitoring and Pilot Modelling

Customer	Port of Brisbane
Project	B232621
Deliverable	24
Version	02
	4 September 2024

Document Control

Document Identification

Title	Invasive Plant Species (Pilot Weed Modelling) in Port of Brisbane
Project No	B232621
Deliverable No	24
Version No	02
Version Date	4 September 2024
Customer	Port of Brisbane
Classification	BMT (OFFICIAL)

Author	Julian Manning, Kara Borthwick
Checked By	Darren Richardson, Mackenzie Stacey
Project Manager	Mackenzie Stacey

Amendment Record

The Amendment Record below records the history and issue status of this document.

Version	Version Date	Distribution	Record
00	28 June 2024	Port of Brisbane	Draft
01	03 September 2024	BMT	Internal Draft
02	04 September 2024	Port of Brisbane	Final

Executive Summary

PBPL has been completing annual weed monitoring surveys since 2001, which provides the basis for identifying and managing incursions of new priority weeds and weed outbreaks on Port lands. The weed monitoring program has to date relied on a field-based methodology, focussing on sites that are potentially vulnerable to weed invasions. However, this has numerous practical limitations (e.g. extent of areas surveyed) and is limited in predicting potential locations of future weed incursions.

In addition to presenting the field results from the 2024 weed monitoring survey, this report also includes results from a pilot study which employed Species Distribution Modelling (SDM) to predict potential species distribution based on known occurrences and environmental conditions. The SDM focuses on examining the environmental characteristics which influence the spread of specific invasive plant species. SDMs are widely used in conservation ecology to predict the presence-absence of species based on quantitative relationships to habitat variables.

This SDM approach consists of three main components:

- Occurrence Data: Geographic coordinates marking the locations of invasive plant species (obtained from the 2024 weed monitoring survey).
- Environmental Explanatory Variables (EEV): Abiotic and biotic conditions at these locations.
- Algorithm: A mathematical model linking occurrence data and environmental conditions to estimate species distribution probabilities.

The 2024 monitoring survey identified 38 invasive plant species in total within the 12 predefined survey areas. All the weed species recorded on PBPL lands are widespread in degraded coastal habitats of south-east Queensland. Weed composition and distribution remain relatively stable with only giant devils fig identified as a newly imported weed.

Only the most prevalent species were then selected for further descriptive and predictive modelling via an SDM, these were: castor oil, coral berry, easter cassia, groundsel bush, lantana, leucaena, mile-a-minute, broad-leaved pepper tree and sesbania pea. For SDM modelling the study utilised eight EEVs: soil temperature, aspect, digital elevation model (DEM), leaf area index (LAI), normalized difference vegetation index (NDVI), slope, solar radiation, and topographic wetness index (TWI). Each of these variables was individually modelled for the study. A machine learning algorithm based on the maximum entropy theory was used for modelling.

The model accurately predicted the spatial distribution of the nine selected species with high confidence. Key results include:

- The models were highly precise, forecasting over 80% of the species distribution beyond the initial target area.
- Soil temperature and solar radiation (particularly in summer) are the key predictors of weed distribution for most selected species. Other key predictors are NDVI, LAI and slope.
- Water stress is likely to be a key determining factor in weed colonisation and proliferation into the future. The most problematic weeds amongst the pilot subset were found to be castor oil, easter cassia, broad-leaved pepper tree, groundsel bush and lantana.

Based on the nine model outputs the key priority weeds which have higher probabilities of occurrence in each of the study areas was determined via visual inspection of the relative model outputs. These are summarised in Table 3.4.

The study has resulted in the following conclusions/recommendations for the Port:

- Regular monitoring of the key priority species identified as having high probabilities of occurence in each study area to better target weed control.
- Further calibration and development of the SDM would be required to provide long term forecasting of weed specie distributions. In the short term (<2 years) additional occurrence data would need to be collected to increase sample size and improve model accuracy. At the same time, high-resolution imagery from commercial satellites could be used to classify individual vegetation communities and tidal influence to improve the spatial resolution of the model.In the long-term (>2 years), the improved SDM could provide more accurate, spatially explicit predictions that could be used to help focus weed surveys in potential high-risk areas, which are not currently investigated.
- Early detection of new weed species will still require field surveys. Therefore, SDM and field survey methods are complimentary tools which will help meet the key objectives of monitoring priority weeds and detecting introduced species.

Contents

Tables

Figures

1 Introduction

1.1 Background

The Port of Brisbane Pty Ltd (PBPL) is responsible for the control and management of weeds on port lands. PBPL has been completing annual weed monitoring surveys since 2001, which provides the basis for identifying and managing incursions of new priority weeds and weed outbreaks on Port lands. The composition of weeds on port lands has remained relatively constant over time, although some pre-existing species vary in distribution and densities from year to year.

The weed monitoring program has to date relied on a field-based methodology, focussing on sites that are potentially vulnerable to weed invasions. The field-based approach has practical limitations in terms of survey area coverage, and there is a potential risk of undetected weed incursions in un-surveyed locations. The monitoring program also does not provide an objective means for predicting potential locations of future weed incursions.

Species distribution modelling (SDM) is widely used in conservation ecology to predict the presence-absence of species based on quantitative relationships to habitat variables. SDM allows for local scale customisation, integrating detailed plant occurrence reports with corresponding environmental variables such as temperature, rainfall, soil type, and sunlight exposure. The SDM can therefore provide enhanced understanding of plant species distribution over a broad area, and changes over time in response to changes in environmental drivers, especially climatic (past and potentially future) conditions.

In addition to presenting the results from the 2024 weed monitoring survey, this report describes the approach and findings of a pilot study into the application of SDM techniques to predict weed occurrence on Port lands. Nine weed species were modelled via the SDM technique (corresponding to the nine most prevalent weeds identified during the 2024 survey) to produce predictions of their distributions on Port lands more broadly (i.e. both inside and outside current survey boundaries). The models also allowed for an analysis of how each of the nine weeds responds to different environmental conditions/variables.

1.2 Objectives

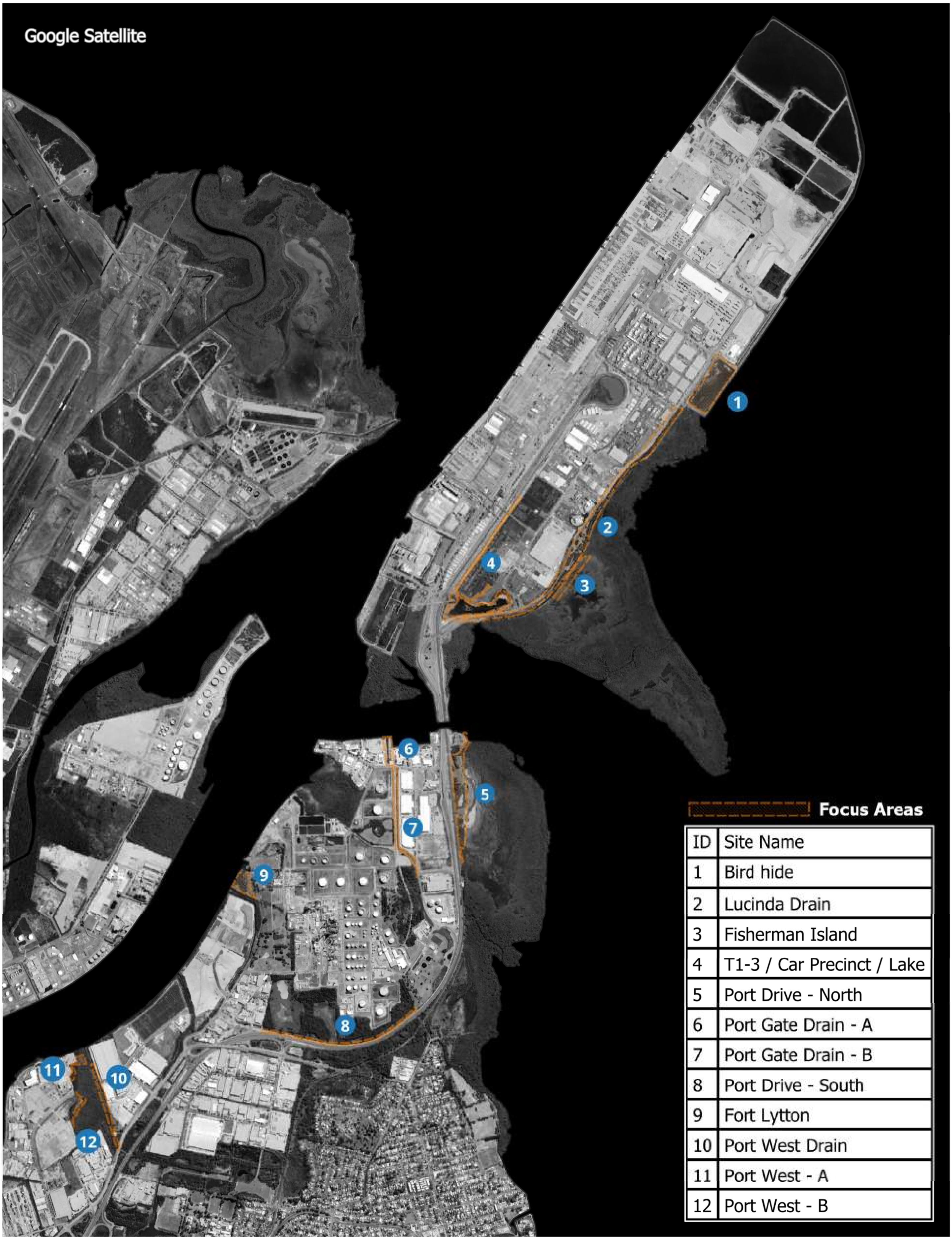
The specific objectives of this report are to:

- Based on the established weed monitoring program methodology:
  - Characterise habitat conditions at each survey site
  - Monitor priority weed species within high value natural assets managed by PBPL
  - Detect the introduction and spread of new weed species at survey sites and the broader port area
  - Provide recommendations for strategic weed management at the Port based on a risk-based approach which considers feasibility, likelihood of success and impact.
- For the nine most prevalent weed species, develop sub-models to:
  - quantify relationships between weed distribution and environmental variables
  - determine environmental variables best predicting weed distribution on PBPL lands at monthly time intervals
  - produce species distribution maps that extrapolate current data outside of existing survey boundaries to cover the entirety of Port lands

    - identify priority areas for management attention for each of the nine target weed species, and how these may change over time
- Provide recommendations for the future implementation of the PBPL weed monitoring program, taking into account cost, effort and additional data needs to improve model accuracy.

1.3 Study Area

The key focus areas surveyed during the 2024 weed monitoring event are displayed in Figure 1.1 and align with previous weed monitoring surveys. It is important to note that while the SDM pilot study modelled weed distributions for all Port lands (i.e. not solely confined to the survey boundaries), some mangrove areas were masked out for the modelling as growth of weed species in these areas is anticipated to be low due to tidal conditions.



Title:

Key Focus Areas for the Study of Invasive Plant Species

Figure: **1.1**

Rev: **A**

N 0 1 2 km

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants\QGIS\StudyArea.qgz

2 Methodology

2.1 Priority Target Species

Priority weeds targeted in the survey are plant species listed under one or more of the following categories:

- Weeds of National Significance (WoNS) (refer Annex A)
- Prohibited and Restricted Matters regulated under the Queensland *Biosecurity Act 2014* (refer Annex B)
- Environmental weeds listed by the Brisbane City Council (refer Annex C).

In addition to weed species in the categories listed above, the survey targeted native species that have the potential to negatively impact local natural assets. In particular, the survey targeted Sesbania pea (*Sesbania cannabina*), which is a native woody species that is being monitored at PBPL for it's potential to spread within and alter habitat conditions in local saltmarsh for waders. As the species can form dense thickets and substantial seedbanks it may have the potential to displace low saltmarsh cover and may provide conditions more suitable for exotic grasses.

2.2 Survey Approach

In accordance with previous monitoring surveys, weed inspections in 2024 were undertaken in late April (post summer). The survey sites assessed in 2024 are shown in Figure 1.1 with site coordinates documented in Table 2.1.

Table 2.1 Centroid coordinates and area of weed survey sites

ID	Site Name	Latitude (WGS84)	Longitude (WGS84)	Area (hectare)
1	Bird Hide	-27.374	153.186	8.10
2	Lucinda Drain	-27.385	153.176	15.20
3	Fisherman Island	-27.389	153.175	2.10
4	T1-3 / Car Precinct / Lake	-27.390	153.167	5.20
5	Port Drive - North	-27.405	153.167	7.55
6	Port Gate Drain - A	-27.402	153.161	1.55
7	Port Gate Drain - B	-27.407	153.162	2.80
8	Port Drive - South	-27.424	153.158	2.75
9	Fort Lytton	-27.413	153.149	2.00
10	Port West Drain	-27.430	153.139	2.45
11	Port West - A	-27.427	153.136	0.85
12	Port West - B	-27.430	153.136	0.65

The survey was conducted by qualified ecologists. All surveys were conducted on-foot. Incidental observations of target weed species outside the survey sites were also recorded. The locations of all notable weed observations were recorded on a handheld GPS and weed identification was undertaken on site.

Whilst every effort has been made to identify targeted weed species in the PBPL survey sites, the detectability of plant species and the ability to accurately identify these in the field varies with seasonal and climatic conditions. Such conditions influence the presence of reproductive features (flowers, fruits and seeds) which are useful, and in some cases essential, for species identification. Consequently, the survey conducted should not be regarded as conclusive that targeted weeds do not occur at the Port.

2.3 Species Distribution Modelling

The construction of an SDM for this assessment (illustrated in Figure 2.1) involved three key components:

1. Occurrence data— Geographic coordinates (latitude and longitude) representing recorded instances of invasive plant species, providing information on current species locations

2. Environmental explanatory variables (EEVs)— Abiotic (non-living, e.g., climate) and biotic (living, e.g., vegetation indices) environmental conditions at the locations where the occurrence data are collected.

3. Algorithm— A mathematical model that links the occurrence data with the environmental conditions, statistically associating the known species distribution with environmental predictor variables to estimate species distribution probabilities across a specific area.

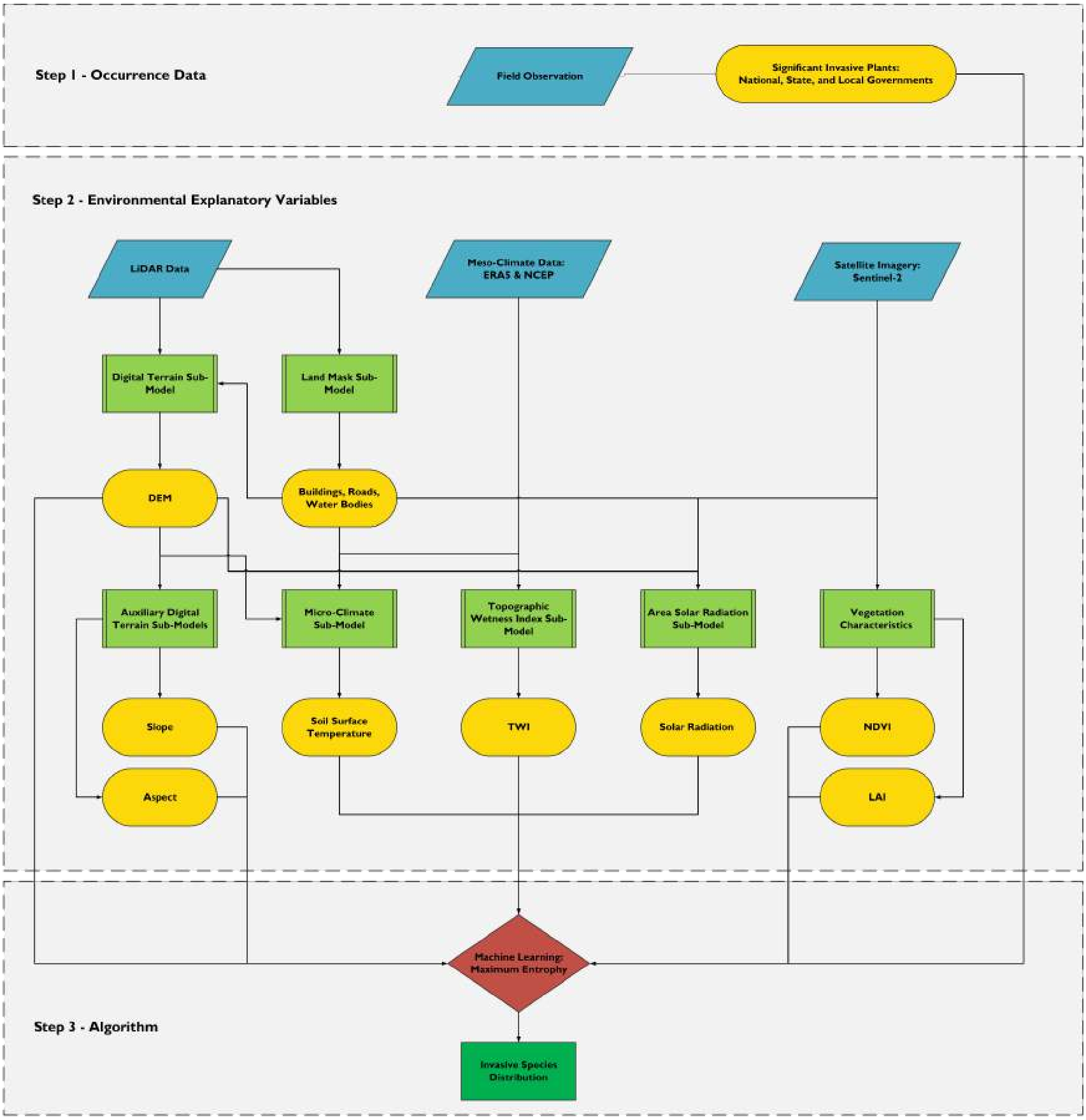


Figure 2.1 Conceptual Framework for the SDM

2.3.2 Occurrence Data

Occurrence data refers to the recorded instances (presence/absence) of invasive plant species, represented geographically as coordinates (latitude and longitude). It provides information about where the species is currently found. Our models were calibrated using field data in the 2024 survey to determine the presence/absence of species in the predefined areas.

2.3.3 Environmental Explanatory Variables

EEVs are the abiotic (non-living e.g. climate) and biotic (living e.g. vegetation indices) environmental conditions at the sites where the occurrence data were collected. These variables represent the environmental conditions that can influence a species' ability to survive and reproduce, thereby affecting its distribution. The selection of EEVs in an SDM is critical due to their ability to significantly influence the model's descriptive and predictive performance.

This pilot study selected biotic and abiotic EEVs to determine suitable areas throughout the Port, as well as possible accessible areas. These were based on the biotic-abiotic mobility diagram depicted in Figure 2.3, using a microscale resolution of 5 meters. The approach is designed to enhance both the descriptive and predictive capabilities of the model. Where relevant, the temporal scale of the analysis for highly dynamic variables was set to monthly. Each of the selected EEVs is explained in further detail in the following subsections. Some of the EEVs used required individual models to be created which are referred to in the method as 'sub-models'.

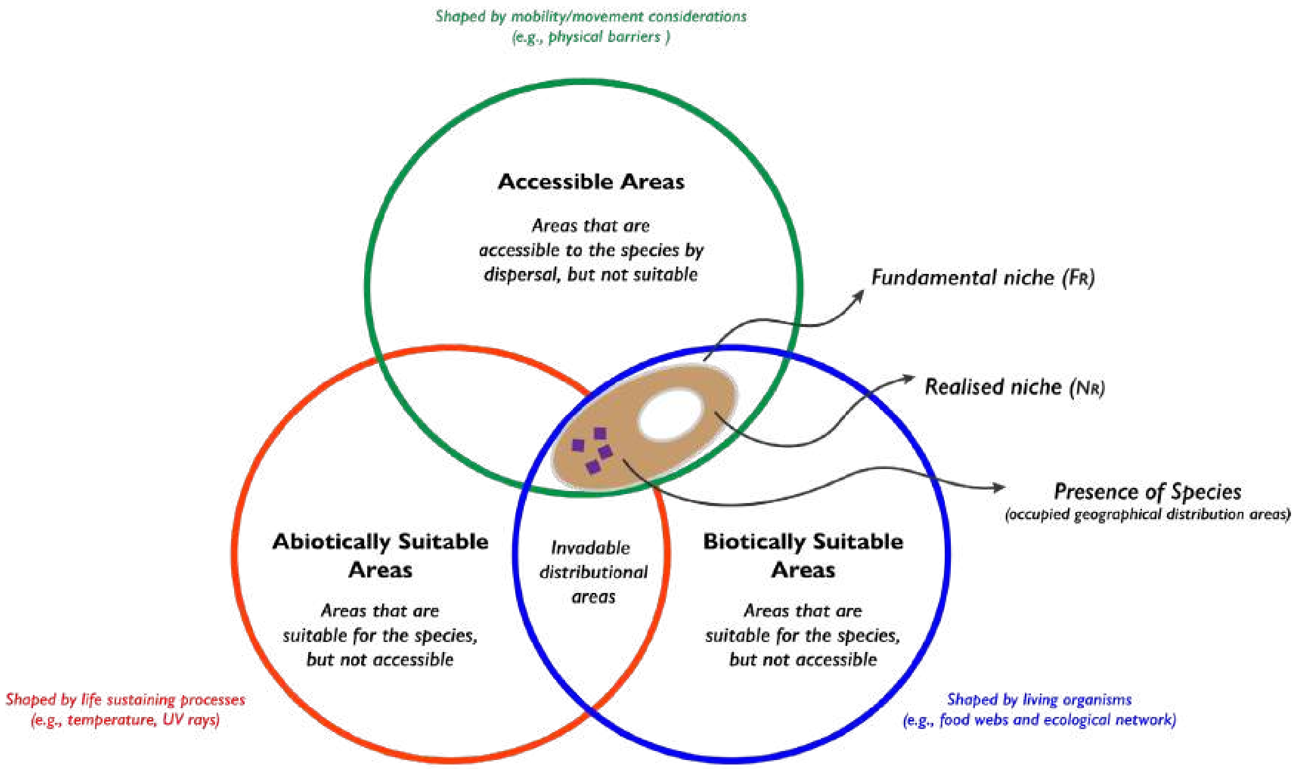


Figure 2.2 Biotic-abiotic mobility diagram

Digital Terrain Sub-Model

The Digital Terrain Model (DTM)[1] plays a pivotal role in the ecosystem by influencing plant physiology. It affects elements such as sunlight exposure, water drainage, and soil composition, which subsequently determines plant growth and distribution. For instance, it has been observed that slopes exposed to more sun usually have different vegetation compared to shaded slopes, a variation attributed to differences in sunlight exposure and soil moisture. Furthermore, the DTM shapes the microclimate of the ecosystem by influencing factors such as temperature, humidity, and wind patterns. The DTM was derived from Light Detection and Ranging (LiDAR) technology gathered by the Queensland Government in 2019. . The

[1] Also known as Digital Elevation Model (DEM)

LiDAR data for this project was post-processed using a specilised R[2] package (Roussel et al. 2020) to generate a DTM at 5 meters spatial resolution.

Land Mask Sub-Model

It is important to identify and exclude areas where the target invasive species could not grow. These unsuitable habitats include man-made structures like buildings and infrastructure, as well as natural features such waterbodies. The process of excluding these areas from the analysis involved the use of the same LiDAR point cloud dataset described above. The output was a Boolean mask with two categories: suitable and unsuitable for the growth of the invasive plant species. This mask was applied to all the EEVs generated in this study.

Auxiliary Digital Terrain Sub-Models

The DTM creation process also generated several other valuable byproducts, including detailed data on the slope and aspect of the terrain. The slope plays an important role in understanding ecological and geological processes since it has the potential to influence factors such as water flow, soil erosion, and the distribution of vegetation. The aspect is also important since it has the ability to affect microclimatic conditions, including sunlight exposure and wind patterns. These conditions, in turn, influence the types of vegetation that could thrive in a specific area. These DTM byproducts provide us with a more comprehensive understanding of the terrain and its ecological context.

Micro-climate Sub-Model

Climate has a significant impact on the physiology, ecology, behaviour, evolution, and preservation of the majority of species. Despite this, predictive studies frequently rely on coarse resolution climate data, which is approximately 1 km or more, even though many organisms encounter conditions that fluctuate at much smaller scales. This discrepancy is often bridged by assuming that average climatic variables can predict ecological responses. However, to understand the mechanistic links between climate and physiology, and the role of microclimates in buffering ecological change, high-spatial resolution data was necessary for this study.

R packages ‘Microclima’ and ‘Mecera5’ were used to model microclimatic conditions based on various environmental parameters. A custom R code was written using these packages to calculate the soil temperature. Based on the parameters outlined in Table 2.2, a detailed and accurate model of the soil temperature across the extended research area was generated (i.e., beyond the key focus areas presented in Figure 1). This model, represented at a 5-meter spatial resolution, provided a monthly temporal resolution for the entire year of 2023. Monthly temporal products, such as the average, maximum, and minimum temperatures, were derived for each hour of each month.

Table 2.2 Parameters influencing soil temperature

Parameters	Description
Air temperature, elevation (DTM/DEM), wind, humidity, precipitation, atmospheric pressure, cloud cover	
Cold-air drainage	Cold air, being denser than warm air, tends to sink and flow downhill due to gravity
Land/Sea surface temperature	Temperature difference between land and sea
Vegetation characteristics	The leaf distribution character of vegetation

[2] R is a programming language that is widely used for statistical computing and data visualisation.

The dataset for the micro-climate sub-model, which included climate and atmospheric related data, was sourced from two meso-climate[3] models. The first of these models was ERA5 (Table 2.3), the fifth generation European Centre for Medium-Range Weather Forecasts (ECMWF) atmospheric reanalysis of the global climate. It provides 'hourly' estimates of a large number of atmospheric, land, and oceanic climate variables. The data covers the globe on a grid of 31 km (or 0.25° x 0.25°) spatial resolution and captures atmospheric details across 137 levels, from the surface to an altitude of 80 km. The data, available from the year 1940, is continually updated up to five days behind real-time.

The sea surface temperature (SST) data was sourced from the National Centres for Environmental Prediction (NCEP), which provides modelled mesoscale climate products. The SST data was extracted from a dataset with a spatial resolution of 2.5° x 2.5° (~ 300 km) and a temporal resolution of 6 hours. The dataset was interpolated to match the spatial and temporal specifications of the ERA5 dataset.

Table 2.3 ERA5 parameters

Parameters	Definition
Dewpoint temperature at 2 m	The temperature to which air must be cooled to become saturated with water vapor.
Temperature at 2 m	The air temperature measured at 2 meters above the ground.
Total precipitation	The total amount of rain, snow, or other forms of moisture falling from the sky.
Surface pressure	The atmospheric pressure at the Earth's surface.
U & V wind component at 10 m	The eastward (U) and northward (V) components of the wind speed at 10 meters above the ground.
Total cloud cover	The fraction of the sky obscured by clouds when observed from a particular location.
Total sky direct solar radiation at surface	The amount of solar radiation received directly from the sun at the Earth's surface.
Mean surface downward long-wave radiation flux	The average rate of longwave energy emission downwards at the Earth's surface.
Mean surface net long-wave radiation flux	The average rate of net longwave energy emission at the Earth's surface.
Surface short-wave (solar) radiation downwards	The amount of shortwave solar radiation received at the Earth's surface.

Topographic Wetness Index Sub-Model

Water availability is a key determinant of survival and proliferation of both indigenous and invasive plant species. The presence or absence of water greatly influences their geographical distribution and growth trajectories. Therefore, gaining insights into the impact of water availability is important for understanding the spatial distribution and population density of both indigenous and invasive plant species.

The Topographic Wetness Index (TWI), or Compound Topographic Index (CTI), was used in this SDM. This steady-state wetness index is widely used to quantify the influence of topography on hydrological processes (Beven & Kirkby, 1979). It is often employed to study spatial scale effects on hydrological processes, identify hydrological flow paths for geochemical modelling, and characterise biological

3 A meso-climate model is a climate model for a specific, geographically limited area. It's used to study the climate of areas influenced by features like forests, valleys, or mountains. The model's output is not representative of the overall regional climate but rather the specific area under study. The resolution of these models can range from 10 to 500 km, depending on whether they are local, regional, or global. They consider various atmospheric, oceanic, and land surface processes.

processes such as annual net primary production, vegetation patterns, and forest site quality (Pourali et al., 2016).

The process of calculating the TWI commenced with hydrologically conditioning the DTM (see 'Digital Terrain Sub-Model'). Firstly, the Monte Carlo Simulation[4] (MCS) statistical approach was used to estimate the outcome of uncertainty in the data (e.g. potential LiDAR error sources, time lapse and alterations in elevation from natural or built phenomena). Within the framework of the TWI, the MCS was utilised to address uncertainties present in both the data and the model by running 500 iterations in Python using the PCRaster package. During each iteration, the elevation value was randomly adjusted within a predefined range of 10 cm. Following the MCS, 'sinks' (i.e. a cell that lacked a defined drainage direction – had no surrounding lower elevation cells) were identified and filled. The 'pour point', or the boundary cell within the sink's contributing area with the lowest elevation, was then identified. Following identification of the 'pour point', the TWI was calculated for each iteration. The final TWI output was then ascertained by calculating the mean of the TWI values obtained from all the 500 iterations. This methodology effectively reduced the majority of errors, resulting in a more precise and dependable TWI.

To better understand the monthly variations in water availability for plant species, the TWI was multiplied by the total rainfall for each month to create a more dynamic and time-sensitive measure of wetness. The rainfall data was sourced from the Bureau of Meteorology (BOM) for the year 2023 (weather station 40913). By multiplying the TWI with the monthly total rainfall, the resulting index not only reflects the influence of the local topography on water retention but also incorporates the actual amount of rainfall that the area received in a specific month. This provides a more comprehensive and nuanced understanding of the wetness conditions of the location throughout the year 2023.

Table 2.4 Monthly total rain from BOM station ID: Brisbane - 40913

Year 2023	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Total (mm)	93.0	65.0	58.8	56.0	77.6	1.8	48.6	22.8	27.4	18.4	100.4	207.6
Long-Term Average[5]	141.1	181.9	129.3	60.5	70.9	58.8	30.2	33.0	29.2	84.8	94.0	131.7

Area Solar Radiation Sub-Model

Solar area radiation significantly influences the formation and characteristics of microclimates. An analysis of solar radiation across the research area was conducted. This analysis was based on the hemispherical viewshed algorithm in ArcGIS (Fu & Rick 2000, 2002). The total radiation for a specific area was represented as global radiation. This encompasses the calculations of direct, diffuse, and global insolation, which were performed for each feature location, thereby covering the entire topographic surface.

Vegetation Characteristics Sub-Model

The Normalised Difference Vegetation Index (NDVI) and Leaf Area Index (LIA) play an important role in elucidating biotic interactions among species. NDVI, is typically utilised as an indicator of plant productivity.

[4] The Monte Carlo method, also known as Monte Carlo simulation, was invented by John von Neumann and Stanislaw Ulam during World War II. The method was developed to improve decision making under uncertain conditions. The name "Monte Carlo" comes from the Monte Carlo Casino in Monaco, where Stanislaw Ulam was inspired by his uncle's gambling habits. At that time, they both were involved in the Manhattan project, and they came up with this technique to simulate a chain reaction in highly enriched uranium.

[5] The calculation of the long-term monthly average rainfall at weather station ID: 40913 is based on data that has been collected consistently since the year 1999.

Conversely, LAI, denotes the total one-sided area of leaf tissue per unit of ground surface area. Within the framework of SDMs, LAI serves as an environmental predictor variable, aiding in the modelling of the relationship between environmental conditions and species presence. The estimation of LAI is achieved by analysing the light interception effects of leaves with varying angular distributions. The formula uses specific bands of light that are captured by satellite or aerial sensors. Each band is sensitive to different aspects of plants, for example the 'NIR' band is sensitive to the spongy mesophyll structure of vegetation, while the 'Red' and 'Blue' bands are absorbed by chlorophyll. By taking the ratio of these bands, LAI effectively measures the density of green vegetation on a patch of land. It provides a standardised method of comparing the health and vigour of vegetation across different areas or over time.

These vegetation indices were derived from the Surface Reflectance datasets provided by Digital Earth Australia (DEA) via the Sentinel-2 satellites. For 2023, the values of each vegetation index were computed for each pixel and then averaged on a monthly basis. This approach provides a comprehensive and detailed picture of vegetation patterns and changes over the course of the year. Since this is a coarser resolution compared with the rest of the sub-models the final layer was downscaled to 5 meters resolution.

2.3.4 Algorithm

The algorithm serves as a bridge between occurrence data and environmental conditions discussed in subsections 2.2.1 and 2.2.3 respectively. It uses statistical methods to correlate the observed distribution of a species (derived from field data) with EEVs. This correlation is then used to estimate the likelihood of the species' distribution across a designated area, as illustrated in Figure 2.3

In this study, the presence-background modelling algorithm[6] for SDM was adopted. This choice was influenced by the robustness of occurrence data and the often-insufficient quality and availability of absence data. The presence-background algorithm compensates for the scarcity of absence data by simulating it with randomly generated points across the study area. This strategy resulted in the formation of presence-background models, which integrated the simulated absence data during the calibration phase. These models, while using the same algorithms as presence-absence models, offer a distinct interpretation of absences and background points. The calibration of these algorithms is sensitive to changes in the study area due to their relationship with the background.

Furthermore, the machine learning algorithm 'Maximum Entropy theory' was used. The algorithm operates on the premise that in the absence of specific constraints, a system will gravitate towards maximum entropy, where entropy is a measure of uncertainty or randomness (in accordance with the principle by Shannon (1948))[7]. Ultimately, maximum entropy chooses the distribution that introduces the least bias, given the current knowledge. This approach ensures a fair and unbiased representation of the data, thereby enhancing the reliability of the findings. The algorithm is often used in the literature and employs logistic-like regressions to compare the densities of occurrences, random points, and environmental variables during the calibration process.

[6] There are three main categories of SDM algorithms: presence-absence, presence-background, and presence-only.

[7] In information theory, the entropy of a random variable is the average level of "information", "surprise", or "uncertainty" inherent to the variable's possible outcomes.

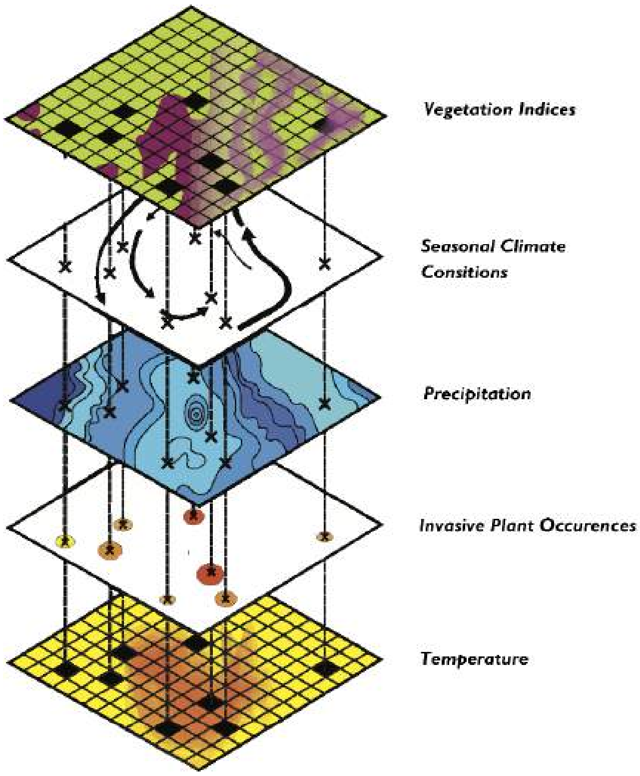


Figure 2.3 Explanatory variables for modelling invasive plant species that are linked through correlation algorithms.

A machine learning algorithm was developed with the following parameters:

1. Random test percentage (25%)— This refers to the proportion of the dataset that is set aside for testing the performance of the model. In this case, 25% of the data is used for testing, while the remaining 75% is used for training the model. This helps in evaluating the model's performance on unseen data and prevents overfitting.
2. Replicates (5)—The model is run five times with different subsets of the data. This is done to ensure the robustness of the model and to get a more reliable estimate of its performance. Each run is independent of the others and uses a different random seed.
3. Replicated run type (cross-validate)— Cross-validation is a technique used to assess how well the model will generalise to an independent dataset. It involves dividing the data into subsets, training the model on some subsets (training set), and then evaluating it on the remaining subsets (validation set).
4. Max background (10000)— This parameter sets the maximum number of background points that can be used in the model. Background points are locations where the presence of the species being modelled is unknown. They provide a contrast to the presence locations and help the model learn the difference between suitable and unsuitable conditions for the species.
5. Output (clog-log)— The clog-log output format is used for the model's predictions. This is a type of transformation that helps in dealing with extreme values and improves the interpretability of the model's output.
6. Max iteration (500)— This is the maximum number of iterations that the algorithm will run for. An iteration is a single step in the training process, where the model's weights are updated based on the error it made on the training data. Setting a maximum number of iterations ensures that the algorithm doesn't run indefinitely and helps in preventing overfitting.

7. Threshold rule (10 percentage training presence)— This is the threshold used to convert the model's continuous output into binary presence/absence predictions. In this case, the threshold is set at the value which gives a 10% training presence. This means that the top 10% of the training data, ranked by predicted suitability, are classified as presence.

2.3.5 Jackknife Test

The jackknife test (a resampling method) was conducted on the model for each weed species to assess its robustness using the Area Under the Curve (AUC) method. The test involves three scenarios:

- Running the model without a particular variable,
- Running the model with only that particular variable, and
- Running the model with all variables.

In each scenario, one EEV is systematically excluded or included at a time from the dataset. Then the model is run to evaluate its performance. The process increases understanding of the impact of each variable on the model's accuracy. The AUC value, ranging from 0 to 1, serves as a measure of the model's predictive accuracy. An AUC of 0.5 implies that the model's predictions are no better than random chance, while an Area Under the Curve (AUC) of 1 signifies perfect predictive discrimination.

3 Results

3.1 Field Observation

During field surveys, 38 weed species were observed with Figure 3.1 illustrating the occurrence of each species. Observations of weed species at each survey site are detailed below.

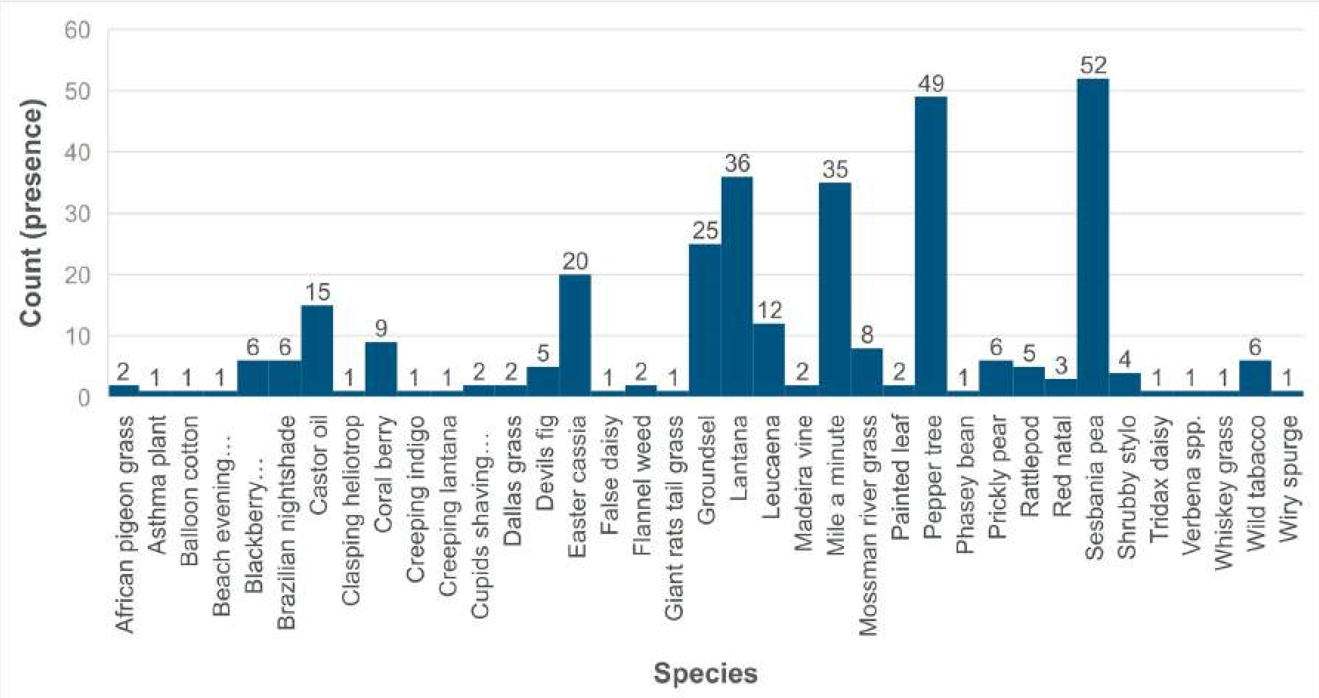


Figure 3.1 Observed weed species on PBPL lands.

3.1.2 Bird Hide

PBPL has constructed an artificial wetland near the future port expansion (FPE) on Fisherman Islands to provide high-tide roosts for migratory shore birds and waders. This site is referred to as the 'bird hide' and consists of open saline water, seagrass, saltmarsh, intertidal mudflats and sparse mangroves, and is bounded by exotic maintained grasslands. Culverts in the eastern bund wall provide tidal connection between the bird hide wetlands and Moreton Bay.

The fill that surrounds the waterbody is above tidal influence and supported terrestrial grasslands which are regularly mown and comprised a range of exotic grasses and herbaceous environmental weeds widespread throughout the region.

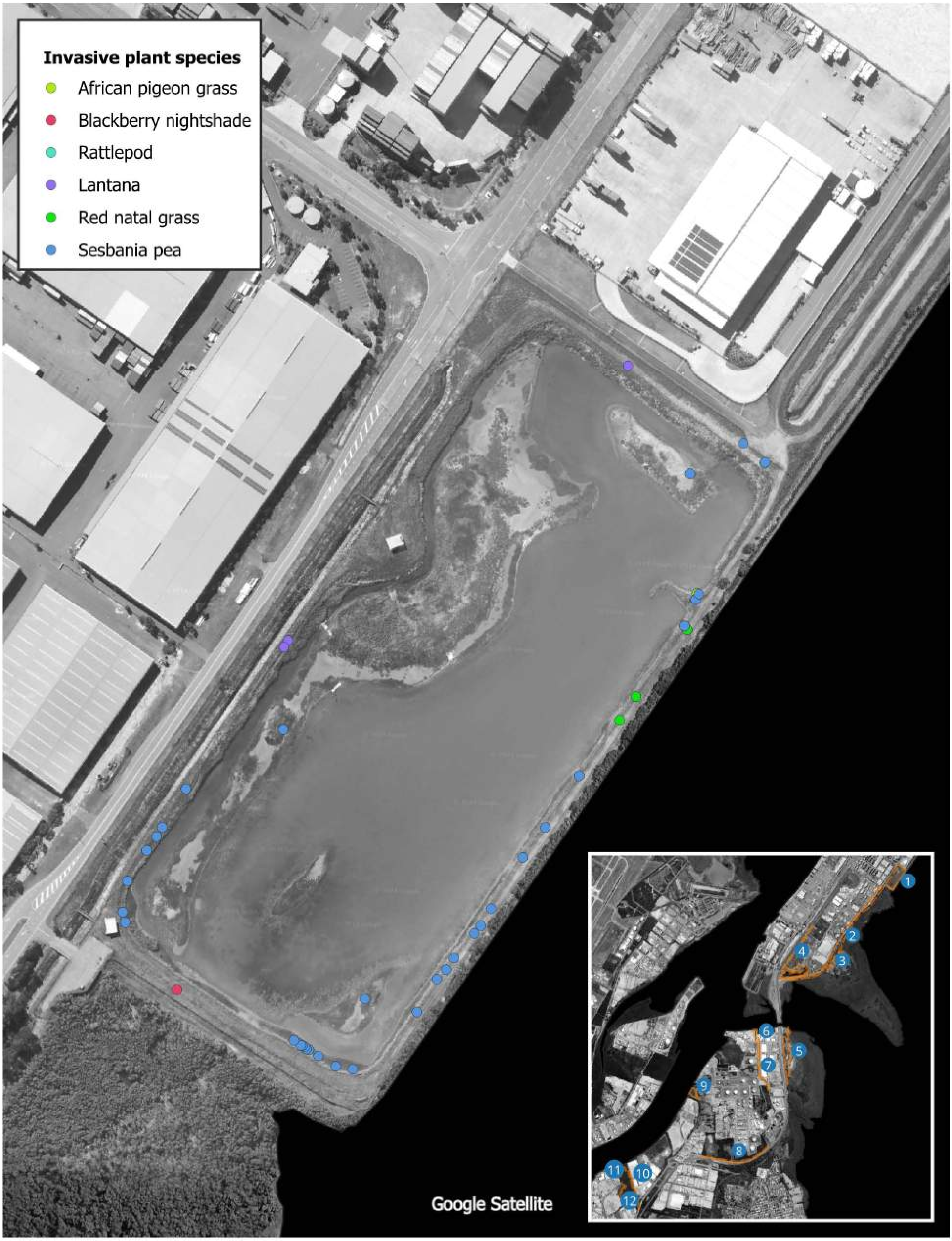
The following observations were made in the 2024 survey:

- New weed species for the site included rattlepod (*Crotalaria sp.)*
- **Restricted Matters** recorded included: sparse lantana (*Lantana camara*) and Singapore daisy (*Sphagneticola trilobata syn. Wedelia trilobata*).
- **Exotic grasses and groundcover**: Rhode's grass (*Chloris gayana)*, green panic (*Megathyrsus maximus* var. *maximus*), Dallas grass (*Paspalum* spp.) and red natal grass (*Melinis repens)*

- **Vines**: Siratro (*Macroptilium atropurpureum*) (covering all fences and observed in the samphire zones)
- **Herbs**: Creeping indigo (*Indigofera spicata*), pink purslane (*Portulaca pilosa*), common plantain (*Plantago major*), blackberry nightshade (*Solanum nigrum*), shrubby stylo (*Stylosanthes scabra*), tridax daisy (*Tridax procumbens*), gomphrena weed (*Gomphrena celosioides*), hairy fleabane (*Erigeron bonariensis*), common sowthistle (*Sonchus oleraceus*), beggar's tick (*Sonchus oleraceus*), purslane (*Portulaca oleracea*), beach evening primrose (*Oenothera drummondii*)
- Large patches of sesbania pea were observed to inhabit the western banks of the waterbody (Figure 3.2).

Weed composition on the fill surrounding the wetlands has not greatly changed between survey episodes. The distribution of the major weeds can be observed in Figure 3.3.

Figure 3.2 Sesbania pea along the western banks of the waterbody



Title:

Observed invasive plant species at Key Area 1: Bird Hide

Figure: 3.3

Rev: A

N 0 50 100 150 m

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants\QGIS\StudyArea.qgz

3.1.3 Lucinda Drain

Lucinda Drain is a constructed channel located east of Lucinda Drive that provides drainage for stormwater run-off from hardstand areas at the Port to the north. The drain lies adjacent to locally significant estuarine wetlands and discharges through the Lucinda Weir into the Boat Passage.

The tidal channel does not contain extensive aquatic macrophyte cover but supported a low, discontinuous fringe of native grey mangrove (*Avicennia marina*). The drain is periodically maintained, with mangroves actively removed to ensure the drain provide its primary purpose of conveying stormwater run-off.

The channel banks supported planted and naturally recruited shrubs and trees comprised of a mix of local native terrestrial species such as eucalypts (*Eucalyptus spp.*), she-oaks (*Casuarina* spp.), figs (*Ficus* spp.), cotton tree (*Hibiscus tiliaceus*), paperbark (*Melaleuca* spp.) and parasol leaf tree (*Macaranga tanarius)*.

The western bank of the drain adjacent to Lucinda Drive undergoes regular maintenance involving mowing and weed spraying. Poor access along the eastern bank of Lucinda Drain limits regular maintenance but weeds are reportedly removed on an annual basis.

The weed species recorded at Lucinda drain were typical of past surveys and weed density remains low. An example of weeds in the drain are shown in Figure 3.4 and the distribution of grasses recorded along the drain in 2024 are shown in Figure 3.6.

The following observations were made in the 2024 survey:

- New weed species were recorded within the site including cupids shaving brush (*Emilia sonchifolia*) and asthma plant (*Chamaesyce hirta*)
- **Restricted Matters** recorded included: widespread patches (ranging from 1-5 trees to 10+ trees) of broad-leaved pepper tree (*Schinus terebinthifolius*), lantana and groundsel (*Baccharis halimifolia*).
- **Woody weeds** were consistent with previous surveys, the dominant woody weed recorded at Lucinda Drain was broad-leaved pepper tree with minimal observations of rattlepod.
- **Vines** observed were patches of siratro and mile a minute (*Ipomoea cairica)* along the upper banks adjacent to the drain
- **Exotic grasses and groundcover** included Rhode's grass, green panic and red natal grass and very sparse Mossman River grass (*Cenchrus echninatus*).
- **Herbs** included shrubby stylo, tridax daisy, creeping Cinderella, gomphrena weed, hairy fleabane, pink purslane, blue billygoat weed (*Ageratum houstonianum*) cobblers peg (*Bidens pilosa*) and beach evening primrose
- No **aquatic macrophyte** weed species were recorded.

Figure 3.4 Mowed exotic grass corridor of Lucinda drain

3.1.4 The Lake

The Lake is located at Port of Brisbane Park at the southern end of Fisherman Island. The Lake is a highly modified, constructed wetland that provides habitat values for local wetland bird species. There have been no major changes in weed species composition at the Lake, and 2024 results were consistent with the previous survey as follows:

- **Restricted Plants** recorded included broad-leaved pepper tree and groundsel
- Dominant **woody weeds** included broad-leaved pepper tree, groundsel, and lantana with large patches of castor oil (*Ricinus communis*) (adjacent to the south-western bank of the lake) and scattered sesbania pea
- **Vines** recorded included patches of mile a minute and siratro
- The most widespread exotic **groundcovers/grasses** were green panic, Mossman River grass, red natal grass, Dallas grass and Rhode's grass
- **Herbs and forbs** included a large patch (~5 m by 5 m) of asthma plant adjacent to the south-western bank of the Lake. Other scattered species included, Phasey bean ((*Macroptilium lathyroides*), wandering Jew (*Commelina benghalensis*), creeping Cinderella, rattlepod, shrubby stylo, cupid's shaving brush, ribwort plantain (*Plantago lanceolata*), blackberry nightshade, flatweed (*Hypochaeris radicata*), wiry spurge (*Phyllanthus virgatus*), tridax daisy, gomphrena weed, clasping heliotrope (*Heliotropium amplexicaule*), hairy fleabane, beach evening primrose, verbena (*Verbena spp.)* purslane and threelobe false mallow
- Exotic **aquatic macrophytes** recorded in the shallow waters on the Lakes edge included umbrella sedge (*Cyperus involucratus*) and long-leaved willow primrose (*Ludwigia longifolia*)

3.1.5 T1-3 and Car Precinct

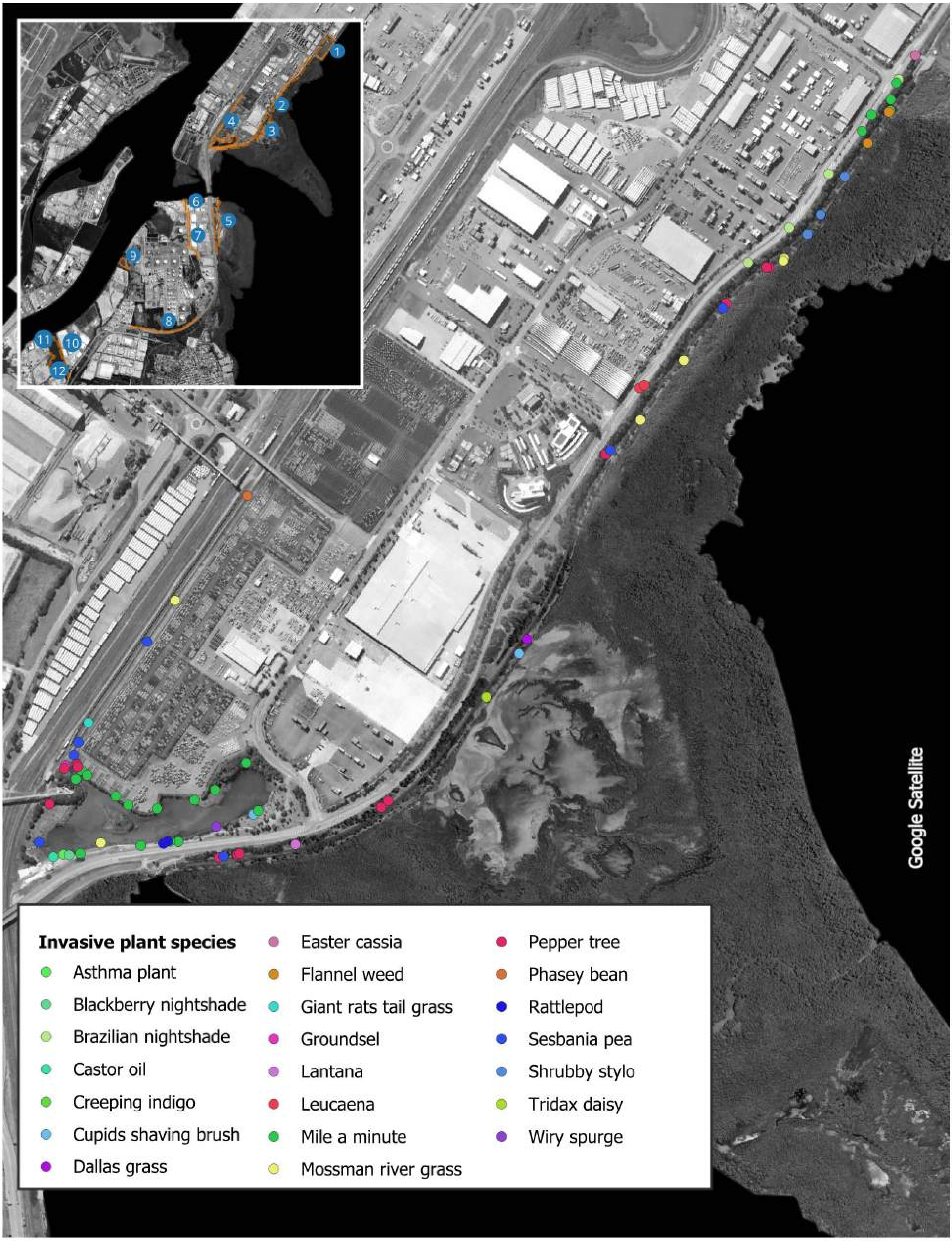
The T1-3 and Car Precinct areas at the Port store imported vehicles and are potential vectors for newly introduced weed species entering the country via container ships. The survey site is adjacent to the Lake and includes constructed concrete drains, regularly maintained roadside lawn, landscaped garden beds and the maintained Queensland Rail freight line easement.

The survey site is heavily modified and cleared and undergoes regular maintenance including mowing and spraying for weeds. Weeds recorded for this site are combined with the Lake and included:

- New **Restricted Plants** that were recorded were the giants rat's tail (*Sporobolus sp.)* between the railway track and the car precinct. Additional Restricted Plants included broad-leaved peppertree and groundsel.
- Dominant **woody weeds** included broad-leaved pepper tree, groundsel, and lantana and Easter cassia (*Senna pendula var.glabrata*)
- **Vines** recorded included mile a minute, siratro and glycine
- **Groundcover and grasses include** green panic, Mossman River grass, red natal grass. Dallas grass and Rhode's grass
- Common exotic **herbs and forbs** included asthma plant, Phasey bean, wandering Jew, creeping Cinderella, rattlepod, shrubby stylo, cupid's shaving brush, ribwort plantain, blackberry nightshade, flatweed, wiry spurge, tridax daisy, gomphrena weed, clasping heliotrope, hairy fleabane, beach evening primrose, verbena, purslane and threelobe false mallow

The weed species recorded at the Lake and T1-3 and Car Precinct showed similar distribution and densities as past surveys, with the exception of a new occurrence of the giant rat's tail (Figure 3.5).The Figure 3.6 illustrates the distribution of weeds at the Lake, T1-3 and Car Precinct.

Figure 3.5 (Top left) Incursion of giant rats tail adjacent to Car Precinct, (Top right) Patch (~5m by 5m) of asthma plant south-western bank of the Lake, (Bottom) Patch of castor oil adjacent to the south-western bank of the Lake.



Title:

Observed invasive plant species at Key Area 2, 3, 4: Lucinda Drain/Fisherman Island, Lake, T1-3 & Car Precinct

Figure: 3.6

Rev: A

N

0 150 300 450 m

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants\QGIS\StudyArea.qgz

3.1.6 Port Drive North

This site is located on Whyte Island south of Boat Passage on the eastern side of Port Drive and south of the Port of Brisbane boat ramp. Whyte Island supports extensive intertidal wetlands comprising mangroves and saltmarsh of high ecological value.

All weed species recorded at this site are widespread across the Port and are well-established in the Brisbane region and throughout coastal south-east Queensland. The following observations were made in the 2024 survey:

- New species recorded on site include Whiskey grass (*Andropogon virginicus*) and herb painted spurge (*Euphoria cyathophora).* Whiskey grass species is not a restricted matters but is regulated under the Natural Asset Local Law.
- **Restricted matters** recorded included widespread but sparce broad-leaved pepper tree on the eastern side (mangrove and saltmarsh areas) but dense patches of broad-leaved pepper tree and lantana on the western side (adjacent to railway tracks). Widespread groundsel was also observed.
- Additional **woody weeds** include castor oil plant and Easter cassia
- **Exotic vine** recorded include siratro, mile a minute and passionflower (*Passiflora spp.)*
- **Groundcover and grasses** recorded include green panic, Rhodes grass and pampus grass
- **Herbs and forbes** include Brazilian nightshade, tridax daisy, false daisy, wandering Jew, beach primrose, hairy fleabane, shrubby stylo, blackberry nightshade gomphrena, coral berry, cobblers peg, creeping cinderella, asthma plant, creeping indigo, clasping heliotrope, hairy fleabane, ribwort plantain, phasey bean, cupids shaving brush, flatweed and verbena.
- Sesbania pea was also recorded.

The eastern edge of Port Drive North is dominated by mangroves, saltmarsh and saltpans. These habitats are not typically prone to weed invasion due to regular saline water inundation. Slightly elevated areas within these habitats supported patches of broad-leaved pepper tree. New weed species identified are illustrated in Figure 3.7. The distribution of weeds recorded at Port Drive North is shown in Figure 3.9.

Figure 3.7 (Top) Patch of broad-leaved pepper tree, (Bottom) whisky grass

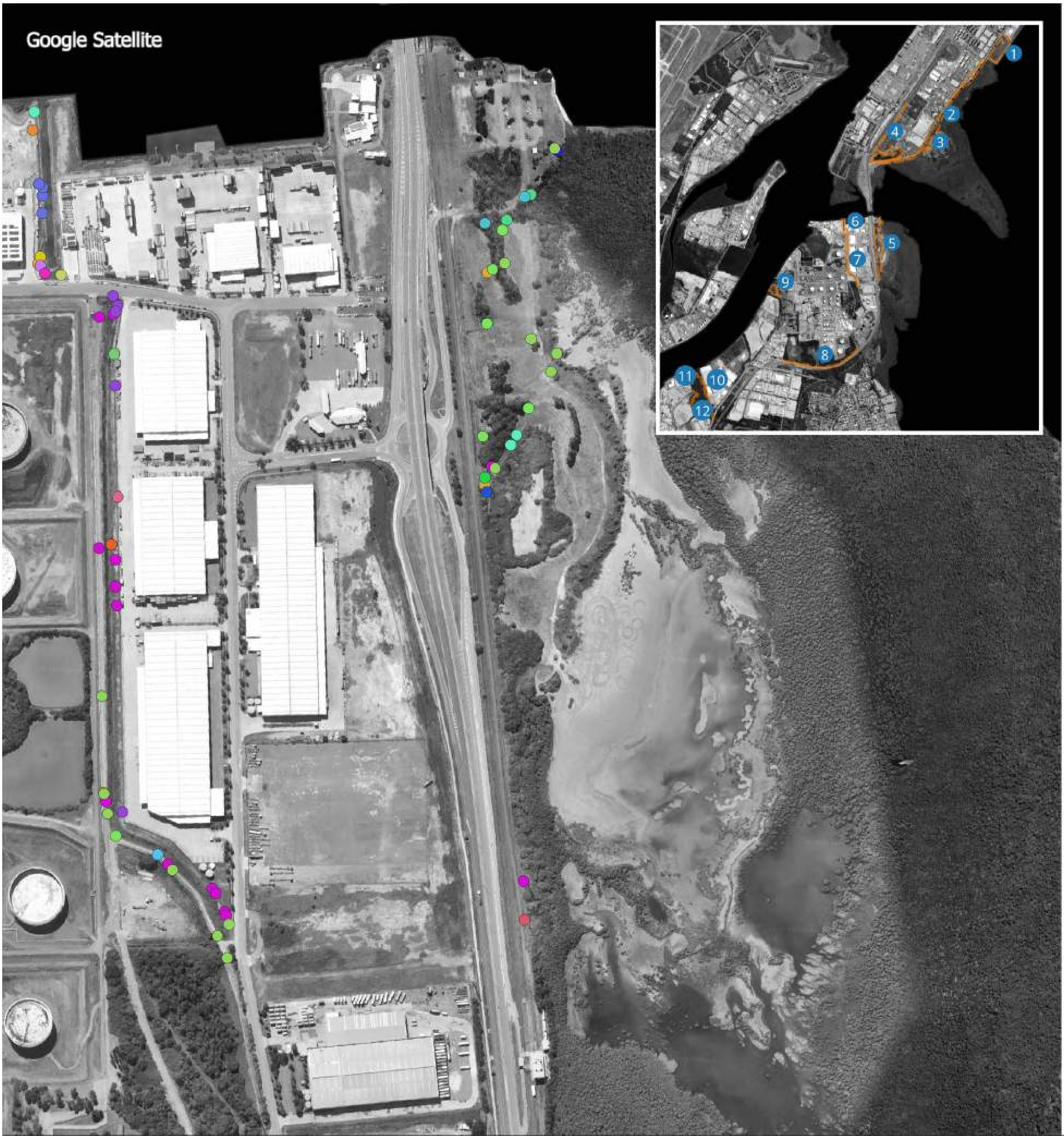
3.1.7 Port Gate Drain

Port Gate Drain lies to the south of Boat Passage and collects stormwater run-off from the adjacent hardstand areas and drains into, and partially receives, the tidal waters in Boat Passage. The banks of the drain are constructed of concrete, gravel and/or compacted earth, which limits extensive vegetation growth. The following observations were made in the 2024 survey:

- New species recorded in the area include Giant devil's fig (*Solanum hispidum)* that is regulated under the Natural Assets Law, beach evening primrose and *Verbena spp.*
- **Restricted Matters** recorded included: broad-leaved pepper tree, groundsel and lantana
- **Additional woody weeds** include castor oil plant, rattlepod and large patches of leucaena and groundsel within and adjacent to the drain.
- **Vines**: siratro and passionflower
- **Groundcover and grasses**: red natal, Rhodes grass, African pigeon grass, green panic and Mullumbimby couch
- **Herbs and forbes:** phasey bean, hairy fleabane, false daisy, Tridax daisy, gomphrena, cobblers peg, snakeweed, cupids shaving brush, common sowthistle, creeping lantana (*Lantana montevidensis*), asthma plant, creeping indigo, blackberry nightshade, shrubby stylo, wandering Jew
- Sesbania pea and phragmites were also recorded.

An example of weeds at the Port Gate Drain are shown in Figure 3.8 with the weed observation distribution shown in Figure 3.9.

Figure 3.8 (Top) Giant devils fig, (Bottom-left) large patch of leucaena within the south side of Port Gate drain (Bottom-right) patches of grounsel adjacent to the southside of Port Gate drain



Invasive plant species

- African pigeon grass
- Blackberry nightshade
- Brazilian nightshade
- Castor oil
- Clasping heliotrop
- Coral berry
- Creeping lantana
- Devils fig
- Easter cassia
- False daisy
- Groundsel
- Lantana
- Leucaena
- Mile a minute
- Painted spurge
- Pepper tree
- Beach evening primrose
- Rattlepod
- Sesbania pea
- Shrubby stylo
- Verbena spp.
- Whiskey grass

Title:

Observed invasive plant species at Key Area 5, 6, 7: Port Drive North, Port Gate Drain - A and B

Figure: 3.9

Rev: A

N

0 100 200 300 m

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants\QGIS\StudyArea.qgz

3.1.8 Port Drive South

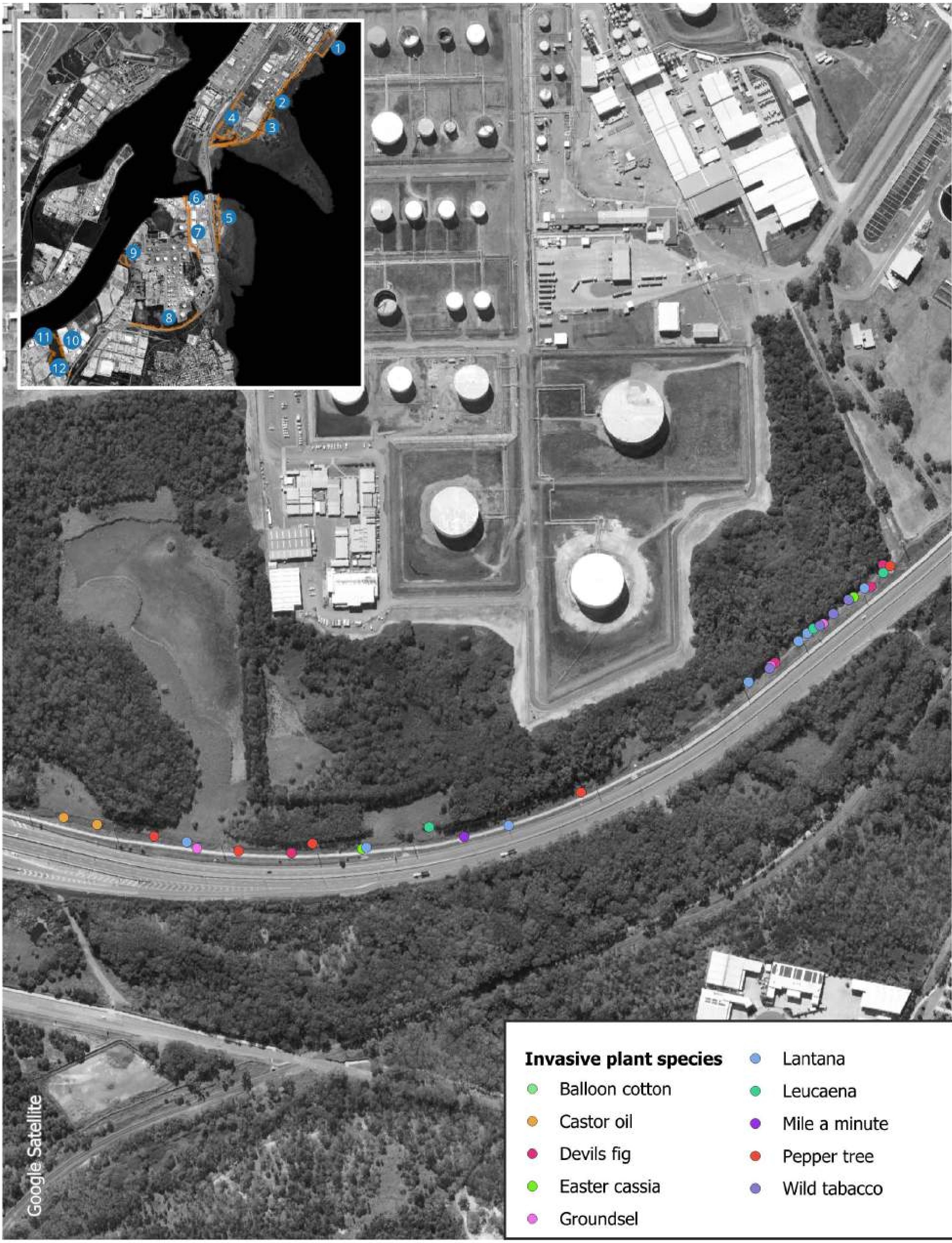
The western road corridor off Port Drive supports remnant *Melaleuca quinquenervia* wetlands in relatively healthy condition. The following weeds were observed in the 2024 survey:

- New species recorded in the area include Giant devil's fig (*Solanum hispidum)* that is regulated under the Natural Assets Law.

- **Restricted Matters** recorded included fragmented patches of broad-leaved pepper tree and lantana along the northern fringes of the survey site. More scattered patches of groundsel and leucaena were also recorded.
- **Other woody weeds** identified include rattlepod, castor oil plant, wild tobacco (*Solanum mauritianum*), and Easter cassia.
- **Vines** observed were mile a minute, silver leaf desmodium, siratro, and passionflower.
- **Groundcover and grasses** include Johnson grass and signal grass (*Urochloa decumbens)*
- **Herbs and forbs:** creeping indigo, flannel weed, wandering Jew, balloon cotton, billygoat weed, black nightshade, phragmites, thatch grass, ribwort plantain, wiry spurge, gomphrena, asthma plant, phasey bean, wandering jew, creeping cinderella, pink purslane, clasping heliotrope and fine leafed verbena
- Sesbania pea was also present.

The new species recorded is illustrated in 0 with weed distribution observed in Figure 3.11.

Figure 3.10 Giant devils fig located on the northern boundary of mangrove community on Port Drive South.



Title:

Observed invasive plant species at Key Area 8: Port Drive South

Figure: **3.11**

Rev: **A**

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N 0 80 160 240 m

BMT www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants\QGIS\StudyArea.qgz

3.1.9 Fort Lytton

Port lands at Fort Lytton adjacent to the Brisbane River support intertidal wetlands comprising mangroves and saltmarsh of high ecological value, including one of the largest remaining patches of saltmarsh near the mouth of the Brisbane River.

Less than 0.5 ha of filled land within the site previously supported dense weeds before it was cleared and reprofiled in late 2019. Bollards were also installed on the eastern boundary between the saltmarsh and parking lot to protect saltmarsh from vehicle disturbance. Within the restoration area there is regenerating saltcouch (*Sporobolus virginicus*), shoreline sea purslane (*Sesuvium portulacastrum*) and native reed (*Phragmites australis*) (Figure 3.12). The cover of saltmarsh, particularly saltcouch, has overall increased since the restoration works in 2019. There has been a slight decrease in Phragmites reedland. Refer to Table 3.1 for a comparison of the area of ground cover species in the rehabilitation area between the 2023 and 2024 surveys.

The weed survey focused within the disturbed terrestrial lands to the east of the rehabilitation site. Weed species recorded in the 2024 survey include:

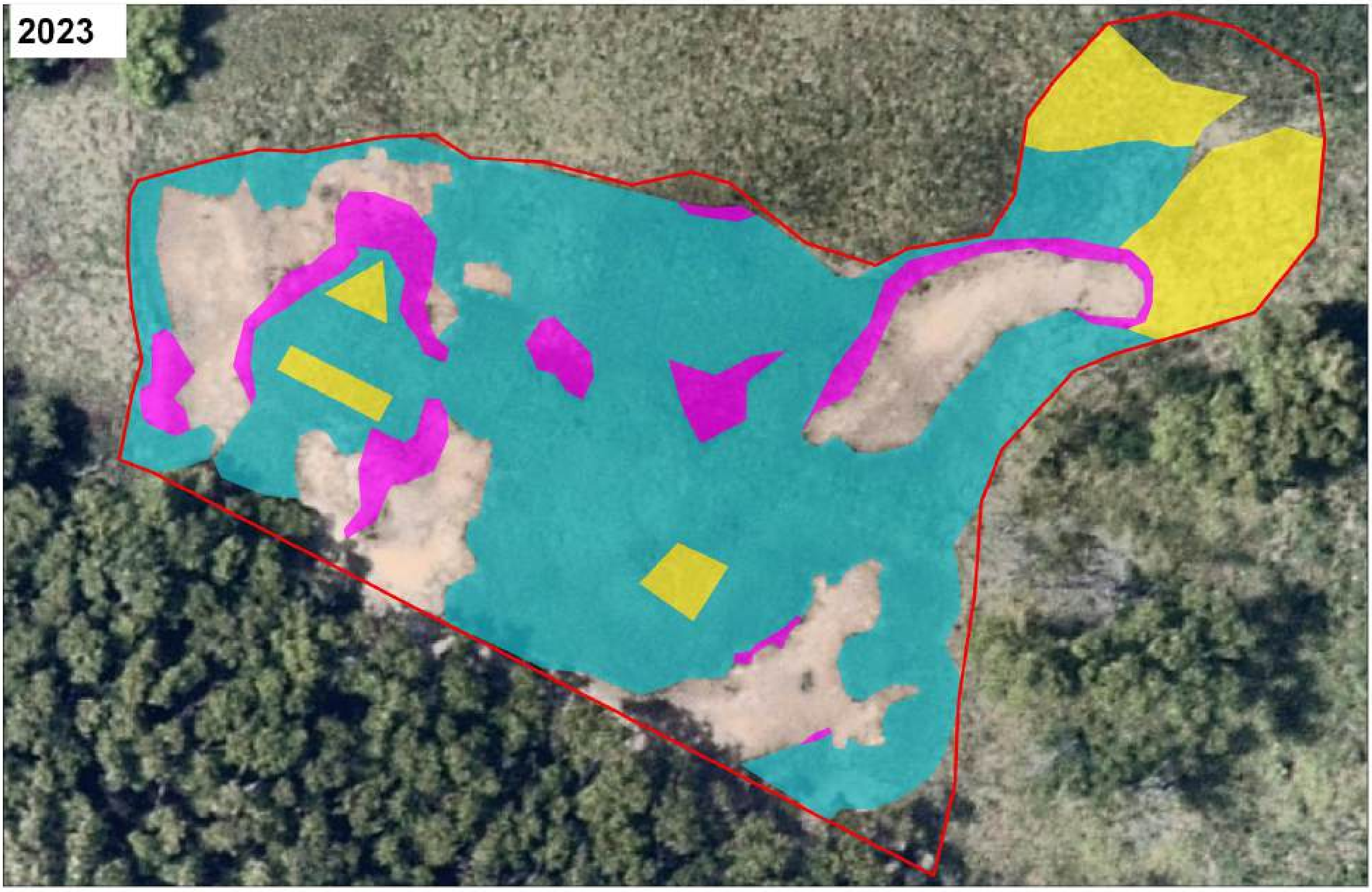
- **Restricted Matters** recorded included broad-leaved pepper tree, lantana, and madeira vine (*Anredera cordifolia)*
- **Other woody weeds** included leucaena, lantana, easter cassia, and wild tobacco
- **Vines** recorded include passionflower and mile a minute
- **Groundcover and grasses** include Rhodes grass, green panic and Johnson grass
- **Herbs and forbes** observed were wandering jew, balloon cotton, clasping heliotrope, cobblers peg, and hairy fleabane
- Phragmites were also recorded amongst the weed cover

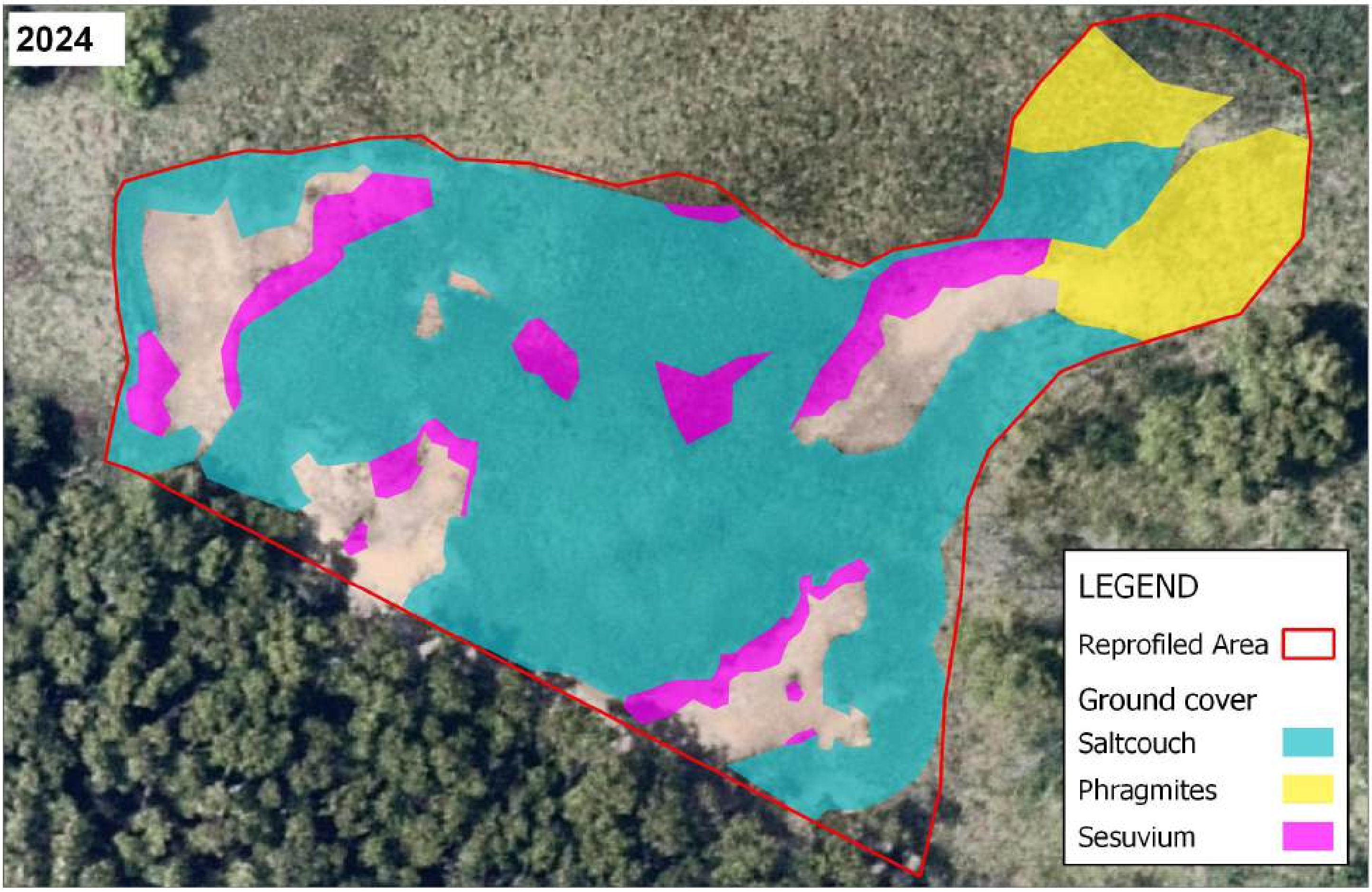
Figure 3.12 shows the saltmarsh rehabilitation site and an example of the weeds to the east of the rehabilitation site. Weed species observed onsite is shown in Figure 3.14. The change in extent of saltmarsh between 2023 and 2024 is shown in Figure 3.13.

Table 3.1 Comparison of area of species in the restoration area between 2023 and 2024

Saltmarsh habitat type	2023 area (m^2)	2024 area (m^2)	Difference in area (m^2)
Saltcouch grassland	703	772.4	69.4 (increase)
Sesuvium dominated samphire	108	118	10 (increase)
Phragmites reedland	129	123	6 (decrease)

Figure 3.12 (Top) Saltmarsh rehabilitation site (Bottom) Leucaena patch east of rehabilitation area.





Title:

Fort Lytton rehabilitation area 2023 vs 2024

Figure: 3.13

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

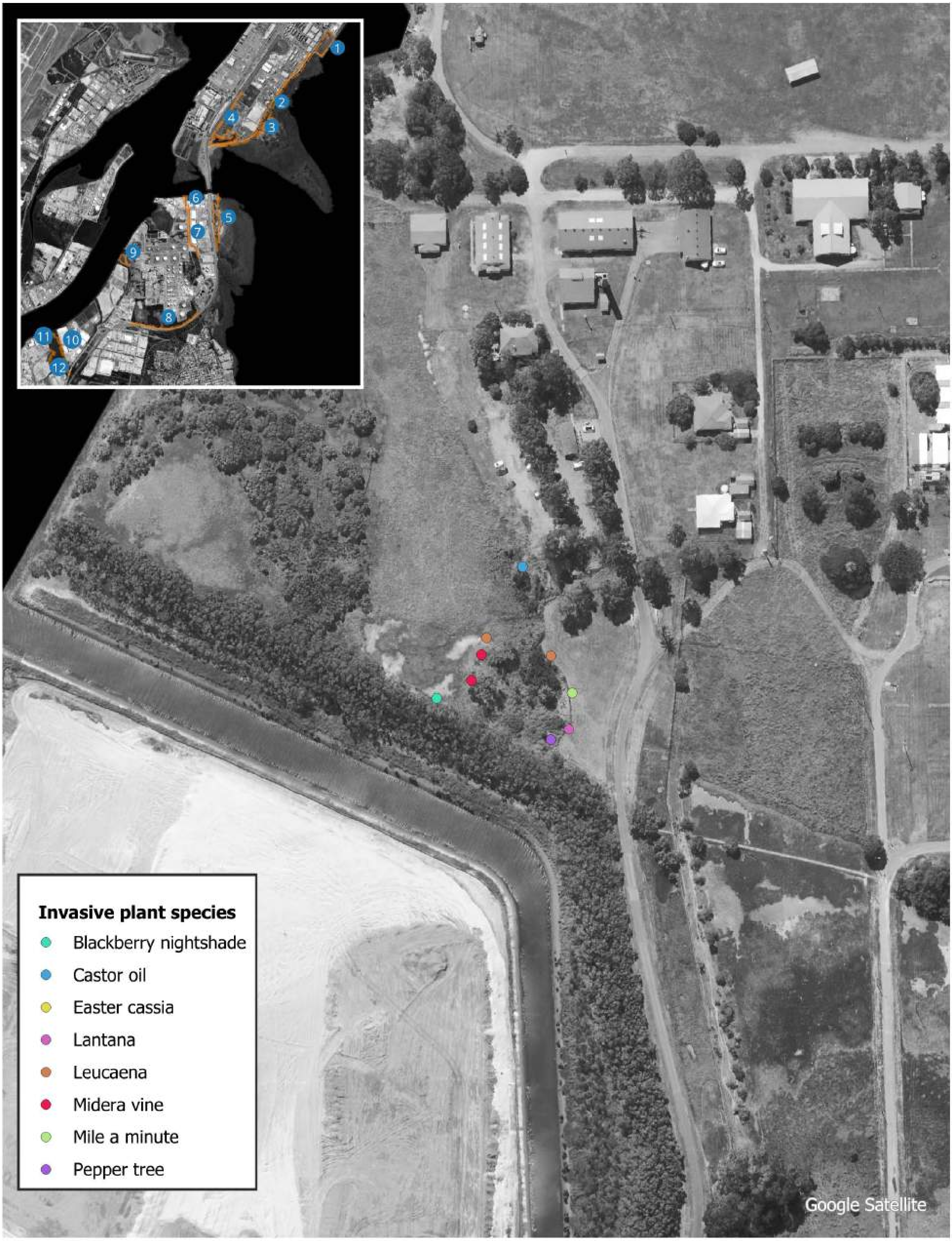
N

0 5 10 m

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\DRG\2023_Weeds\ECO_002_230315_FortLytton2024.qgz



Title:

Observed invasive plant species at Key Area 9: Fort Lytton

Figure: 3.14

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 25 50 75 m

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants\QGIS\StudyArea.qgz

3.1.10 Port West (Wetlands)

Port West, located west of Lytton Road approximately 4 km south-west of the Port, supports a mosaic of mangroves and saltmarsh wetlands directly connected to the Brisbane River. Like other sites at the Port, the saltmarsh-mangrove ecotone and upper tidal limits adjacent to industrial land uses are susceptible to disturbance and weed invasion. Weed species recorded in the 2024 survey include:

- **Restricted Matters** recorded included broad-leaved pepper tree, lantana, groundsel and prickly pear. Very sparse coverage of pepper tree and prickly pear were recorded in a clearing in the north-western area of dense mangrove. This clearing was noted to be at higher elevations compared to surrounding mangrove.

- **Other woody weeds** observed include broad-leaved pepper tree, lantana, groundsel, Easter cassia, wild tobacco, Chinese elm and, umbrella tree castor oil plant.

- **Vines** include siratro, mile a minute, and passionflower.

- **Groundcover and grasses** recorded Rhodes grass, green panic, African pigeon grass and red natal grass

- **Herbs and forbes** observed were hairy fleabane and coral berry

An example of weeds at Port West is shown in and their distribution is shown in Figure 3.15 and Figure 3.17.

Figure 3.15 (Top) Prickly pear and pepper tree in elevated clearing north-west of dense mangrove (Bottom) Prickly pear patch on the western fringes of the dense mangrove

3.1.11 Port West (Drain)

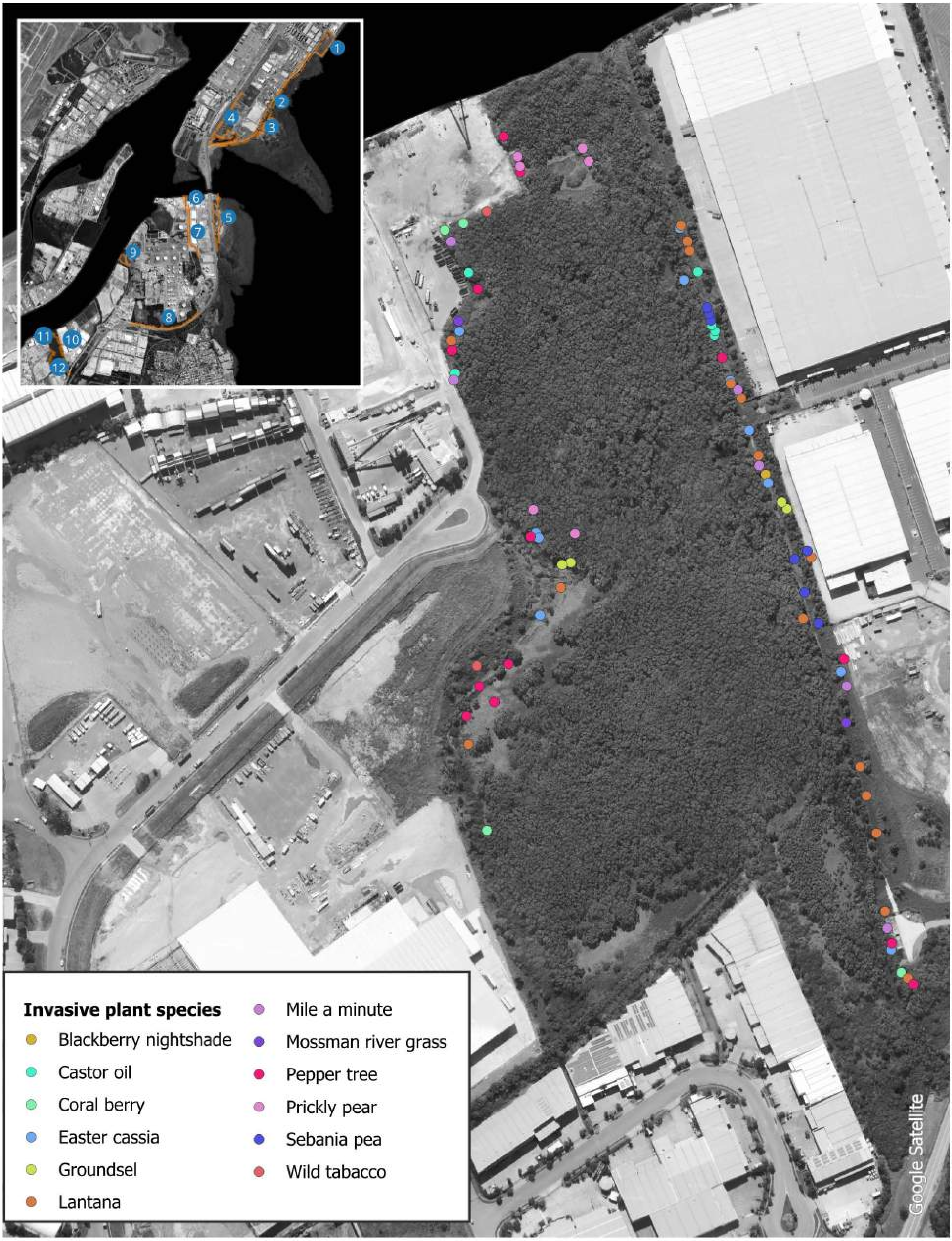
The drain (western area of Port West) is a narrow intertidal channel fringed by remnant mangroves comprised of native grey mangrove. The channel is bounded to the west by extensive mangrove forest (described above) and to the east by cleared land for industrial purposes.

The drain on the eastern side of Port West has extensive and dense weeds on either side of the access track, with sections of dense weeds across the access track. The following observations were made of this area in 2024:

- **Restricted Matters** recorded include broad-leaved pepper tree, lantana, groundsel, prickly pear.
- **Other woody weeds** broad-leaved pepper tree, lantana, groundsel, easter cassia, castor oil plant, and rattlepod.
- **Vines** identified include mile a minute and passionflower. Additionally, siratro was identified in large patches across the access track.
- **Groundcover and grasses** observed include Mossman River grass, green panic and red natal.
- **Herbs and forbes**: asparagus fern, New Zealand spinach, blackberry nightshade, fine-leafed verbena (*Glandularia aristigera*), coral berry, hairy fleabane, cobblers peg, phasey bean, wandering jew, beach evening primrose, balloon cotton, false daisy
- Sesbania pea were also recorded.
- No observations of madeira vine were recorded.

An example of weed species are shown in Figure 3.16 with observed records shown in Figure 3.17.

Figure 3.16 Siratro growth over access track



Title:	Figure:	Rev:
Observed invasive plant dpecies at Key Area 10, 11, 12: Port West Drain, Port West - A and B	3.17	A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N 0 60 120 180 m

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants\QGIS\StudyArea.qgz

3.2 Model Outputs

It is important to note that the SDM analysis excluded all field observations related to the occurrences of invasive plant species where the occurrence was less than nine (see Table 3.1). This was done to ensure the statistical robustness of the SDM.

The following sections contain detailed information on each of the nine invasive plant species in Table 3.1 and overall summary of the priority targeted species in each of the study areas. Comprehensive supporting maps and statistical data are also provided in the Annex to allow a more in-depth understanding of the respective distribution and impacts. The SDMs for each month are presented in Annex E. These models provide a visual representation of the geographical distribution of each species, offering insights into their preferred habitats and potential areas of invasion.

The Receiver Operating Characteristic (ROC) curves for each month are included in Annex H. These curves illustrate the performance of the predictive models, with the area under the curve indicating the accuracy of the model in distinguishing between presence and absence of the species. The monthly omission rates, which measure the percentage of actual presences that are incorrectly predicted as absences by the model, are documented in Annex I. These rates can help assess the reliability of the predictions made by the model.

Table 3.2 Selected Species for Distribution Modelling

ID	Common Name	Number Observed
1	Castor oil	15
2	Coral berry	9
3	Easter cassia	20
4	Groundsel	25
5	Lantana	36
6	Leucaena	12
7	Mile a minute	35
8	Pepper tree	49
9	Sesbania pea	52

3.2.2 Castor Oil

Ricinus communis (castor oil plant[8]) is recognised as an environmental issue in most Australian states. This plant is infamous for its highly toxic seeds, which pose a significant danger to both humans and livestock. The castor oil plant is a large, sturdy shrub that can often grow over 3 meters tall. It is characterised by its thick, hollow, and hairless stems that carry large leaves. The castor oil plant is commonly found in creek banks (i.e., riparian areas), dry riverbeds, waterways, roadsides, railways, disturbed sites, pastures, gardens, neglected suburban areas, and other waste areas. It thrives in tropical, sub-tropical, temperate, and occasionally semi-arid environments.

[8] https://weeds.brisbane.qld.gov.au/weeds/castor-oil-plant

EEVs

The SDM identified several crucial EEVs that significantly influenced the distribution of castor oil in 2023. The outcomes of the Jackknife Test (see Section 2.2.5) for each of the eight EEVs, are graphically presented in Annex F and key results are described below.

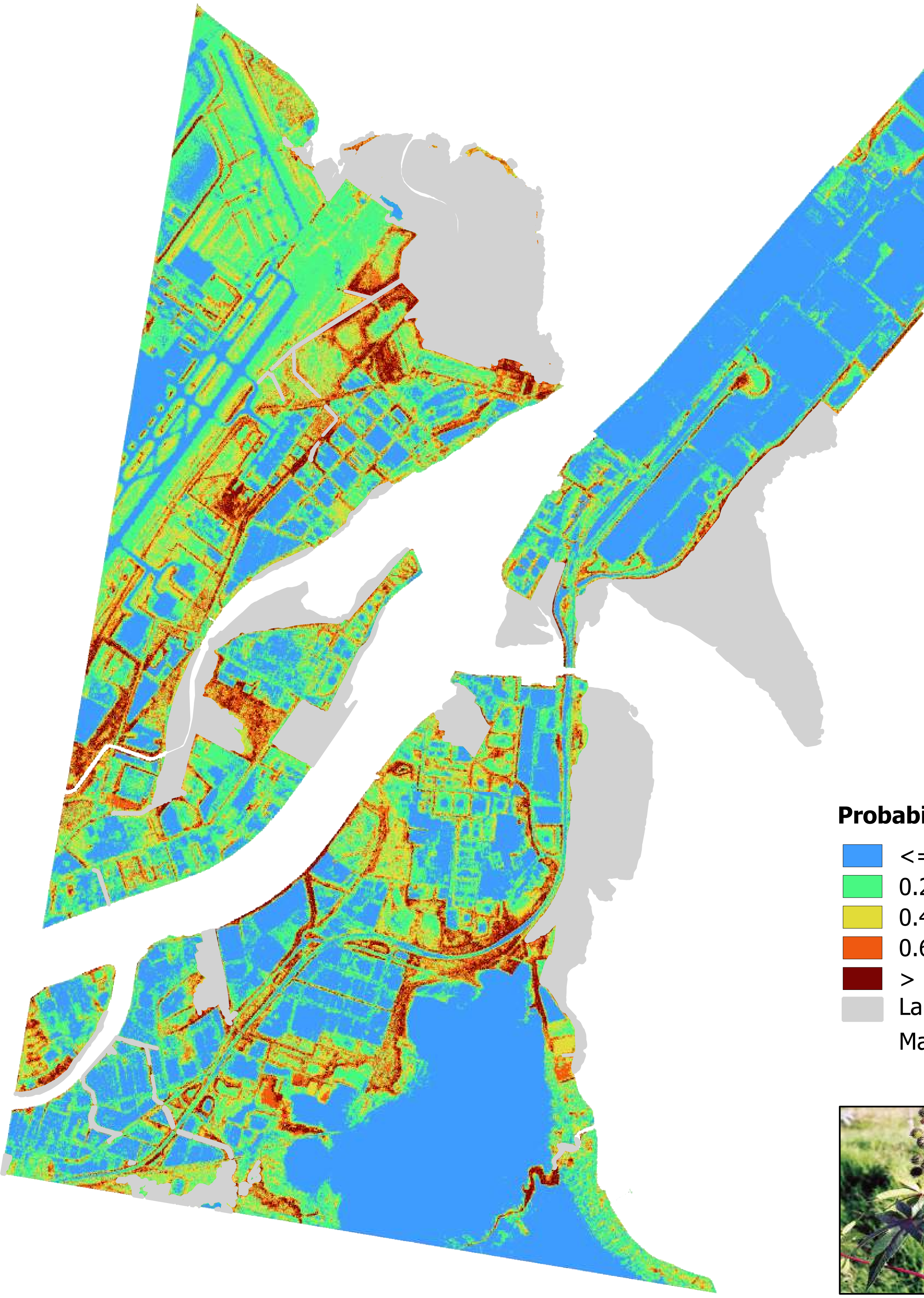
For January, the following EEVs had AUC values above 0.6 (i.e. had some predictive discrimination): soil temperature, LAI, NDVI, slope, solar radiation and TWI. Aspect and DEM did not have strong predictive discrimination in January. When the model was run without each focus EEV, the AUC values remained high, suggesting that no one EEV was the main predictor of castor oil distribution. The two EEVs that appeared to have the highest predictive accuracy were slope and solar radiation. February and March had similar patterns to January, with slope remaining a strong predictor, however the predictive accuracy of solar radiation reduced significantly. In March, soil temperature had strong predictive discrimination. The AUC values for EEVs in April remained very similar to those experienced in previous months. In May, June and July, the model performed noticeably worse, having an overall AUC of approximately 0.65 – 0.74 (compared to 0.8 in previous months). The predictive accuracy of all EEVs decreased, with the exception of slope which remained a strong predictor. In July, LAI, NDVI and TWI had higher AUC values than their 'without variable' counterparts. AUC values for the entire model increased again post-July, back to approximately 0.8. The following EEVs remained as potential predictors of castor oil distribution (i.e. AUC above 0.6): soil temperature, LAI, NDVI, Slope and TWI, with slope and soil temperature consistently having the highest AUC values. Solar radiation becomes a strong predictor from October onwards.

The outcomes of the Jackknife Test suggest that the SDM is better at predicting castor oil distribution in the summer months, with higher overall AUC values observed. Key EEVs which influence distribution in summer are primarily slope, solar radiation and LAI. The SDM is less effective at predicting castor oil distribution in the winter months, with lower overall AUC values observed. Key EEVs which influence distribution in winter are primarily slope, soil temperature and TWI. The model's accuracy, according to Receiver Operating Characteristic (ROC) is 80 percent.

Similar patterns are displayed in the April response curves (Annex G), which suggest that increased temperatures, lower elevation/DEM, higher LAI/NDVI, moderate/high solar radiation, moderate/high slope and low/moderate TWI favoured the proliferation of this species.

Spatial Distribution

The predicted spatial distribution for castor oil around the study area is presented in Figure 3.18. The SDM shows the highest probabilities of weed occurrence along narrow roadside areas which correlate to more manicured gardens and disturbed vegetation. This aligns with castor oil's preferred habitat types, which include roadsides, railways, disturbed sites and gardens. The SDM also shows some areas of moderate occurrence probability in densely vegetated areas and saltmarsh/swampy areas, often near a water body. This aligns with the riparian habitat preferences of the weed, however, the salinity of these areas and how it relates to castor oil's tolerance requires further investigation. Areas displayed as having the lowest probabilities of occurrence include urban/developed areas, bare ground and manicured verges.



Title:

Castor Oil Distribution

Figure: **3.18**

Rev: **A**

N

0 1 2 km

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz

3.2.3 Coral Berry

Rivina humilis (the coral berry[9]) is classified as an environmental weed in Queensland and New South Wales. In other parts of Australia, they are considered a “sleeper weed”, having not yet reached their potential to establish widespread populations. This plant is a small shrub or a woody herb that thrives in moist and shaded environments. It is commonly found in enclosed forests, forest edges, near bodies of water, disturbed areas, waste spaces, urban bushland, and gardens within tropical/sub-tropical climates.

EEVs

The model identified several crucial EEVs that significantly influenced the distribution of coral berry in 2023. The outcomes of the Jackknife Test (see Section 2.2.5) for each of the eight EEVs, are graphically presented in Annex F and key results are described below.

Overall model AUC values remained lower on average (0.7-0.75) for coral berry than for castor oil, suggesting the SDM is not as effective at predicting this weed. For January, only three EEVs had AUC values above 0.6 (i.e. had some predictive discrimination): soil temperature, LAI and NDVI. Aspect, DEM, slope, solar radiation and TWI did not have strong predictive discrimination in January. When the model was run without each focus EEV, the AUC values remained high, suggesting that no one EEV was the main predictor of coral berry distribution. February and March had similar patterns to January, however the predictive accuracy of soil temperature reduced significantly in February. April also experienced a significant decline in the predictive accuracy of soil temperature. LAI and NDVI remain the strongest predictors with the highest AUC values, however, solar radiation also shows an increase in AUC values. May, June and August replicate this pattern, with the only noticeable changes being fluctuations in the AUC of soil temperature. July has a higher overall AUC of approximately 0.78 (compared to the 0.70 of previous months) and soil temperature is once again a strong predictor of weed distribution. September and October display a very similar AUC pattern, with soil temperature, LAI, NDVI and solar radiation having the strongest predictive accuracy. Finally, November and December show increases in soil temperature AUC but decreases in LAI, NDVI and solar radiation AUC.

The outcomes of the Jackknife Test suggest that the SDM predictions for coral berry distribution are more seasonally consistent than for castor oil but are less effective overall (with the exceptions of March, July, September and October). Key EEVs which influence distribution are primarily soil temperature (very variable), LAI, NDVI and solar radiation (very variable). The model’s accuracy, as evaluated by the ROC, averages to 70 percent. This is likely due to the lower sample size for coral berry compared with other weeds in the 2024 monitoring survey.

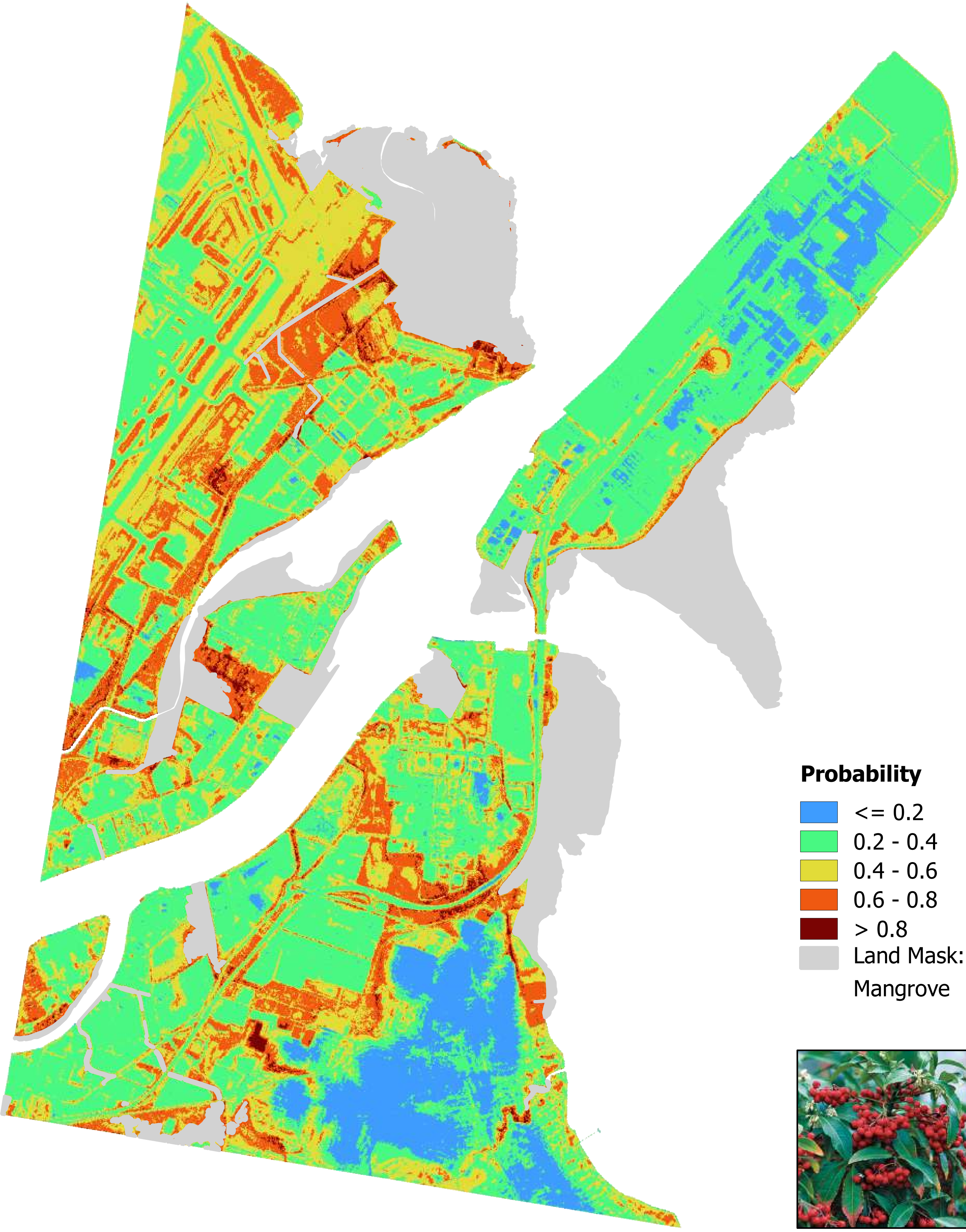
Similar patterns are displayed in the April response curves (Annex G), which suggest that low elevation/DEM, higher LAI/NDVI, gentle slope, and low/moderate solar radiation, low to high TWI was favoured the proliferation of this species.

Spatial Distribution

The predicted spatial distribution for coral berry around the study area is presented in Figure 3.19. The SDM shows the highest probabilities of weed occurrence in densely vegetated areas, particularly near water bodies. This aligns with coral berry’s preferred habitat types, which include enclosed forests, forest edges, near bodies of water and urban bushland. However, the model has flagged many high probability areas as occurring within saltmarsh/swampy areas. The salinity of these areas and how it relates to coral berry’s tolerance requires further investigation. The SDM shows some areas of moderate occurrence probability around roadsides, railways and gardens which aligns with the species’ preference for disturbed vegetation. Areas displayed as having the lowest probabilities of occurrence include urban/developed areas.

---

[9] https://weeds.brisbane.qld.gov.au/weeds/coral-berry



Title:

Coral berry Distribution

Figure: **3.19**

Rev: **A**

N

0 1 2 km

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz

3.2.4 Easter Cassia

Senna pendula var. glabrata (the easter cassia[10]) is recognised as a substantial environmental weed in New South Wales and Queensland. This species typically outperforms native species due to its abundant fruit production and swift growth rate. The easter cassia is an upright or sprawling shrub that typically grows between 2-4 meters tall. It typically invades waterways, gardens, disturbed locations, waste areas, roadsides, enclosed forests, forest edges, and urban bushland in tropical, sub-tropical, and warmer temperate regions.

EEVs

The model identified several crucial EEVs that significantly influenced the distribution of easter cassia in 2023. The outcomes of the Jackknife Test (see Section 2.2.5) for each of the eight EEVs, are graphically presented in Annex F and key results are described below.

Overall model AUC values remained higher on average (0.85-0.90) for easter cassia than for the previous two weeds, suggesting the SDM is more effective at predicting this weed. For January, all EEVs except TWI had AUC values above 0.6 (i.e. had some predictive discrimination). LAI and NDVI were the strongest predictors in January. When the model was run without each focus EEV, the AUC values remained high, suggesting that no one EEV was the main predictor of easter cassia distribution. February and March had very similar patterns to January, however the predictive accuracy of solar radiation reduced significantly. April also experienced a similar pattern, however the AUC values for aspect, DEM, LAI, NDVI, slope and TWI all increased. May and June displayed similar trends again, with the only noticeable difference being a significant decrease in soil temperature as a predictor. Soil temperature increases from July onwards. September and October display a significant decrease in AUC value for TWI. Finally, in November and December the predictive accuracy of LAI, slope and solar radiation increase. NDVI remained the strongest predictor of coral berry throughout all twelve months.

The outcomes of the Jackknife Test suggest that the SDM predictions for easter cassia distribution are relatively seasonally consistent and more effective overall than for the previous two weeds. Key EEVs which influence distribution are primarily soil temperature (very variable), LAI, NDVI, slope (very variable) and aspect. The model's accuracy, as evaluated by the ROC, averages to 90 percent.

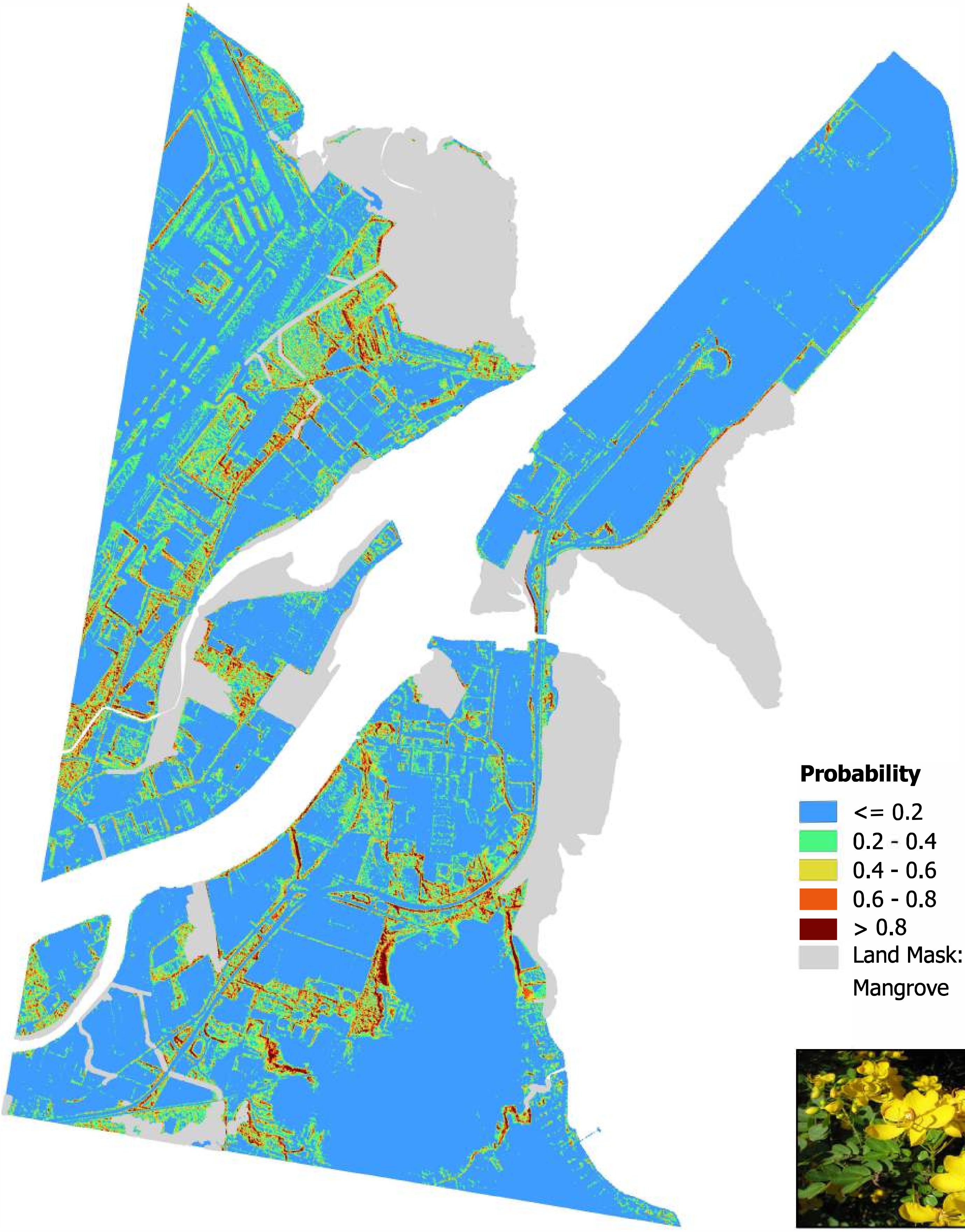
Similar patterns are displayed in the April response curves (Annex G), which suggest that higher soil temperature, low/certain elevation/DEM, high/certain NDVI, moderate slope generally facing west, and moderate solar radiation, and low TWI is favoured for proliferation of this species.

Spatial Distribution

The predicted spatial distribution for easter cassia around the study area is presented in Figure 3.20. The SDM shows the highest probabilities of weed occurrence along narrow roadside areas which correlate to more manicured gardens and disturbed vegetation. This aligns with easter cassia's preferred habitat types, which include gardens, disturbed locations, waste areas and roadsides. Areas of moderate occurrence probability tend to branch out from the high probability areas and into more densely vegetated areas. This aligns with the enclosed forests, forest edges, and urban bushland preferences of the weed. The distribution map is dominated by area of low probability of occurrence, which encompass all other land use types.

---

[10] https://weeds.brisbane.qld.gov.au/weeds/easter-cassia



Title:

Easter Cassia Distribution

Figure: **3.20**

Rev: **A**

N

0 1 2 km

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz

3.2.5 Groundsel Bush

Baccharis halimifolia (the groundsel bush[11]) is a prominent environmental weed in Queensland and New South Wales, holding the second rank among invasive plants in south-eastern Queensland. The species is a significant threat to sub-tropical melaleuca wetlands, forming a dense understorey that suppresses native sedges and disrupts ecosystems. It is described as a bushy shrub which stands 1-3 m tall with stems that become woody as they age and waxy leaves. The groundsel bush is a weed found in open woodlands, forests, waste areas, disturbed sites, coastal canals, swampy areas, estuaries, mangrove wetlands, pastures, forestry plantations, orchards, plantation crops, irrigation channels, creek banks, parks, gardens, roadsides, and urban bushland. It prefers warmer temperate and sub-tropical climates.

EEV's

The model identified several crucial EEVs that significantly influenced the distribution of groundsel bush in 2023. The outcomes of the Jackknife Test (see Section 2.2.5) for each of the eight EEVs, are graphically presented in Annex F and key results are described below.

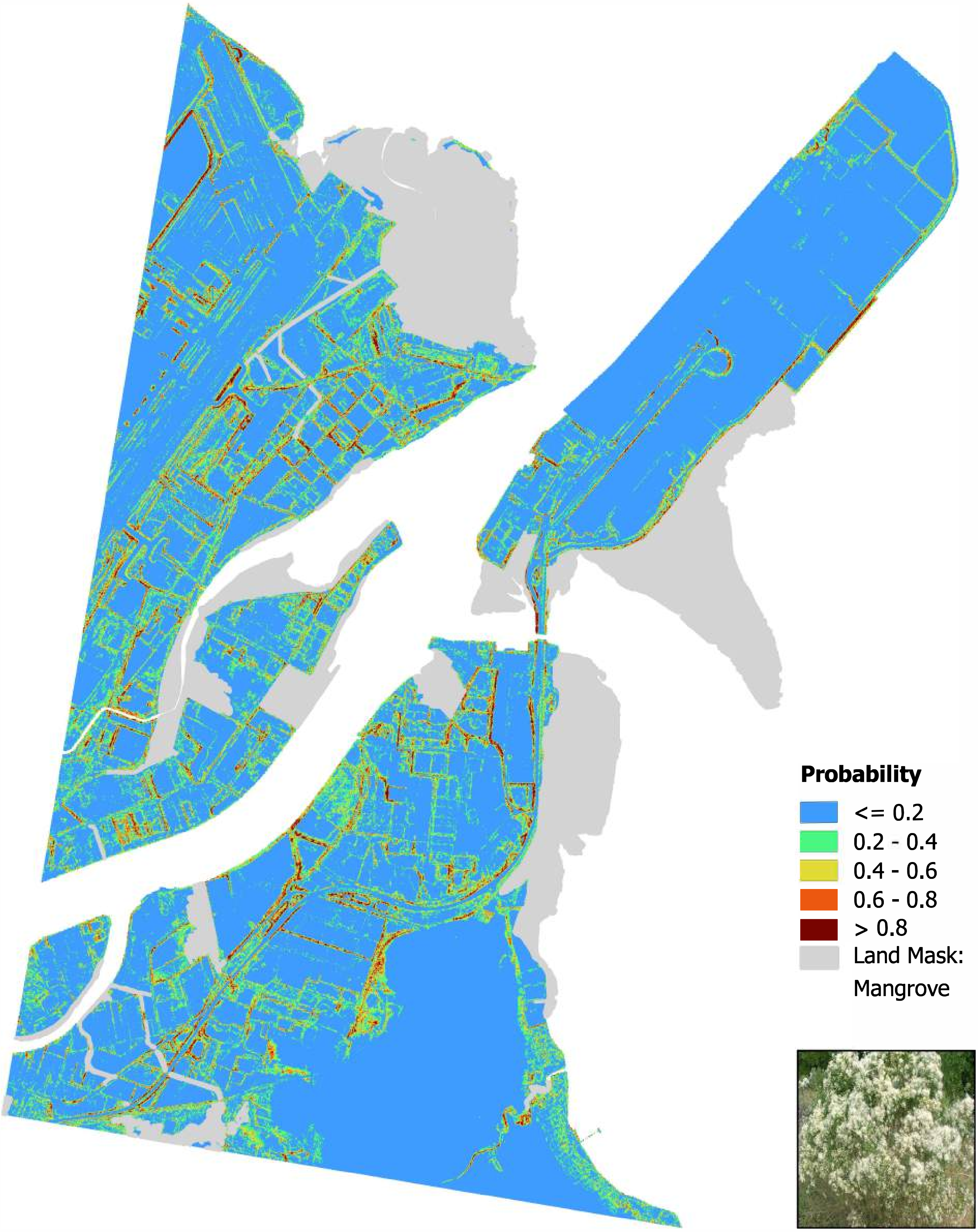
Overall model AUC values remained high on average (0.85-0.90) for groundsel bush (similar to easter cassia), suggesting the SDM is effective at predicting this weed. For January, all EEVs except aspect had AUC values above 0.6 (i.e. had some predictive discrimination). Soil temperature, slope and solar radiation were the strongest predictors in January. When the model was run without each focus EEV, the AUC values remained high, suggesting that no one EEV was the main predictor of groundsel bush distribution. February, March and April had very similar patterns to January, however the predictive accuracy of solar radiation reduced significantly, while it increased for slope. May, June and July displayed similar trends again, with the only noticeable difference being a decrease in soil temperature as a predictor. August displayed a significant increase in soil temperature, becoming the strongest predictor (highest AUC value) for that month. AUC values for most EEVs increased in September and October (particularly solar radiation, DEM, LAI, NDVI). A significant increase in solar radiation was also observed in November and December, with the strongest predictors for that month being soil temperature, slope and solar radiation.

The outcomes of the Jackknife Test suggest that the SDM predictions for groundsel bush distribution are relatively seasonally consistent and effective overall. Key EEVs which influence distribution are primarily soil temperature (very variable), slope, NDVI and solar radiation (very variable). The model's accuracy, as evaluated by the ROC, averages to 90 percent. Similar patterns are displayed in the April response curves (Annex G), which suggest that higher soil temperature, low/certain elevation/DEM, high/certain NDVI, high LAI, moderate/high slope generally facing north, east, and south, and moderate/high solar radiation, and low TWI was favoured the proliferation of this species.

Spatial Distribution

The predicted spatial distribution for groundsel bush around the study area is presented in Figure 3.12. The SDM shows the highest probabilities of weed occurrence along narrow roadside areas which correlate to more manicured gardens, verges and disturbed vegetation. This aligns with groundsel bush's preferred habitat types, which include disturbed sites, parks, gardens, roadsides, and urban bushland. Areas of moderate occurrence probability tend to branch out from these high probability areas, following the same patterns. The distribution map is dominated by area of low probability of occurrence, which encompass all other land use types. It should be noted that groundsel bush can be found in coastal canals, swampy areas, estuaries, mangrove wetlands, however this model has classed most saltmarsh areas as having low probability. The salinity of these areas and how it relates to groundsel bush's tolerance requires further investigation

[11] https://weeds.brisbane.qld.gov.au/weeds/groundsel-bush



Title:

Groundsel Bush Distribution

Figure: 3.21

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 1 2 km

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz

3.2.6 Lantana

Lantana camara (lantana[12]) is recognised as one of Australia's 20 Weeds of National Significance (WoNS). It's considered a major environmental weed in Queensland, New South Wales, and Norfolk Island, and a potential environmental threat in Western Australia and the Northern Territory. Lantana is characterised by its rough texture, and small tubular flowers. It is a versatile species that primarily thrives in tropical and sub-tropical climates, but it can also adapt to warmer temperate and semi-arid regions. It is commonly found along roadsides, waterways, coasts, railways, fences, waste areas, disturbed sites, closed forests, forest edges, grasslands, plantation crops, pastures, and parklands. Most frequently, it is observed in the understory of open woodlands.

EEVs

The model identified several crucial EEVs that significantly influenced the distribution of lantana in 2023. The outcomes of the Jackknife Test (see Section 2.2.5) for each of the eight EEVs, are graphically presented in Annex F and key results are described below.

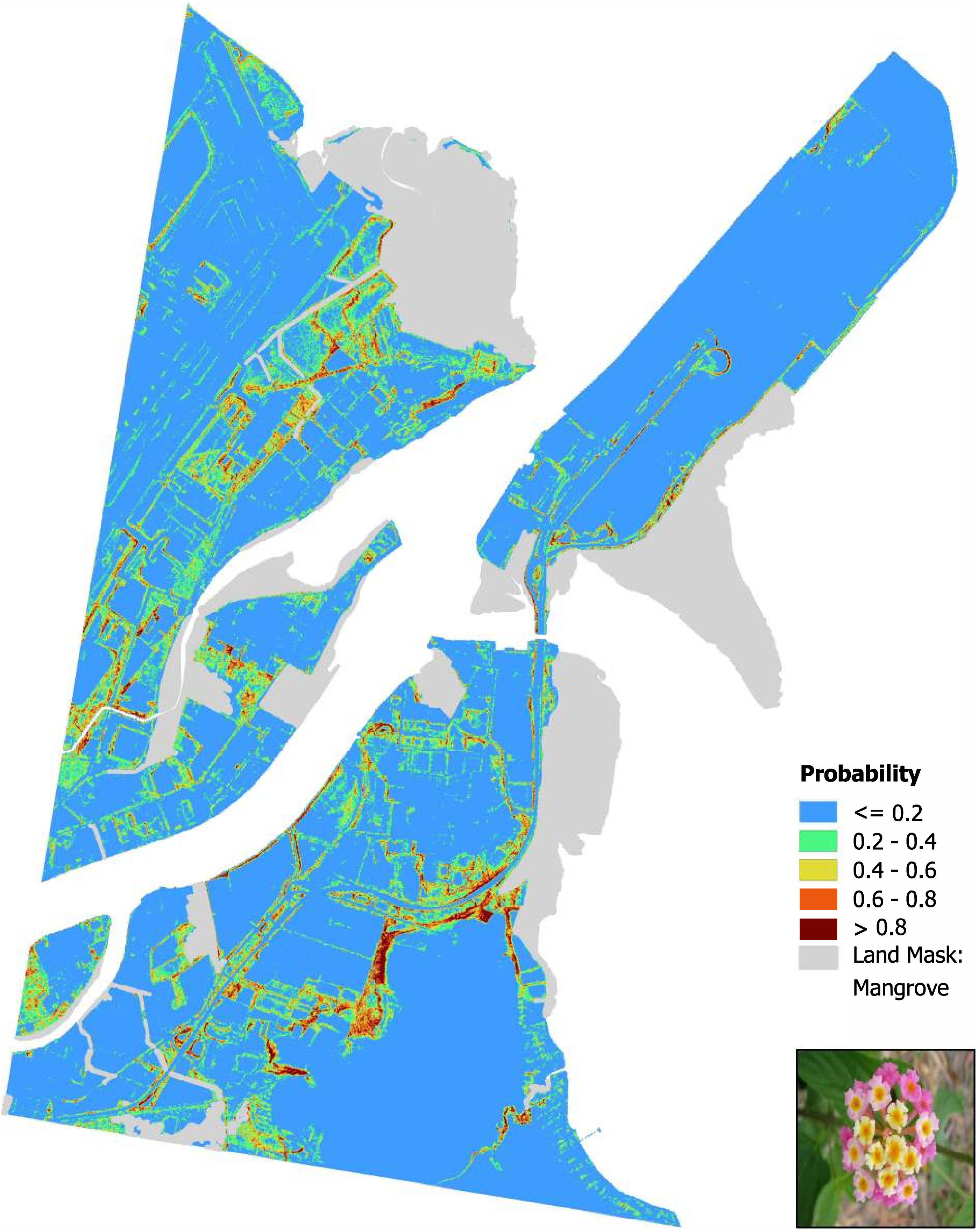
Overall model AUC values remained very high on average (above 0.90) for lantana, suggesting that the SDM is very effective at predicting this weed. For January, all EEVs except aspect had AUC values above 0.6 (i.e. had some predictive discrimination). Soil temperature, LAI and NDVI were the strongest predictors in January. When the model was run without each focus EEV, the AUC values remained high, suggesting that no one EEV was the main predictor of lantana distribution. February, March and April had similar patterns to January, however the predictive accuracy of solar radiation reduced significantly from February onwards, while it increased for TWI. Soil temperature, LAI and NDVI remained the strongest predictors, followed by DEM and slope. May, June and July displayed a significant decrease in the predictive accuracy of soil temperature and a slow decrease for LAI. NDVI and slope were the strongest predictors. August displayed a significant increase in soil temperature, becoming the strongest predictor (highest AUC value) for that month (a trend reminiscent of March and April). September and October displayed very similar trends, before the predictive accuracy of solar radiation increased significantly throughout November and December, with the strongest predictors for December being soil temperature, LAI and solar radiation.

The outcomes of the Jackknife Test suggest that the SDM predictions for lantana distribution are very seasonally consistent and effective overall. Key EEVs which influence distribution are primarily soil temperature (very variable), slope, LAI, NDVI and solar radiation (very variable). The model's accuracy, as evaluated by the ROC, averages to 90 percent. Similar patterns are displayed in the April response curves (Annex G), which suggest that higher soil temperature, low/certain elevation/DEM, high/certain NDVI, high LAI, moderate/high slope generally facing north, east, and south, and moderate/high solar radiation, and low/moderate TWI was favoured the proliferation of this species.

Spatial Distribution

The predicted spatial distribution for lantana around the study area is presented in Figure 3.13. The SDM shows the highest probabilities of weed occurrence along main roadside areas and railways, with a particularly large probability predicted surrounding the railway route towards the south of the study area. These areas correlate to disturbed vegetation and verges. This aligns with lantana's preferred habitat types. Areas of moderate occurrence probability tend to branch out from these high probability areas, following the same patterns. Low probability of occurrence areas include most urban/industrial and residential areas. Some saltmarsh/swampy areas have been flagged as low-moderate probability of occurrence. This also aligns with lantana's ability to establish on coasts and is consistent with local observations (e.g. Brisbane Airport, Port of Brisbane), however the salinity of these areas and how it relates to lantana's tolerance requires further investigation.

[12] https://weeds.brisbane.qld.gov.au/weeds/lantana



Title:

Lantana Distribution

Figure: **3.22**

Rev: **A**

N

0 1 2 km

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz

3.2.7 Leucaena

Leucaena leucocephala (leucaena[13]) is recognised as an environmental weed in Queensland, the Northern Territory, Western Australia, New South Wales, and Christmas Island. It is also noted in the Global Invasive Species Database (GISD) and ranks among the top 100 of the world's worst invasive alien species. The weed can grow into a shrub or small tree up to approximately 10 m tall or more. leucaena is particularly problematic in tropical and sub-tropical regions, where it invades waterways and roadsides. It is also found in open woodlands (typically in the understory), gardens, parks, waste areas, disturbed sites, coastal foreshores, and offshore islands.

EEVs

The model identified several crucial EEVs that significantly influenced the distribution of leucaena in 2023. The outcomes of the Jackknife Test (see Section 2.2.5) for each of the eight EEVs, are graphically presented in Annex F and key results are described below.

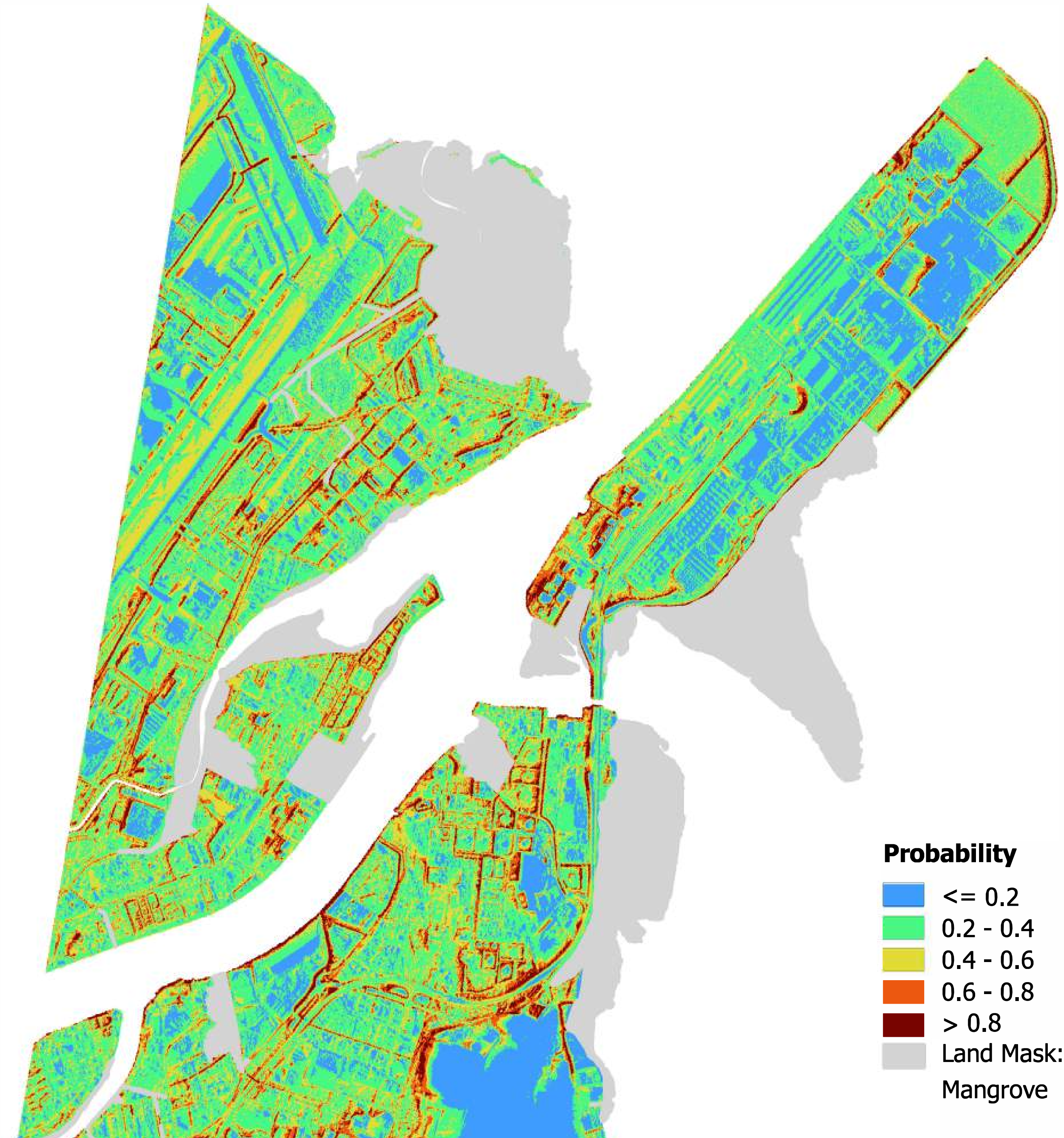
Overall model AUC values remained low-moderate on average (0.70-0.80) for leucaena, suggesting that the SDM is mostly effective at predicting this weed. For January, soil temperature, aspect and solar radiation had AUC values above 0.6 (i.e. had some predictive discrimination). Soil temperature and solar radiation were the strongest predictors in January. When the model was run without each focus EEV, the AUC values remained high, suggesting that no one EEV was the main predictor of leucaena distribution. February, March and April had similar patterns to January, however the predictive accuracy of solar radiation reduced significantly from February onwards, while it increased significantly for LAI and NDVI. Soil temperature and aspect remained the strongest predictors, followed by LAI and NDVI. In May, June and July, the model performed noticeably worse, having an overall AUC of approximately 0.7 (compared to 0.8 in previous months). The predictive accuracy of soil temperature, aspect, LAI and NDVI all decreased. AUC values for the entire model increased again post-July, back to approximately 0.8. The August trend was very similar to January, with soil temperature and aspect returning as the strongest predictors. September, October, November and December had very similar patterns, except for a significant increase in the predictive accuracy of solar radiation from October onwards.

The outcomes of the Jackknife Test suggest that the SDM is better at predicting leucaena distribution in the summer months, with higher overall AUC values observed. The SDM is less effective at predicting leucaena distribution in the winter months, with lower overall AUC values observed. However, soil temperature and aspect are the key EEVs which influence leucaena distribution year-round, with solar radiation playing a larger role in summer. The model's accuracy, as evaluated by the ROC, averages to 80 percent. Similar patterns are displayed in the April response curves (Annex G), which suggest that higher soil temperature, low elevation/DEM, high NDVI/LAI, moderate/high slope generally facing west, and low/moderate solar radiation, was favoured the proliferation of this species.

Spatial Distribution

The predicted spatial distribution for leucaena around the study area is presented in Figure 3.23. The SDM shows the highest probabilities of weed occurrence along roadside and railway areas which correlate to more manicured gardens and disturbed vegetation. This aligns with leucaena's preferred habitat types, which include roadsides, railways, disturbed sites, parks and gardens. The SDM also shows some areas of moderate occurrence probability in densely vegetated areas, often near a water body. This aligns with the riparian habitat preferences of the weed. Some saltmarsh/swampy areas have been flagged as moderate probability of occurrence. This aligns with leucaena's ability to establish on coastal foreshores, however the salinity of these areas and how it relates to leucaena's tolerance requires further investigation. The SDM suggests that leucaena distribution is very widespread, with the only low probability areas being heavily industrialised or residential areas.

[13] https://weeds.brisbane.qld.gov.au/weeds/leucaena



Title:

Leucaena Distribution

Figure: **3.23**

Rev: **A**

N

0 1 2 km

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz

3.2.8 Mile-A-Minute

Ipomoea cairica (mile-a-minute[14]) is a major environmental weed in Queensland (ranking among the top 30 environmental weeds in south-eastern Queensland), as well as in New South Wales, and Norfolk Island. It grows rapidly, smothering trees and understorey plants, and is characterised by its hairless, slender stems. It is prevalent in eastern Australia's coastal districts, invading riverbanks, rainforest margins, and littoral rainforest remnants. Mile-a-minute is also commonly found in waste areas, disturbed sites, open woodlands, bushland, gardens, fences and coastal sand dunes. It thrives in tropical, sub-tropical, and warmer temperate environments, particularly near the coast.

EEVs

The model identified several crucial EEVs that significantly influenced the distribution of Mine-A-Minute in 2023. The outcomes of the Jackknife Test (see Section 2.2.5) for each of the eight EEVs, are graphically presented in Annex F and key results are described below.

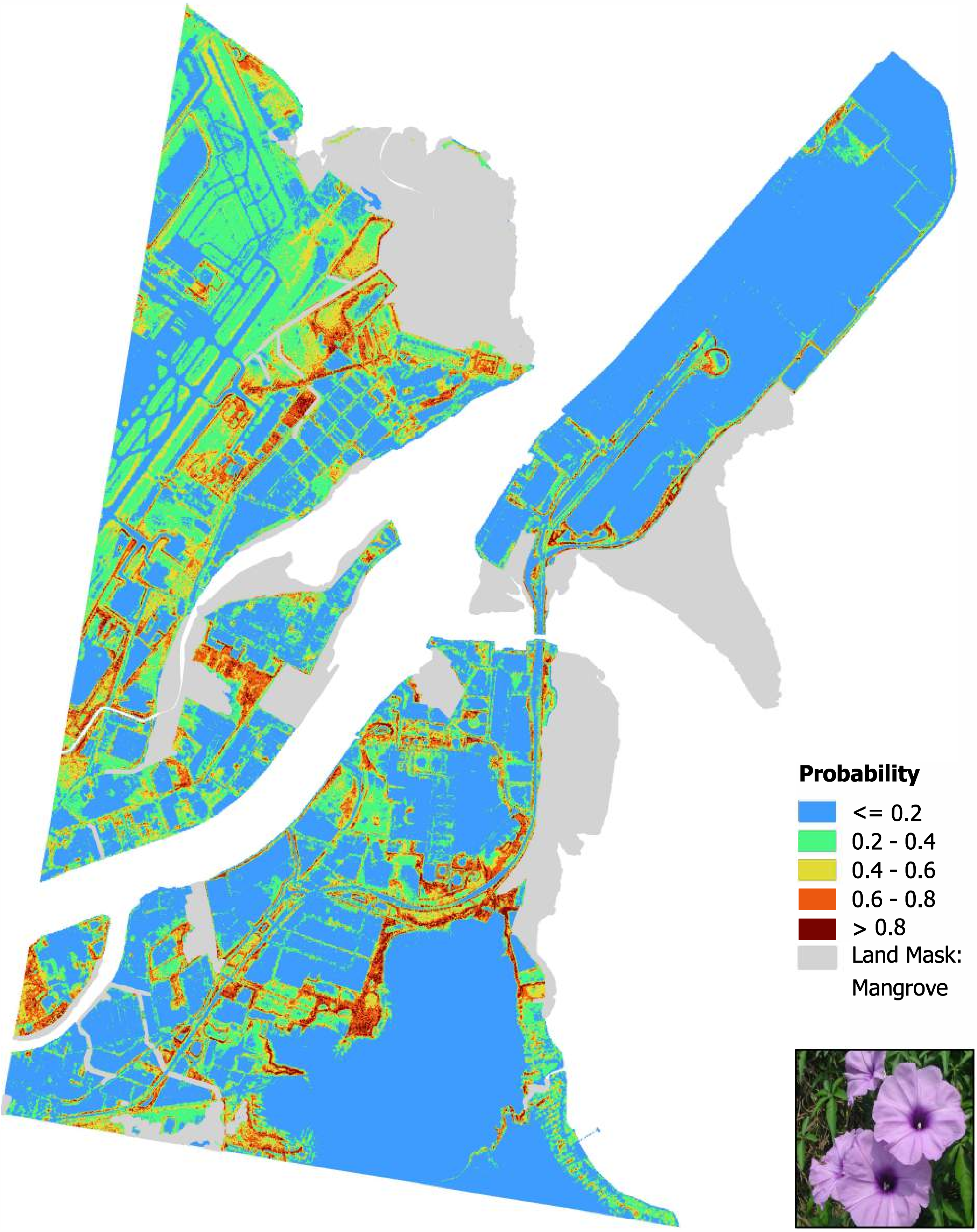
Overall model AUC values remained high on average (approximately 0.85) for mile-a-minute, suggesting that the SDM is effective at predicting this weed. For January, all EEVs except aspect and TWI had AUC values above 0.6 (i.e. had some predictive discrimination). Soil temperature, DEM, NDVI and solar radiation were the strongest predictors in January. When the model was run without each focus EEV, the AUC values remained high, suggesting that no one EEV was the main predictor of mile-a-minute distribution. February, March and April had similar patterns to January, however the predictive accuracy of solar radiation decreased, while the DEM EEV fluctuated. Soil temperature and aspect remained the strongest predictors, followed by LAI and NDVI. May, June, July and August maintained a very similar pattern, however the AUC of solar radiation decreased significantly in July before recovering again in August. September, October and November remained consistent with this trend, with solar radiation becoming a stronger predictor from November onwards.

The outcomes of the Jackknife Test suggest that the SDM predictions for mile-a-minute distribution are seasonally consistent and effective overall. Key EEVs which influence distribution are primarily soil temperature, aspect, LAI, NDVI and solar radiation (very variable – summer strongest). The model's accuracy, as evaluated by the ROC, averages to 90 percent. Similar patterns are displayed in the April response curves (Annex G), which suggest that higher soil temperature, low/certain elevation/DEM, high NDVI, moderate LAI, low/moderate slope facing west particularly, and moderate/high solar radiation, was favoured the proliferation of this species.

Spatial Distribution

The predicted spatial distribution for mile-a-minute around the study area is presented in Figure 3.24. The SDM shows the highest probabilities of weed occurrence along main roadside areas and railways, with a particularly large probability predicted surrounding the main road and railway route towards the south of the study area. Other 'hotspots' of occurrence are identified in dense vegetation patches to the east of the airport. These areas correlate to disturbed vegetation, verges and open woodlands/bushland areas. This aligns with mile-a-minute's preferred habitat types. Areas of moderate occurrence probability tend to more clearly follow verges and gardens, as well as riparian vegetation. Low probability of occurrence areas include most urban/industrial areas, residential areas and saltmarsh/swamps. Mile-a-minute has an ability to establish on coasts and therefore the salinity of these areas and how it relates to mile-a-minute's tolerance requires further investigation.

[14] https://weeds.brisbane.qld.gov.au/weeds/mile-minute



Title:

Mile-A-Minute Distribution

Figure: **3.24**

Rev: **A**

N

0 1 2 km

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz

3.2.9 Broad-Leaved Pepper Tree

Schinus terebinthifolius (the broad-leaved pepper tree[15]) is considered a major environmental weed in Queensland and New South Wales, and a potential threat in Western Australia. It is also seen as a "sleeper weed" in other Australian regions. The broad-leaved pepper tree is a large plant with wide-spreading branches and compound leaves. It is prevalent in sub-tropical, tropical, and warmer temperate regions, especially in areas close to human settlements. It can be found along waterways and roadsides, in urban bushland, open woodlands, disturbed sites, waste areas, and coastal wetlands.

EEVs

The model identified several crucial EEVs that significantly influenced the distribution of the broad-leaved pepper tree in 2023. The outcomes of the Jackknife Test (see Section 2.2.5) for each of the eight EEVs, are graphically presented in Annex F and key results are described below.

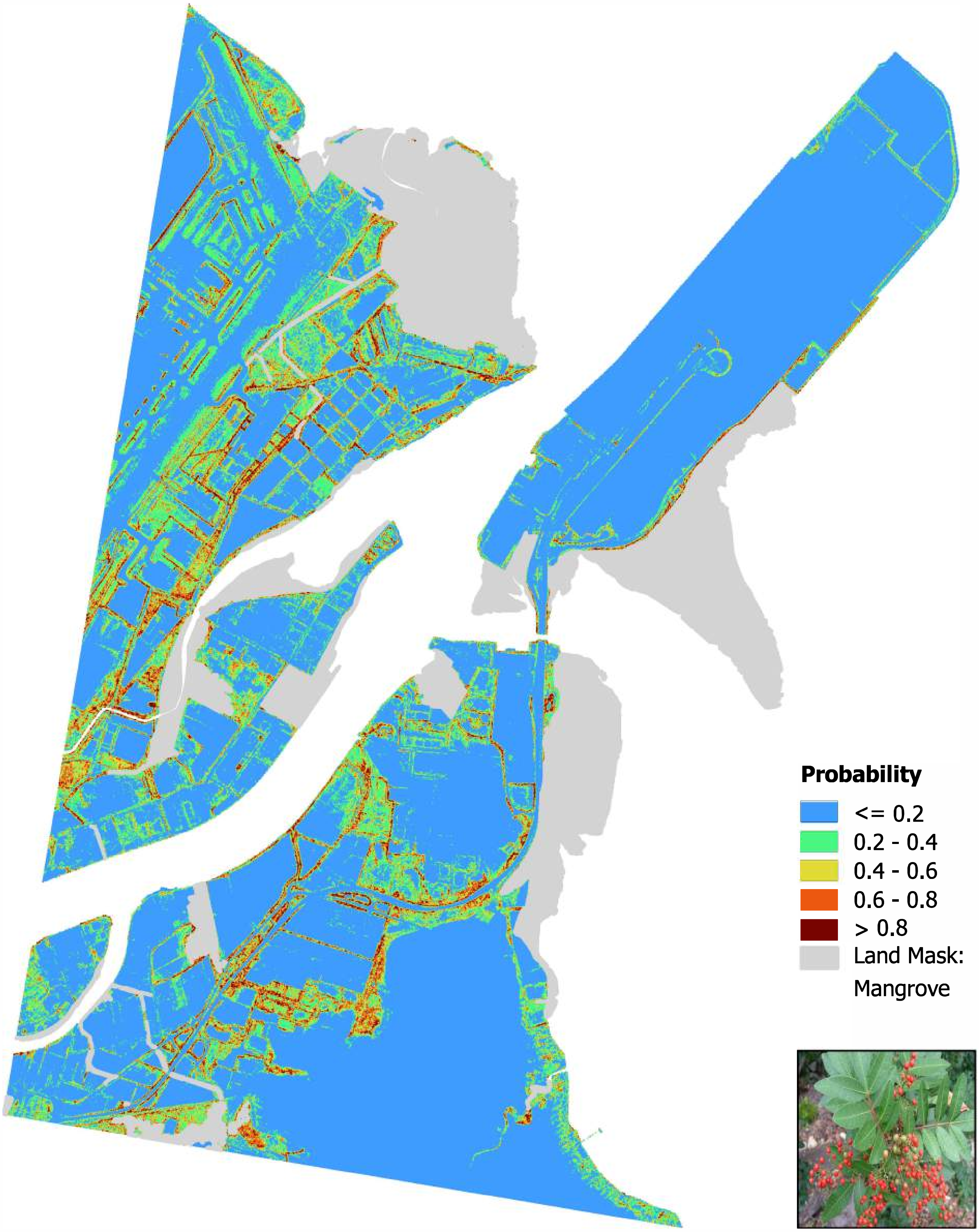
Overall model AUC values remained high on average (0.85-0.90) for the broad-leaved pepper tree, suggesting that the SDM is effective at predicting this weed. For January, all EEVs except aspect had AUC values above 0.6 (i.e. had some predictive discrimination). DEM, NDVI and slope were the strongest predictors in January. When the model was run without each focus EEV, the AUC values remained high, suggesting that no one EEV was the main predictor of broad-leaved pepper tree distribution. February, March and April had very similar patterns to January, with DEM and NDVI remaining strong predictors. Soil temperature AUC increased from February onwards. May, June and July had very similar patterns, characterised by a decrease in soil temperature predictive accuracy and slight increase in NDVI AUC. All EEVs predictability remained the same for August, except for increase in soil temperature. The same patterns are reflected in September, October, November and December, with solar radiation becoming a stronger predictor from November onwards.

The outcomes of the Jackknife Test suggest that the SDM predictions for broad-leaved pepper Tree distribution are seasonally consistent and effective overall. Key EEVs which influence distribution are primarily soil temperature (variable), DEM, NDVI, slope and solar radiation (very variable – summer strongest). The model's accuracy, as evaluated by the ROC, averages to 90 percent. Similar patterns are displayed in the April response curves (Annex G), which suggest that higher soil temperature, low/certain elevation/DEM, high/certain NDVI, moderate/certain LAI, low/moderate slope, moderate/high solar radiation, and low/moderate TWI was favoured the proliferation of this species.

Spatial Distribution

The predicted spatial distribution for Leucaena around the study area is presented in Figure 3.25. The SDM shows the highest probabilities of weed occurrence along roadside and railway areas which correlate to more manicured gardens and disturbed vegetation. This aligns with broad-leaved pepper tree's preferred habitat types, which include near waterways, roadsides, in urban bushland, open woodlands, disturbed sites and waste areas. The SDM also shows some areas of moderate-high occurrence probability in densely vegetated areas, often near a water body. This aligns with the riparian habitat preferences of the weed. Some saltmarsh/swampy areas have been flagged as moderate probability of occurrence. This aligns with broad-leaved pepper tree's ability to establish on coastal wetlands, however the salinity of these areas and how it relates to broad-leaved pepper tree's tolerance requires further investigation. Low probability of occurrence areas include most urban/industrial areas, residential areas and well maintained verges/gardens.

[15] https://weeds.brisbane.qld.gov.au/weeds/broadleaved-pepper



Title:

Broadleaved Pepper Distribution

Figure: **3.25**

Rev: **A**

N

0 1 2 km

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz

3.2.10 Sesbania Pea

Sesbania cannabina (the sesbania pea[16]) is an annual sub-shrub that grows between 1 to 3 meters tall. Despite being considered an environmental weed, the sesbania pea is noted for its nitrogen-fixing ability, making it an effective legume for the environment. It is a widespread local native that can become a problematic weed for agriculture. It thrives in disturbed and waste land along roadsides and in cultivated fields, particularly in seasonally wet areas, and it prefers heavy soils. In particular to PBPL lands the species can become a risk if observed within saltmarsh communities.

EEVs

The model identified several crucial EEVs that significantly influenced the distribution of the sesbania pea in 2023. The outcomes of the Jackknife Test (see Section 2.2.5) for each of the eight EEVs, are graphically presented in Annex F and key results are described below.

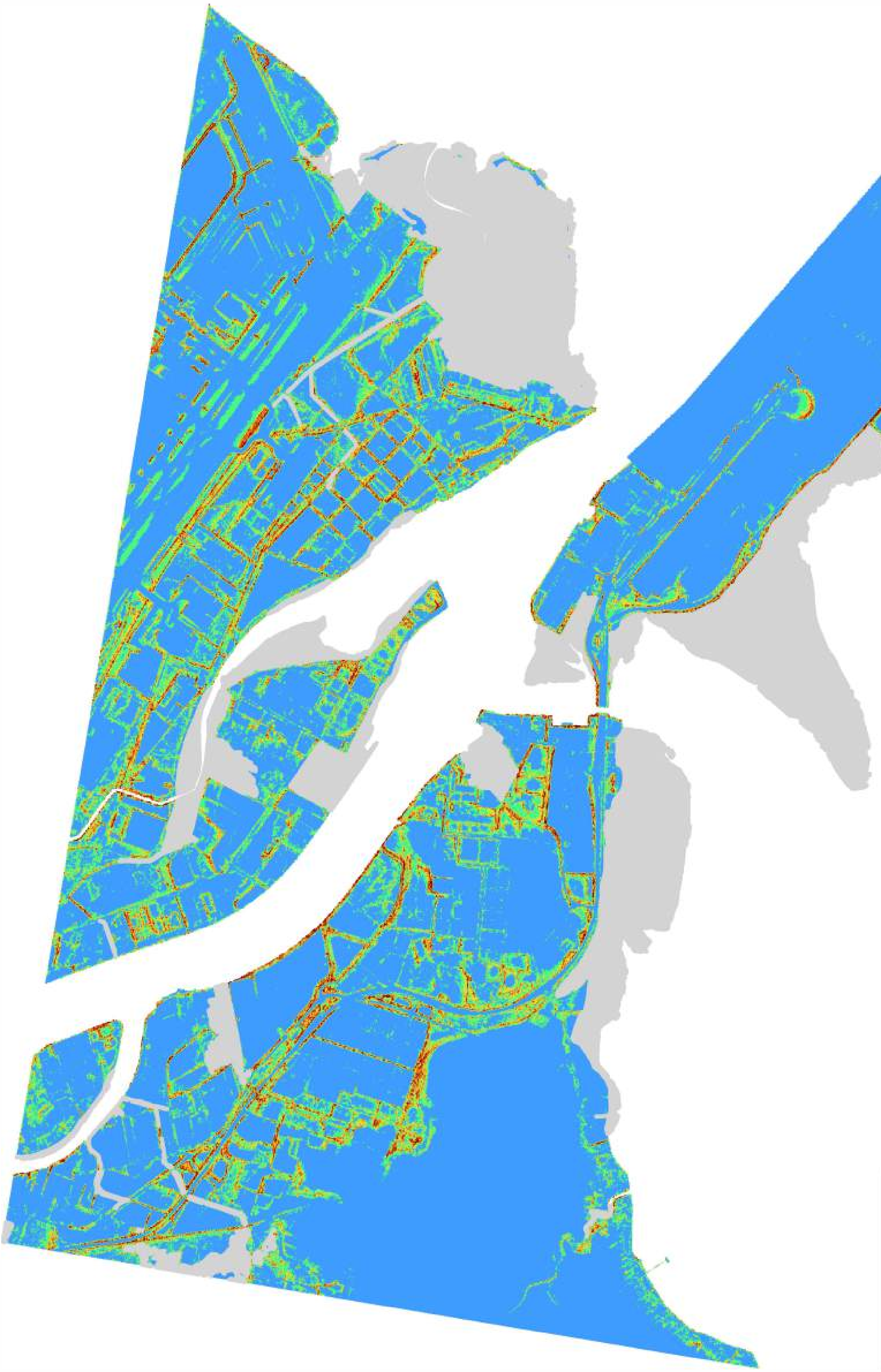
Overall model AUC values remained high on average (0.85-0.93) for sesbania pea, suggesting that the SDM is very effective at predicting this weed. For January, all EEVs except aspect and LAI had AUC values above 0.6 (i.e. had some predictive discrimination). Soil temperature was the strongest predictor in January, followed by NDVI, slope, solar radiation and TWI. When the model was run without each focus EEV, the AUC values remained high, suggesting that no one EEV was the main predictor of sesbania pea distribution. February, March and April had very similar patterns to January, however solar radiation AUC values fluctuated. Soil temperature remained the strongest predictor. May, June and July all had very similar patterns, characterised by a decrease in soil temperature predictive accuracy and increase in slope and solar radiation. Slope was the strongest predictor throughout these months, followed by solar radiation and TWI. Patterns for all EEVs remained the same in August, except for soil temperature which increased significantly. September, October, November and December display a broadly similar pattern, however significant fluctuations in aspect and solar radiation predictive capacities are observed.

The outcomes of the Jackknife Test suggest that the SDM predictions for sesbania pea distribution are seasonally consistent and effective overall. Key EEVs which influence distribution are primarily soil temperature (very variable), slope, TWI and solar radiation (variable). The model's accuracy, as evaluated by the ROC, averages to 90 percent. Similar patterns are displayed in the April response curves (Annex G), which suggest that higher/certain soil temperature, low/certain elevation/DEM, moderate/certain NDVI, high LAI, low/high slope facing north-east/north-west, moderate/high solar radiation, and low/moderate TWI was favoured the proliferation of this species.

Spatial Distribution

The predicted spatial distribution for sesbania pea around the study area is presented in Figure 3.26. The SDM shows the highest probabilities of weed occurrence along narrow roadside/railway areas which correlate to more manicured gardens, verges and disturbed vegetation. This aligns with sesbania pea's preferred habitat types, which include disturbed/waste land along roadsides and cultivated areas. Areas of moderate occurrence probability tend to branch out from these high probability areas, following the same patterns of roadsides and verges. The distribution map is dominated by area of low probability of occurrence, which encompass all other land use types. It should be noted that sesbania pea can be found in areas of heavy soils (e.g. peat soils) and the model has identified some areas of moderate probability near the coast. However, the salinity of these areas and how it relates to sesbania pea's tolerance requires further investigation

[16] https://cqclandcarenetwork.org.au/plants/sesbania-pea-yellow-pea-bush/



Title:

Sesbania Pea Distribution

Figure: **3.26**

Rev: **A**

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 1 2 km

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz

3.2.11 Summary of Outputs

A summary of the model outputs and management implications is outlined in Table 3.3.

Table 3.3 Summary of model outputs for the 9 species

Species	Growth form	Preferred habitat	Predicted spatial distribution on Port lands	Model accuracy (Receiver Operating Characteristic - ROC)	Key predictors	Management implications
Castor oil plant	Woody shrub	Waterways (creek banks, dry riverbeds), roadsides, railways, disturbed sites, pastures, gardens, neglected suburban areas	Road reserves and adjoining disturbed areas, saltmarsh (see management implications)	80% Higher predictive scores in summer than winter	Summer Slope (low) Solar radiation (moderate/high) LAI (high) Winter: Slope (low) Soil temperature (high) TWI (low/moderate)	Hotter and drier summers promote ideal growing conditions Potential intrusion of weed into saltmarsh wetlands – salinity analysis required Roads represent key habitat and potential vector for transport
Coral berry	Woody shrub	Moist and shaded environments, including enclosed forests, forest edges, near bodies of water, disturbed areas, waste spaces, urban bushland, and gardens	Densely vegetated areas, particularly near water bodies, as well as road corridors, saltmarsh (see management implications)	70% Lower predictive scores due to smaller input data sample size. March, July, September and October had higher predictive scores.	Soil temperature (variable) LAI (high) NDVI (high) Slope (low/variable) Aspect	Hotter summers promote ideal growing conditions, however, growth could be restricted by water stress Potential intrusion of weed into saltmarsh wetlands – salinity analysis required Roads represent key habitat and potential vector for transport
Easter cassia	Woody shrub	Waterways (creek banks, dry riverbeds), gardens, disturbed sites, waste areas, roadsides,	Road reserves and adjoining disturbed areas, as well as some more	90% High predictive scores year-round	Soil temperature (high/variable) LAI	Hotter and drier summers promote ideal growing conditions

Species	Growth form	Preferred habitat	Predicted spatial distribution on Port lands	Model accuracy (Receiver Operating Characteristic - ROC)	Key predictors	Management implications
		enclosed forests, forest edges, and urban bushland	densely vegetated areas		NDVI (high) Slope (moderate/variable) Aspect	Roads represent key habitat and potential vector for transport
Groundsel bush	Woody shrub	Open woodlands, waste areas, disturbed sites, coastal canals, swampy areas, estuaries, mangrove wetlands, pastures, forestry plantations, orchards, plantation crops, irrigation channels, creek banks, parks, gardens, roadsides, and urban bushland	Road reserves and adjoining disturbed areas, verges and gardens and saltmarsh (see management implications)	90% High predictive scores year-round	Soil temperature (high/variable) Slope (moderate/high) NDVI (high) Solar radiation (moderate-high/variable)	Hotter and drier summers promote ideal growing conditions Potential intrusion of weed into saltmarsh wetlands – salinity analysis required Roads represent key habitat and potential vector for transport
Lantana	Woody shrub	Roadsides, waterways (creek banks, dry riverbeds), coasts, railways, fences, waste areas, disturbed sites, closed forests, open woodland, forest edges, grasslands, plantation crops, pastures, and parklands	Road reserves, railway corridors and adjoining disturbed areas, saltmarsh (see management implications)	90% High predictive scores year-round	Soil temperature (high/variable) Slope (moderate/high) LAI (high) NDVI (high) Solar radiation (moderate-high/variable)	Hotter and drier summers promote ideal growing conditions Potential intrusion of weed into saltmarsh wetlands – salinity analysis required Roads represent key habitat and potential vector for transport
Leucaena	Woody shrub	Roadsides, waterways (creek banks, dry riverbeds), open woodlands, gardens, parks, waste areas,	Road reserves, railway corridors and adjoining disturbed areas, as well as some	80% Higher predictive scores in summer than winter	Soil temperature (high) Aspect Solar radiation (in summer only)	Hotter summers promote ideal growing conditions, however, growth could be restricted by water stress

Species	Growth form	Preferred habitat	Predicted spatial distribution on Port lands	Model accuracy (Receiver Operating Characteristic - ROC)	Key predictors	Management implications
		disturbed sites, coastal foreshores and offshore islands	more densely vegetated areas, saltmarsh (see management implications)			Potential intrusion of weed into saltmarsh wetlands – salinity analysis required Roads represent key habitat and potential vector for transport
Mile-a-minute	Vine weed	Coastal districts, riverbanks, rainforest margins/remnants, waste areas, disturbed sites, open woodlands, bushland, gardens, fences and coastal dunes	Main road reserves, railway corridors and adjoining disturbed areas/verges, as well as some more densely vegetated areas	90% High predictive scores year-round	Soil temperature (high) Aspect LAI (moderate) NDVI (high) Solar radiation (in summer)	Hotter summers promote ideal growing conditions, however, growth could be restricted by water stress Roads represent key habitat and potential vector for transport
Broad-leaved pepper tree	Woody tree	Waterways (creek banks, dry riverbeds), roadsides, urban bushland, open woodlands, disturbed sites, waste areas, coastal wetlands, near human settlements	Road reserves, railway corridors and adjoining disturbed areas, as well as some more densely vegetated areas (near water bodies), saltmarsh (see management implications)	90% High predictive scores year-round	Soil temperature (high/variable) DEM (low elevation) NDVI (high) Slope (low/moderate) Solar radiation (in summer)	Hotter and drier summers promote ideal growing conditions Potential intrusion of weed into saltmarsh wetlands – salinity analysis required Roads represent key habitat and potential vector for transport
Sesbania pea	Woody shrub/ legume	Disturbed sites, waste lands, roadsides and cultivated fields	Road reserves, railway corridors and adjoining disturbed areas/verges,	90% High predictive scores year-round	Soil temperature (high/variable) Slope Solar radiation (moderate-high/variable)	Hotter summers promote ideal growing conditions, however, growth will be restricted by water stress

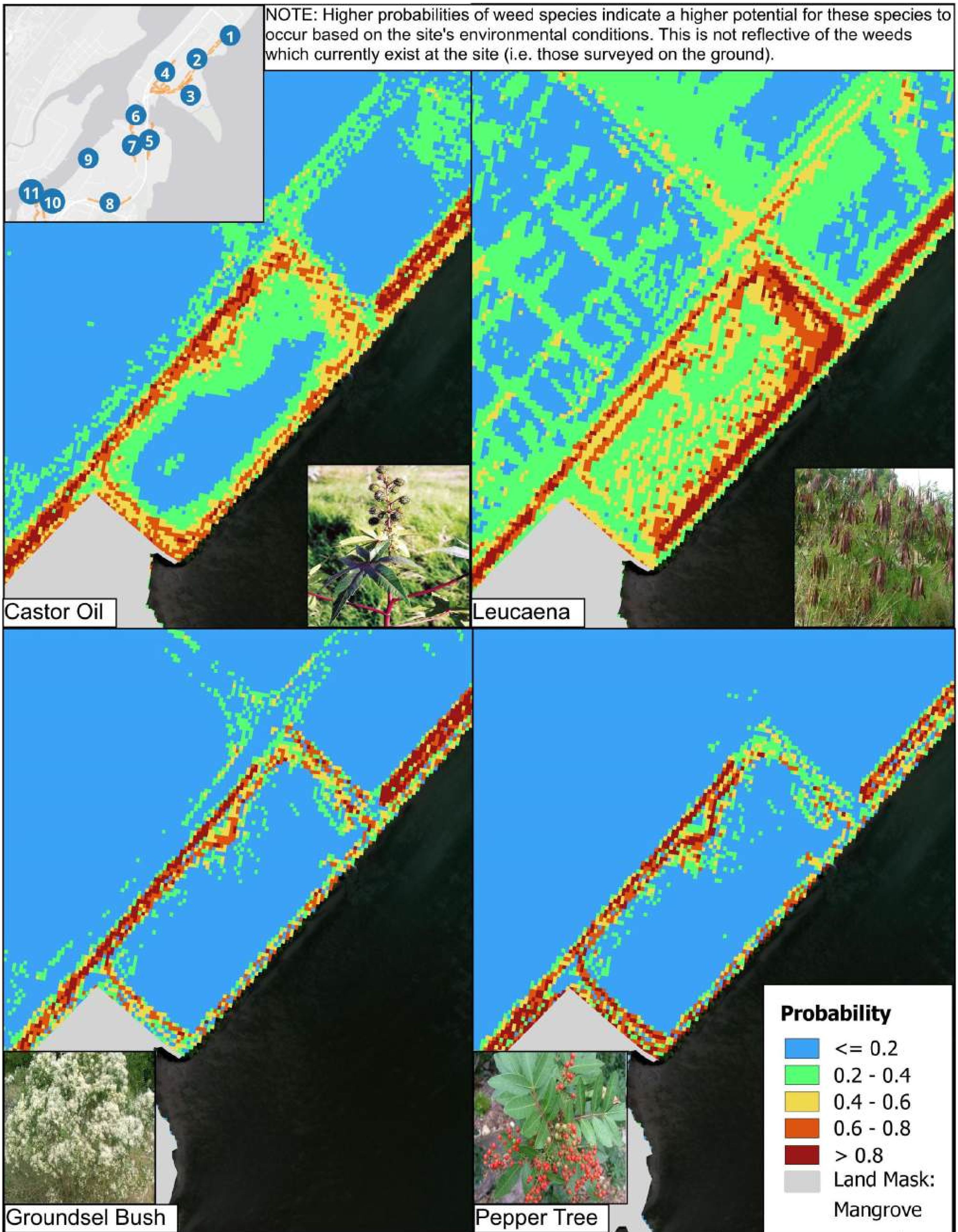
Species	Growth form	Preferred habitat	Predicted spatial distribution on Port lands	Model accuracy (Receiver Operating Characteristic - ROC)	Key predictors	Management implications
			manicured gardens and saltmarsh areas.		TWI (low/moderate)	Potential intrusion of species into saltmarsh wetlands – salinity analysis required Roads represent key habitat and potential vector for transport

3.2.12 Summary of Priority Target Species in Study Areas

Based on the priority species model outputs outlined above, Figure 3.27—Figure 3.35 synthesise the key priority weeds which have higher probabilities of occurrence in each of the study areas (as determined via visual inspection of the relative model outputs). These are also summarised in Table 3.4. Probability of occurrence is based on the site's environmental conditions and is not reflective of weeds observed during field surveys.

Table 3.4 Key priority weed species visually determined to have the highest probabilities of occurrence in the respective study areas

Study Areas	Priority weed species
Bird Hide	Castor oil, leucaena, groundsel bush, pepper tree
Lucinda Drain	Castor oil, leucaena, mile a minute, coral berry
T1-3/ car Precinct/The Lake	Castor oil, leucaena, mile a minute, lantana
Port Drive North	Castor oil, coral berry, mile a minute, pepper tree
Port Gate Drain (A)	Castor oil, coral berry, leucaena, groundsel bush
Port Gate Drain (B)	Castor oil, pepper tree, leucaena, groundsel bush
Port Drive South	Castor oil, pepper tree, leucaena, lantana
Fort Lytton	Castor oil, pepper tree, leucaena, coral berry
Port West	Castor oil, lantana, mile a minute, easter cassia



Title:

Bird Hide Priority Weed Probabilities

Figure: **3.27**

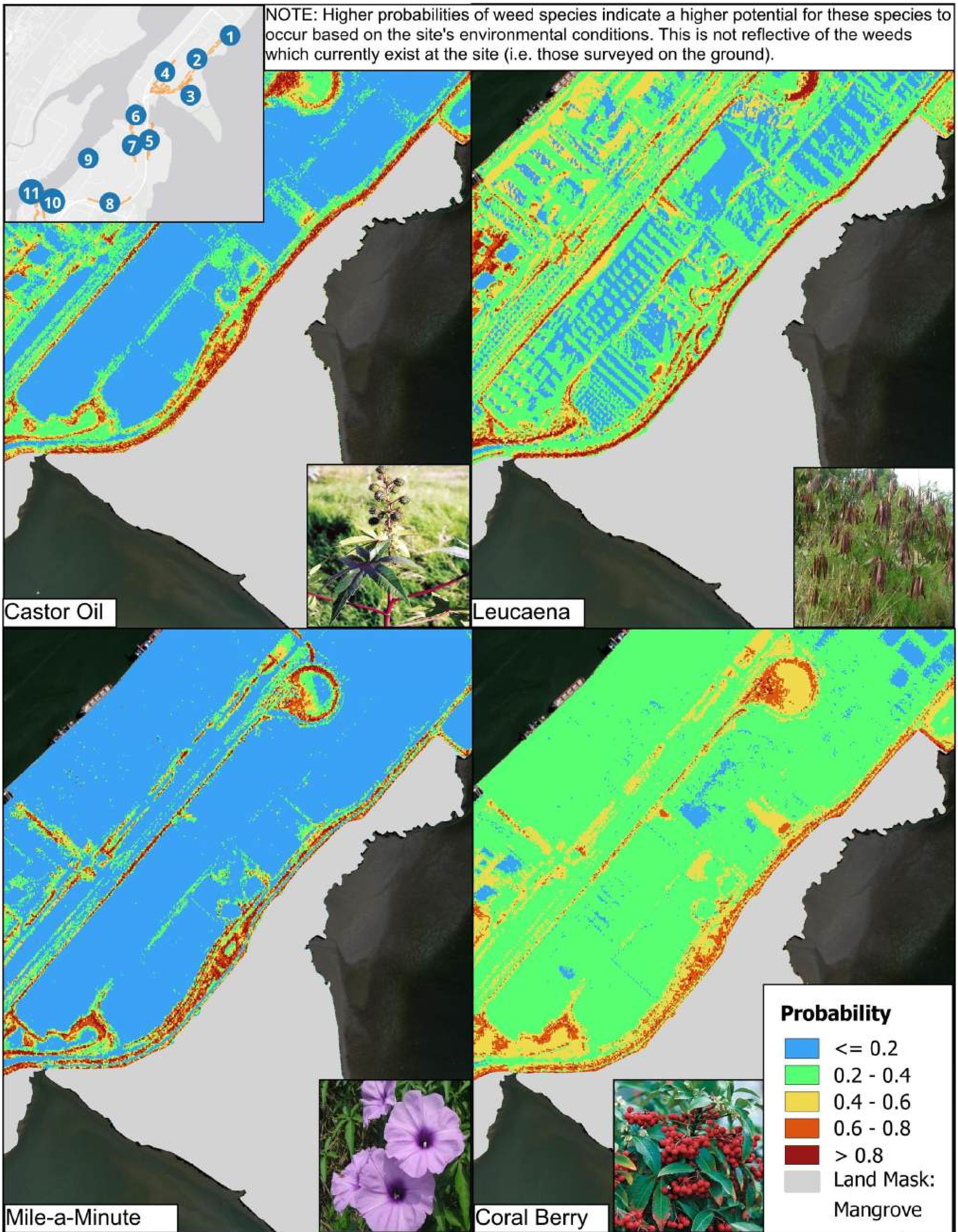
Rev: **A**

N

0 1 2 km

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz



Title:

Lucinda Drain Priority Weed Probabilities

Figure: **3.28**

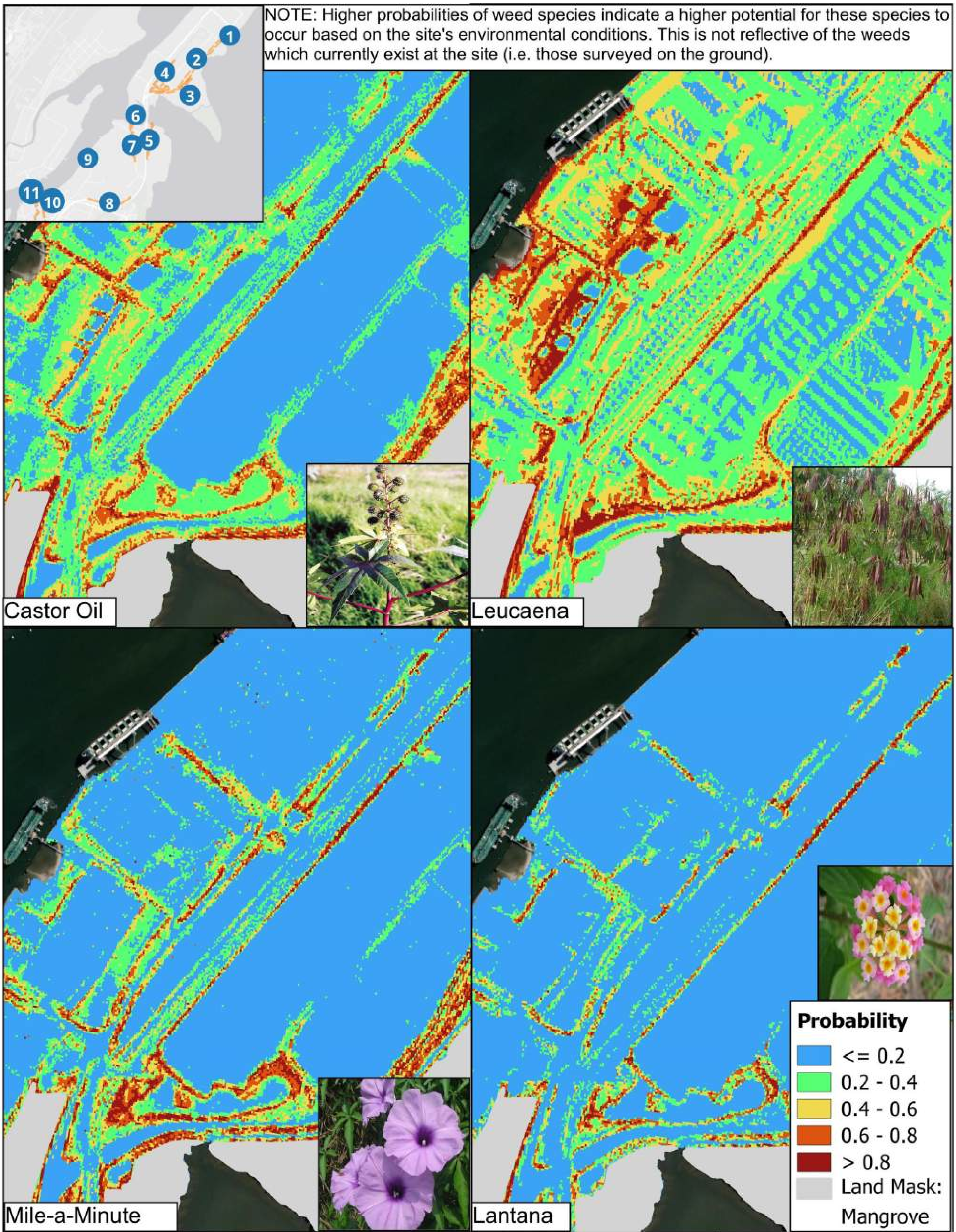
Rev: **A**

N

0 1 2 km

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz



Title:

T1-3 / Car Precinct / Lake Priority Weed Probabilities

Figure: **3.29**

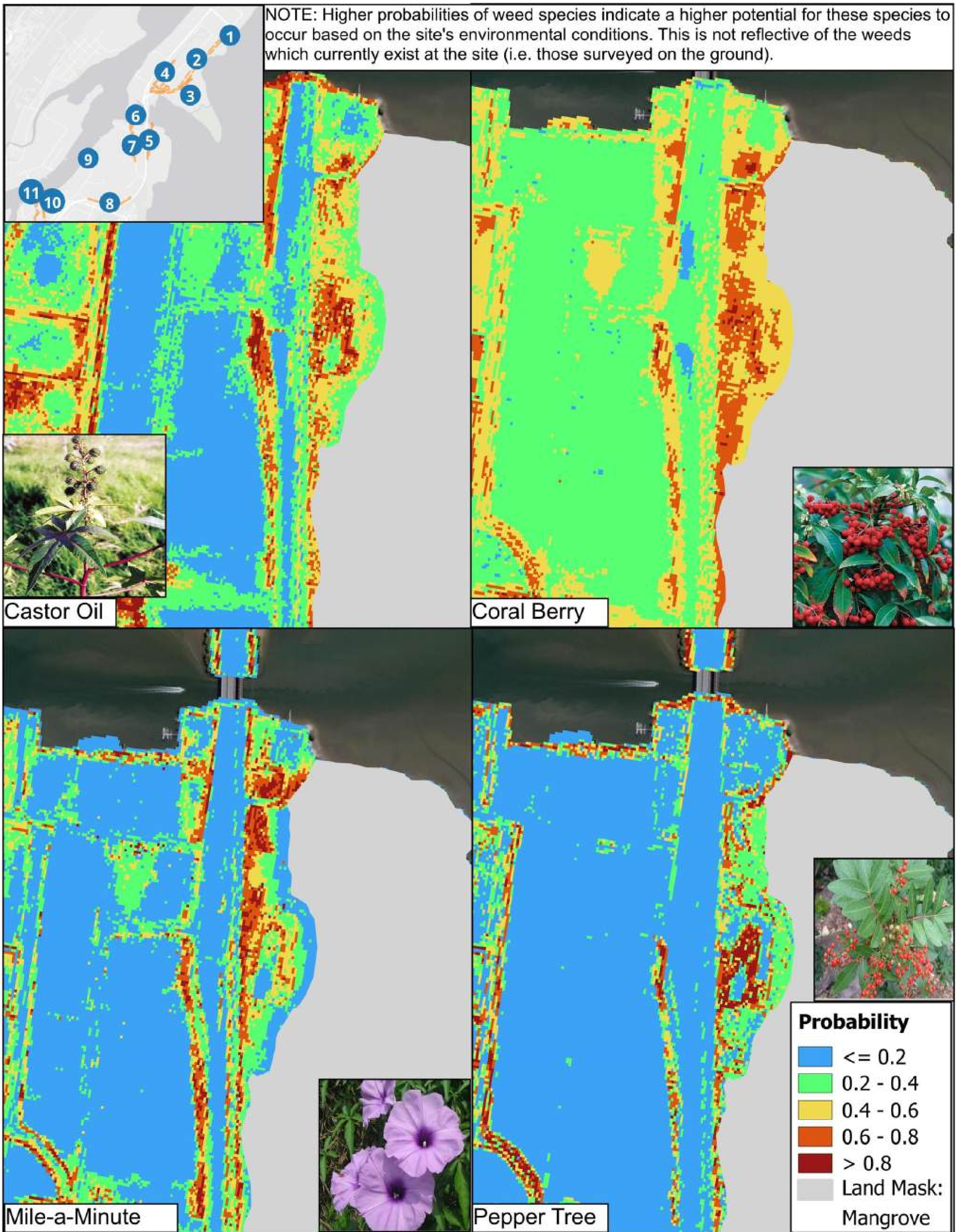
Rev: **A**

N

0 1 2 km

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz



Title:

Port Drive - North Priority Weed Probabilities

Figure: **3.30**

Rev: **A**

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

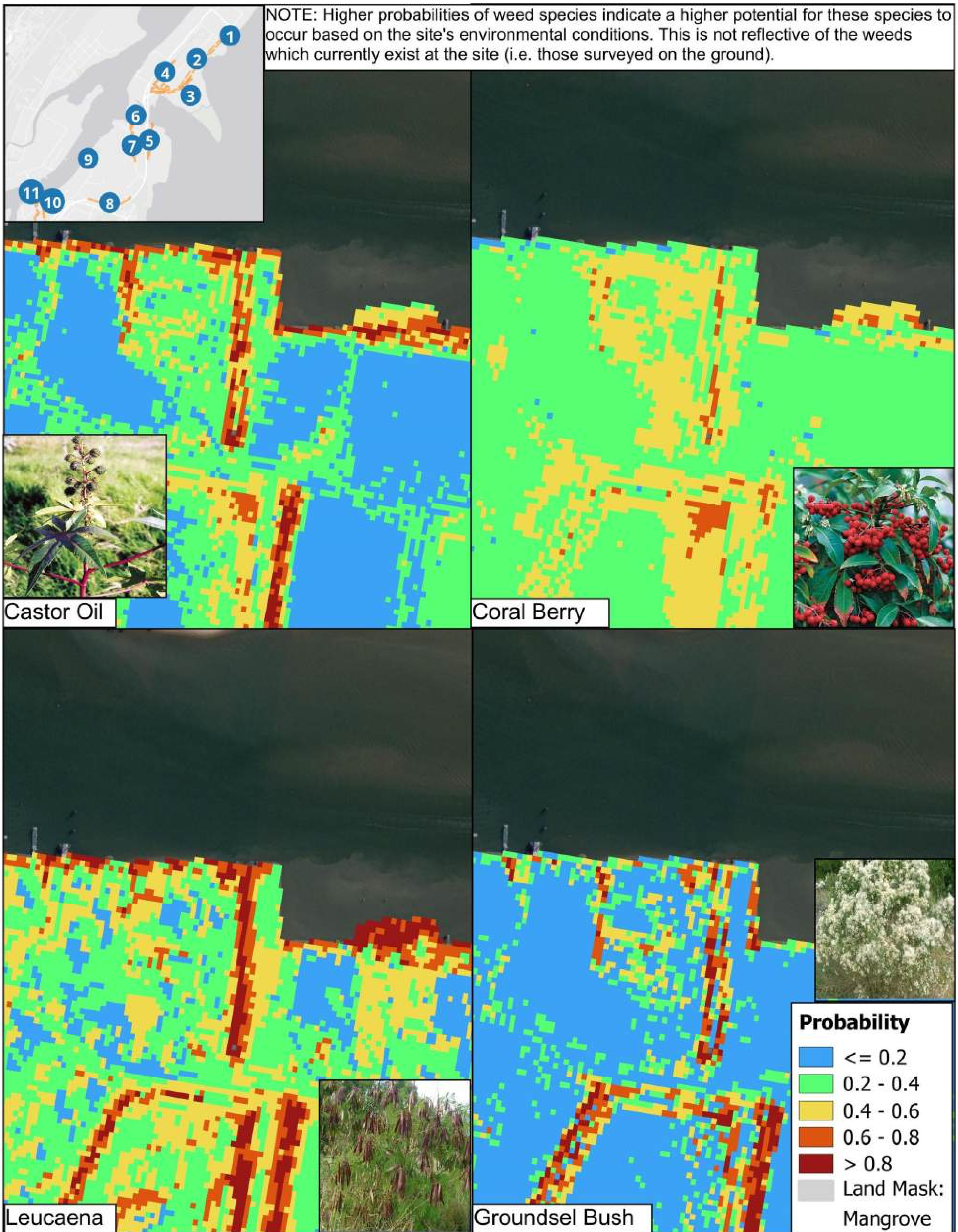
N

0 1 2 km

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz



Title:

Port Gate Drain - A Priority Weed Probabilities

Figure: 3.31

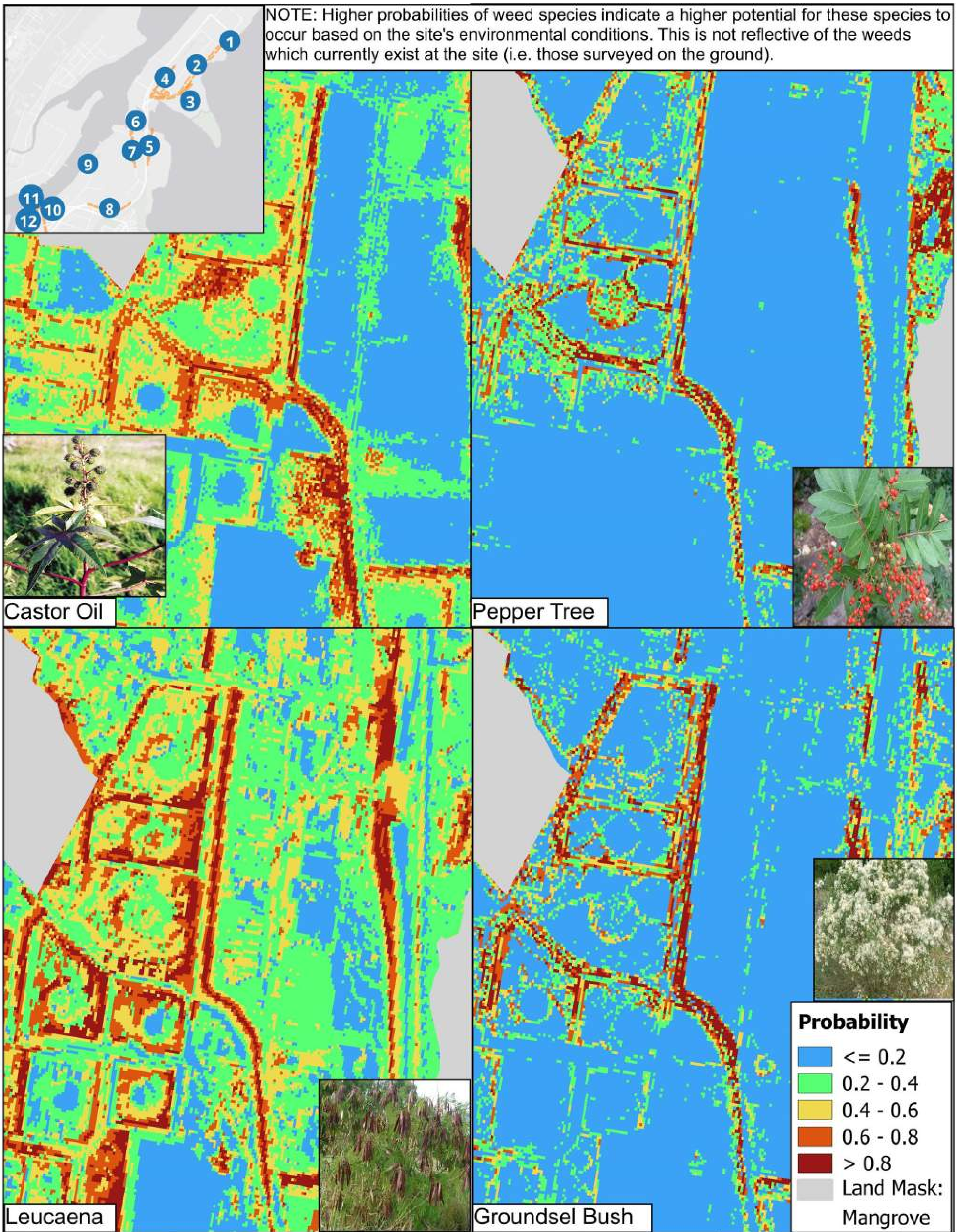
Rev: A

N

0 1 2 km

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz



Title:

Port Gate Drain - B Priority Weed Probabilities

Figure: **3.32**

Rev: **A**

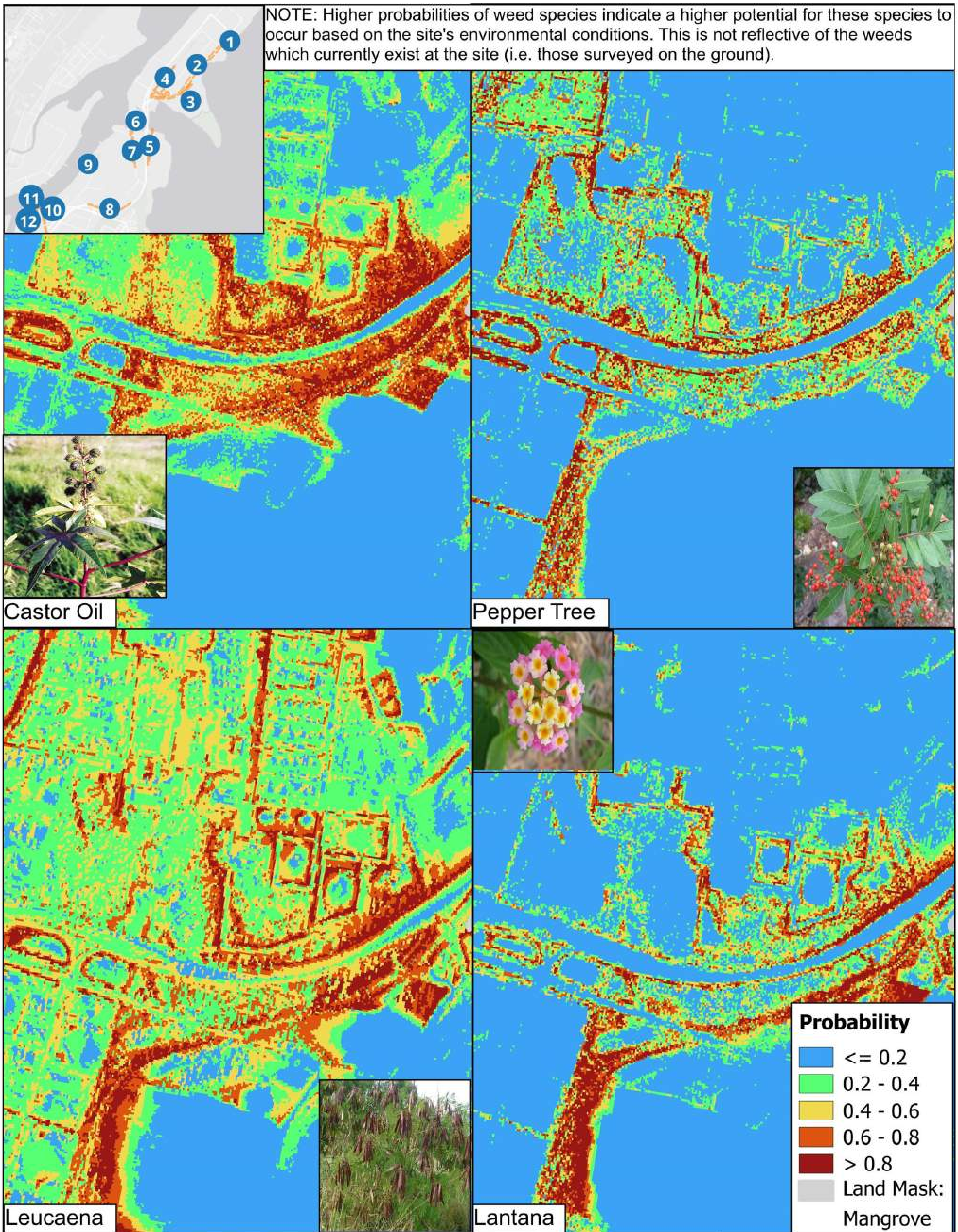
N

0 1 2 km

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz



Title: Port Drive - South Priority Weed Probabilities	Figure: 3.33	Rev: A

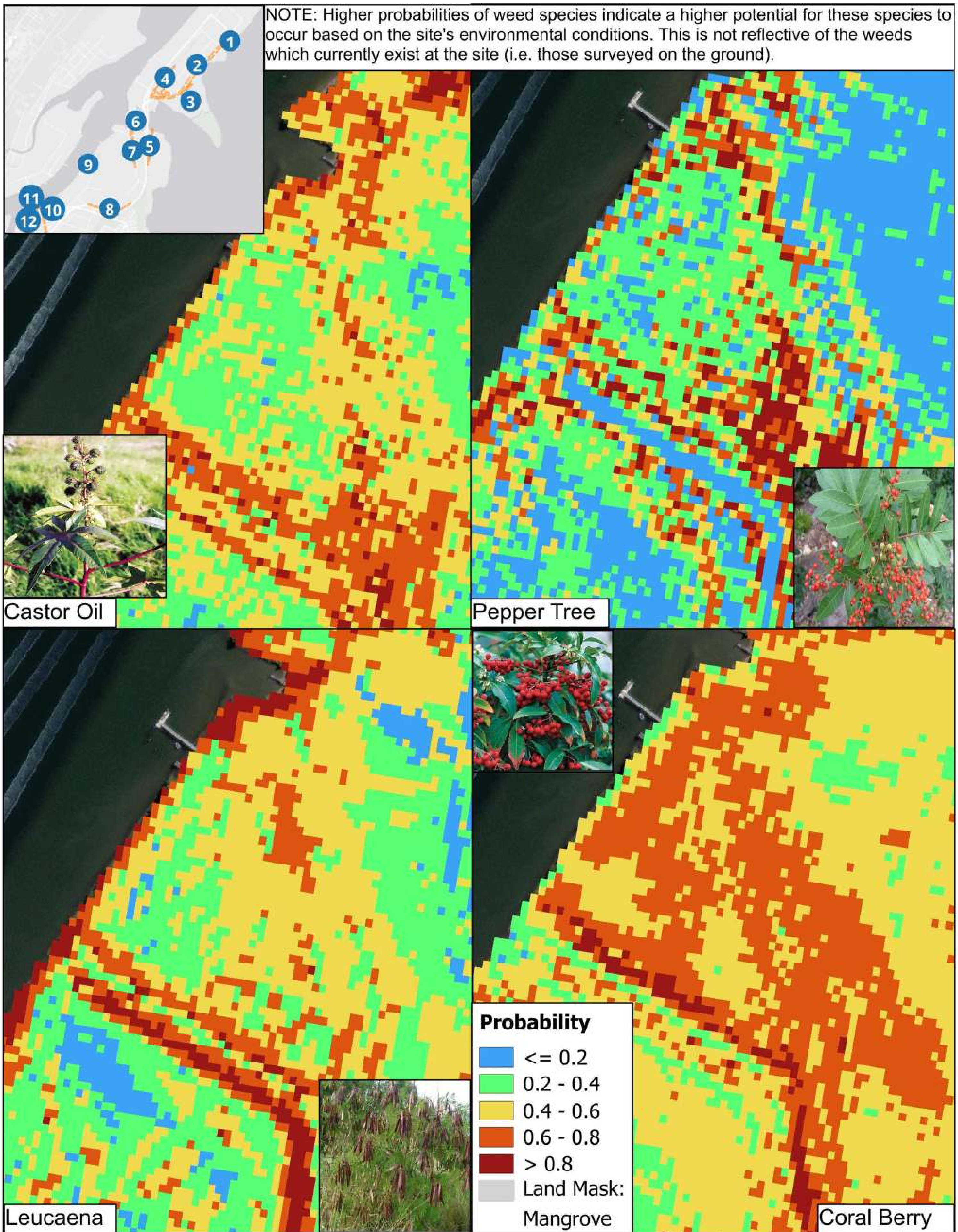
BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 1 2 km

BMT
www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz



Title:

Fort Lytton Priority Weed Probabilities

Figure: **3.34**

Rev: **A**

N

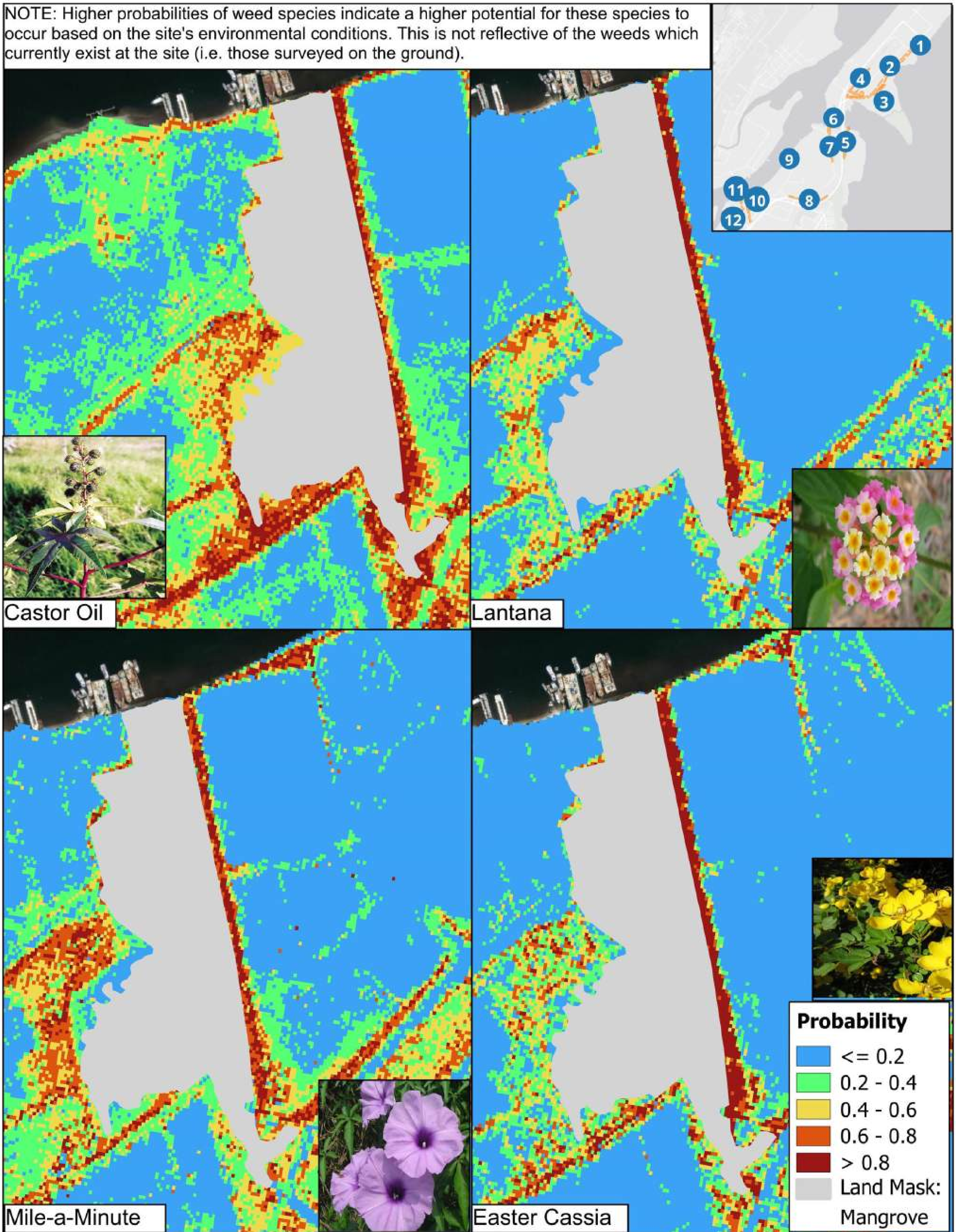
0 1 2 km

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz

NOTE: Higher probabilities of weed species indicate a higher potential for these species to occur based on the site's environmental conditions. This is not reflective of the weeds which currently exist at the site (i.e. those surveyed on the ground).



Title:

Port West Drain, Port West A and Port West B Priority Weed Probabilities

Figure: **3.35**

Rev: **A**

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 1 2 km

BMT

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\SDMs.qgz

4 Discussion

4.1 Findings

The PBPL weed monitoring program aims to detect the introduction and spread of new weed species imported to the Port, as well as monitor priority weed species within high value natural assets, including habitat for migratory waders and locally significant wetlands. A total of 38 invasive plant species were identified in total within the 12 predefined survey areas. In summary:

- All the weed species, including new taxa, recorded on PBPL lands are widespread in degraded coastal habitats of south-east Queensland.
- Weed composition and distribution at the Port remained relatively stable over the monitoring period with giant devils fig (under the Natural Assets Law) being identified as a newly imported weed within PBPL lands. Some species were observed at sites that they had not been previously recorded; however, they are common at other sites and surrounding areas. These included: rattlepod at Bird Hide, Cupid's shaving brush and asthma plant at Lucinda Drain, painted spurge and Whiskey grass at Ports Drive North and giant's rat's tail (Restricted matter) at T1-3 and Car Precinct. Growing patches of madeira vine were observed in the eastern area at Fort Lytton, however none were observed at Port West Drain despite being identified there in 2023. Treatment at Port Lytton is recommended before the patches spread any further into the restoration work area.
- The sites considered most at risk to weed imports are the imported vehicle storage areas (T1-3 and Car Precinct) and downstream environments. However, these sites provide poor habitat conditions for weeds as they are well maintained and/or subject to saline inundation.
- During field surveys sesbania pea was observed on the upper banks adjacent to the waterbody at the Bird Hide. Ongoing monitoring will ensure whether these species are contributing to altered hydrological conditions that may favour the establishment of terrestrial weeds within the adjacent saltmarsh habitat which could reduce saltmarsh values for migratory waders.
- Restoration works at Fort Lytton have resulted in an overall increase in saltmarsh habitat in previously disturbed and degraded habitats at this site which has continued to expand since 2019.

4.2 Pilot Modelling

The above results demonstrate the importance of completing annual weed monitoring surveys to identify and manage incursions of new priority weeds and weed outbreaks in specific areas on PBPL lands. However, there are potential advantages to be gained by introducing a modelling approach to supplement and/or further refine field-based methods. In particular, SDMs can predict future probabilities of certain weeds occurring across land not actively managed by PBPL which can help identify survey priorities.

Detailed modelling of nine selected weed species (selected on the basis of their prevalence in the 2024 survey) was undertaken to allow for further investigation into the environmental factors that significantly influence weed proliferation. Modelling was conducted using an SDM, which incorporated known occurrences and eight key EEVs (soil temperature, aspect, DEM/elevation, LAI, NDVI, slope, solar radiation, and TWI) to describe and predict the distribution of each selected weed species. It is crucial to understand the environmental condition preferences of prolific weed species in order to better predict their potential areas of growth/expansion, refine management techniques and prioritise surveillance efforts.

Key results from the SDM pilot study are presented below:

- The model had the lowest accuracies for castor oil, coral berry and leucaena. This is likely due to these three species having the lowest number of recorded occurrences (at 15, 9, 12 respectively) of the nine species selected for modelling. Typically, larger sample sizes will correlate to more accurate modelling.
- The model for castor oil was very seasonally dependent, with summer and winter distributions having different key EEV predictors. In summer, slope, solar radiation and LAI were the strongest predictors, whereas in winter, slope, soil temperature and TWI were the strongest predictors.
- Soil temperature was a key EEV predictor of weed distribution across all nine selected weeds.
- NDVI, LAI and slope were key predictors of weed distribution for most of the nine selected species across all seasons.
- Solar radiation was a key predictor of weed distribution for most of the nine selected species, however, it was much more seasonally variable and tended to be a stronger predictor in summer (particularly for leucaena, mile-a-minute and broad-leaved pepper tree).
- The highest occurrence probabilities for the nine selected weeds were typically along road reserves, railway corridors and adjoining disturbed areas. These areas represent both key habitat and a potential vector for transport. The spatial distribution patterns identified by the SDM align with known preferred habitats of the weed species.
- Moderate-high occurrence probabilities were typically identified in densely vegetated areas, particularly near water bodies for coral Berry, easter Cassia, leucaena, mile-a-minute and broad-leaved pepper tree. This aligns with the known preferred habitats of these weed species.
- Some moderate-high occurrence probabilities were identified in more manicured verges and gardens particularly for groundsel bush and sesbania pea.
- Castor oil plant, coral berry, lantana, leucaena and broad-leaved pepper tree had low-moderate occurrence probabilities within saltmarsh areas. While some of these species have coastal ecosystems as among their preferred habitats, it is likely that the lower model accuracies for castor oil plant, coral berry and leucaena contributed to their low-moderate occurrence probabilities within saltmarsh. For all species, the salinity of these areas and how it corresponds to each weed’s respective tolerances requires further investigation.
- Based on visual inspection of the model outputs for each species, key priority species which had the highest probabilities of occurrence in each of the study were synthesised. Castor oil was observed to have one of the highest probabilities of occurrence consistently across each study area.

Sample size presents a key limitation of the SDM, since its predictive accuracy is related to the number of observations of that weed. Species which had lower numbers of occurrences within the 2024 survey were typically the species with lower model accuracies. Additionally, the vegetation characteristic sub-model could be improved (which provided NDVI and LAI) by using higher-resolution imagery to enhance the accuracy of the EEVs. Finally, the model/study was unable to mask out all unsuitable areas for weed proliferation (e.g. small inland water bodies and buildings). This was due to a lack of accurate publicly accessible data layers for these areas. This could be improved in future with the use of high-resolution remote sensing data from commercial satellites, such as WorldView-3. Only mangrove areas were masked out (manually) from the analysis.

The results from the SDM pilot study provide further insight into the environmental factors that significantly influence the proliferation of each selected weed species, as well as predicting their current occurrence probability across all Port lands. The response curves generated by the SDMs (presented in Annex G) also provide further details on how each selected weed species responds to changes in the environmental variables. This has important implications for climate change, as it could allow changes in weed distributions in response to changing climate variables to be forecasted.

Southeast Queensland (SEQ) is already experiencing some of the impacts of climate change. Over the past three decades, SEQ has experienced increases in average temperatures by approximately 1°C, as well as significant decreases in rainfall. These impacts have also compounded to increase the frequency of dry years and heatwaves. As the impacts of climate change continue to worsen, SEQ is likely to experience further increases in average temperatures, as well as in the number of extremely hot days (> 35°C). Trends which are likely to be intensified by more frequent El Niño events. Such changes in climate conditions can affect the establishment and proliferation of invasive plant species through a variety of mechanisms. Rising temperatures could create more favourable habitat conditions for invasive species on lands previously restricted by cooler climates. This, coupled with reductions in rainfall could increase the stress on native species and weaken their ability to compete with more drought-tolerant invasive species. Finally, increases in extreme weather events (e.g. heatwaves or droughts) are likely to create favourable conditions for invasive species establishment.

In the context of this pilot study, results indicate that castor oil, easter cassia and broad-leaved pepper tree prefer higher temperatures and are better equipped to handle water stress. Climate change could therefore favour the proliferation of these species. Groundsel bush and lantana are similar, however, appear to be more susceptible to water stress. Coral berry, leucaena, and mile-a-minute also prefer higher temperatures, however, typically thrive in more moist environments. Therefore, their proliferation in future will likely be dependent on water availability. Finally, sesbania pea is unlikely to thrive under future climate change conditions due to its reliance on abundant moisture.

5 Recommendations

5.1 Priority Weed Recommendations

Based on the field surveys and model outputs (including visual investigations into probabilities of occurrence) it is recommended that regular monitoring of the key priority species identified in each study area (Table 3.4) are completed to better target weed control.

5.2 SDM Recommendations

The SDM developed for this pilot project could be further developed to provide long-term forecasting of weed species distributions and focus areas on PBPL lands. Further calibration and development of the SDM would be required to provide this functionality.

In the short term (<2 years), occurrence data from field-based weed monitoring campaigns could be integrated into the model to increase the sample size and improve overall model accuracy. At the same time, high-resolution imagery from commercial satellites could be used to classify individual vegetation communities and tidal influence to improve the spatial resolution of the model. Survey programs could also include more targeted test and control/random sites as ground-truthing points to enhance model accuracy and reduce bias.

In the long-term (>2 years), the improved SDM could provide more accurate, spatially explicit predictions of key weed species across port lands. This could be particularly useful for predicting the spread of new high-risk species. For example, Pond Apple (*Annona glabra*) is a significant weed of north Australian estuarine wetlands that has been recorded on the Sunshine Coast. Site data from the literature and south-east Qld records could be extrapolated to predict species habitat suitability at the Port. This data could then be used to help focus weed surveys in potential high-risk areas, which are not necessarily covered in the current survey program, in order for early detection and management intervention of this weed of national significance.

Early detection of new weed species will still require regular, diligent monitoring and the ability to correctly identify existing weed species and potential new invaders. The SDM and field survey methods are therefore complimentary tools which will help meet the key objectives of the PBPL monitoring program to identify new weed species and monitor priority weeds to assess the risk and to recommend and implement management measures as required.

6 References

Beven, K. J., & Kirkby, M. J. (1979). A physically based, variable contributing area model of basin hydrology / Un modèle à base physique de zone d'appel variable de l'hydrologie du bassin versant. *Hydrological Sciences Bulletin*, *24*(1), 43-69. https://doi.org/10.1080/02626667909491834

Boegh, E., Soegaard, H., Broge, N., Hasager, C. B., Jensen, N. O., Schelde, K., & Thomsen, A. (2002). Airborne multispectral data for quantifying leaf area index, nitrogen concentration, and photosynthetic efficiency in agriculture. *Remote Sensing of Environment*, *81*(2), 179-193. https://doi.org/https://doi.org/10.1016/S0034-4257(01)00342-X

Karssenberg, D., de Jong, K., & van der Kwast, J. (2007). Modelling landscape dynamics with Python. *International Journal of Geographical Information Science*, *21*(5), 483-495. https://doi.org/10.1080/13658810601063936

Klinges, D. H., Duffy, J. P., Kearney, M. R., & Maclean, I. M. D. (2022). mcera5: Driving microclimate models with ERA5 global gridded climate data. *Methods in Ecology and Evolution*, *13*(7), 1402-1411. https://doi.org/https://doi.org/10.1111/2041-210X.13877

Maclean, I. M. D., Mosedale, J. R., & Bennie, J. J. (2019). Microclima: An r package for modelling meso- and microclimate. *Methods in Ecology and Evolution*, *10*(2), 280-290. https://doi.org/https://doi.org/10.1111/2041-210X.13093

Phillips, S. J., Anderson, R. P., Dudík, M., Schapire, R. E., & Blair, M. E. (2017). Opening the black box: an open-source release of Maxent. *Ecography*, *40*(7), 887-893. https://doi.org/https://doi.org/10.1111/ecog.03049

Pourali, S. H., Arrowsmith, C., Chrisman, N., Matkan, A. A., & Mitchell, D. (2016). Topography Wetness Index Application in Flood-Risk-Based Land Use Planning. *Applied Spatial Analysis and Policy*, *9*(1), 39-54. https://doi.org/10.1007/s12061-014-9130-2

Rouse, J. W., Haas, R. H., Schell, J. A., & Deering, D. W. (1974). *Monitoring vegetation systems in the Great Plains with ERTS* 3rd Earth Resources Technology Satellite Symposium, Greenbelt. https://ntrs.nasa.gov/citations/19740022614

Roussel, J.-R., Auty, D., Coops, N. C., Tompalski, P., Goodbody, T. R. H., Meador, A. S., Bourdon, J.-F., de Boissieu, F., & Achim, A. (2020). lidR: An R package for analysis of Airborne Laser Scanning (ALS) data. *Remote Sensing of Environment*, *251*, 112061. https://doi.org/https://doi.org/10.1016/j.rse.2020.112061

Shannon, C. E. (1948). A mathematical theory of communication. *The Bell System Technical Journal*, *27*(3), 379-423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Annex A Weeds of National Significance (Department of Agriculture Water and the Environment)

Common Name	Scientific Name
African boxthorn	*Lycium ferocissimum*
Alligator weed	*Alternanthera philoxeroides*
Asparagus fern	*Asparagus aethiopicus*
Asparagus fern	*Asparagus scandens*
Athel pine	*Tamarix aphylla*
Bellyache bush	*Jatropha gossypiifolia*
Bitou bush, boneseed	*Chrysanthemoides monilifera subsp. monilifera and rotundata*
Blackberry	*Rubus fruticosus agg.*
Bridal creeper	*Asparagus asparagoides*
Bridal veil creeper	*Asparagus declinatus*
Broom	*Cytisus scoparius*
Cabomba	*Cabomba caroliniana*
Cats claw vine	*Dolichandra unguis-cati*
Chilean needle grass	*Nassella neesiana*
Climbing asparagus	*Asparagus africanus*
Climbing asparagus fern	*Asparagus plumosus*
Cotton-leaved physic-nut	*Jatropha gossypifolia*
Delta arrowhead	*Sagittaria platyphylla*
Fireweed	*Senecio madagascariensis*
Flax-leaved broom	*Genista linifolia*
Gamba grass	*Andropogon gayanus*
Gorse	*Ulex europaeus*
Hymenachne	*Hymenachne amplexicaulis*
Lantana	*Lantana camara*
Mesquite	*Prosopis spp.*
Madeira vine	*Anredera cordifolia*
Mimosa	*Mimosa pigra*
Montpellier broom	*Genista monspessulana*
Parkinsonia	*Parkinsonia aculeata*

Common Name	Scientific Name
Parthenium weed	*Parthenium hysterophorus*
Pond apple	*Annona glabra*
Prickly acacia	*Vachellia nilotica ssp. indica*
Prickly pear	*Austrocylindropuntia spp.*
Prickly pear	*Cylindropuntia spp.*
Prickly pear	*Opuntia spp.*
Rubber vine	*Cryptostegia grandiflora*
Salvinia	*Salvinia molesta*
Serrated tussock	*Nassella trichotoma*
Silver nightshade	*Solanum elaeagnifolium*
Water hyacinth	*Eichhornia crassipes*
Willows except weeping willows, pussy willow and sterile pussy willow	*Salix spp. except S. babylonica, S. X calodendron and S. X reichardtiji*

Annex B Restricted Invasive Plants under the Queensland Biosecurity Act (Department of Agriculture and Fisheries)

Restricted matter	Category
Bitou bush *(Chrysanthemoides monilifera ssp. rotundifolia)*	2, 3, 4 and 5
Boneseed *(Chrysanthemoides monilifera ssp. monilifera)*	2, 3, 4 and 5
Bridal creeper *(Asparagus asparagoides)*	2, 3, 4 and 5
Bunny ears *(Opuntia microdasys)*	2, 3, 4 and 5
Hudson pear *(Cylindropuntia pallida syn. Cylindropuntia rosea and C. tunicata)*	2, 3, 4 and 5
Jumping cholla *(Cylindropuntia prolifera)*	2, 3, 4 and 5
Koster's curse *(Clidemia hirta)*	2, 3, 4 and 5
Limnocharis or yellow burrhead *(Limnocharis flava)*	2, 3, 4 and 5
madras thorn *(Pithecellobium dulce)*	2, 3, 4 and 5
Mexican bean tree *(Cecropia pachystachya, C. palmata and C. peltata)*	2, 3, 4 and 5
Mexican feather grass (Nassella tenuissima)	2, 3, 4 and 5
Miconia *(M. calvescens, M. cionotricha, M. nervosa and M. racemosa)*	2, 3, 4 and 5
Mikania vine *(Mikania micrantha)*	2, 3, 4 and 5
Mimosa pigra *(Mimosa pigra)*	2, 3, 4 and 5
Riverina prickly pear *(Opunita elata)*	2, 3, 4 and 5
Water mimosa *(Neptunia oleracea and N. plena).*	2, 3, 4 and 5
African boxthorn *(Lycium ferocissimum)*	3
African fountain grass *(Cenchrus setaceum)*	3
African tulip tree *(Spathodea campanulata)*	3
Alligator weed *(Alternanthera philoxeroides)*	3
Annual ragweed *(Ambrosia artemisiifolia)*	3
Asparagus fern *(Asparagus aethiopicus, A. africanus, A. scandens, A. declinatus and A. plumosus)*	3
Athel pine *(Tamarix aphylla)*	3
Austrocylindropuntia cactus with the following names: Cane cactus *(Austrocylindropuntia cylindrica)* Eve's pin cactus *(A. subulata)*	3
Badhara bush *(Gmelina elliptica)*	3
Balloon vine *(Cardiospermum grandiflorum)*	3
Bellyache bush *(Jatropha gossypiifolia and hybrids)*	3

Restricted matter	Category
Blackberry *(Rubus anglocandicans, Rubus fruticosus)*	3
Broad-leaved pepper tree *(Schinus terebinthifolius)*	3
Broom with the following names: flax-leaf broom *(Genista linifolia)* Montpellier broom *(Genista monspessulana)* Scotch broom *(Cytisus scoparius)*	3
Cabomba *(Cabomba caroliniana)*	3
Camphor laurel *(Cinnamomum camphora)*	3
Candyleaf *(Stevia ovata)*	3
Cat's claw creeper *(Dolichandra unguis-cati)*	3
Chilean needle grass *(Nassella neesiana)*	3
Chinee apple *(Ziziphus mauritiana)*	3
Chinese celtis *(Celtis sinensis)*	3
Cholla cactus with the following names: coral cactus *(Cylindropuntia fulgida)* devil's rope pear *(Cylindropuntia imbricata)* snake cactus *(Cylindropuntia spinosior)*	3
Dutchman's pipe (*Aristolochia spp*. other than native species)	3
Elephant ear vine *(Argyreia nervosa)*	3
Fireweed *(Senecio madagascariensis)*	3
Gamba grass *(Andropogon gayanus)*	3
Giant sensitive plant *(Mimosa diplotricha var. diplotricha)*	3
Gorse *(Ulex europaeus)*	3
Groundsel bush *(Baccharis halimifolia)*	3
Harrisia cactus *(Harrisia martinii syn. Eriocereus martinii, H. tortuosa and H. pomanensis syn. Cereus pomanensis)*	3
Harungana *(Harungana madagascariensis)*	3
Honey locust (*Gleditsia tricanthos* including cultivars and varieties)	3
Hygrophila (*Hygrophila costata)*	3
Hymenachne or olive hymenachne (*Hymenachne amplexicaulis* and hybrids)	3
Kudzu (*Pueraria montana var. lobata, syn. P. lobata, P. triloba other than in the Torres Strait Islands*)	3
Lantanas: creeping lantana *(Lantana montevidensis*) lantana or common lantana (*Lantana camara*)	3

Restricted matter	Category
Madeira vine (*Anredera cordifolia*)	3
Mesquites: honey mesquite (*Prosopis glandulosa*) mesquite or algrroba (*Prosopis pallida*) Quilpie mesquite (*Prosopis velutina*)	3
Mother-of-millions (*Bryophyllum delagoense syn. B. tubiflorum, Kalanchoe delagoensis*)	3
Mother-of-millions hybrid (*Bryophyllum × houghtonii*)	3
Ornamental gingers: kahili ginger (*Hedychium gardnerianum*) white ginger (*Hedychium coronarium*) yellow ginger (*Hedychium flavescens*)	3
Parkinsonia (*Parkinsonia aculeata*)	3
Parthenium (*Parthenium hysterophorus*)	3
Pond apple (*Annona glabra)*	3
Prickly acacia (*Vachellia nilotica*)	3
Prickly pears: common pest pear, spiny pest pear (*Opuntia stricta syn. O. inermis*) drooping tree pear (*O. monacantha syn. O. vulgaris*) tiger pear (*O. aurantiaca*) velvety tree pear (*O. tomentosa*) Westwood pear (*O. streptacantha*)	3
Privets: broad-leaf privet or tree privet (*Ligustrum lucidum*) small-leaf privet or Chinese privet (*Ligustrum sinense*)	3
Rat's tail grasses: American rat's tail grass (*Sporobolus jacquemontii*) giant Parramatta grass (*Sporobolus fertilis)* giant rat's tail grass (*Sporobolus pyramidalis and Sporobolus natalensis*)	3
Rubber vines: ornamental rubber vine (*Cryptostegia madagascariensis*) rubber vine (*Cryptostegia grandiflora)*	3
Sagittaria (*Sagittaria platyphylla*)	3
Salvinia (*Salvinia molesta*)	3
Senegal tea (*Gymnocoronis spilanthoides*)	3
Siam weed (*Chromolaena odorata* and *Chromolaena squalida*)	3
Sicklepods:	3

Restricted matter	Category
foetid cassia (*Senna tora*) hairy cassia (*Senna hirsuta*) sicklepod (*Senna obtusifolia*)	
Silver-leaf nightshade (*Solanum elaeagnifolium*)	3
Singapore daisy (*Sphagneticola trilobata; syn. Wedelia trilobata*)	3
Telegraph weed (*Heterotheca grandiflora*)	3
Thunbergias: Laurel clockvine (*Thunbergia laurifolia*) thunbergia or blue thunbergia (*Thunbergia grandiflora*)	3
Tobacco weed (*Elephantopus mollis*)	3
Water hyacinth (*Eichhornia crassipes syn. Pontederia crassipes*)	3
Water lettuce (*Pistia stratiotes*)	3
Willow (all Salix spp. other than *S. babylonica, S. × calodendron* and *S. × reichardtii*)	3
Yellow bells (*Tecoma stans*)	3
Yellow oleander or Captain Cook tree (*Cascabela thevetia syn. Thevetia peruviana*).	3

Annex C Brisbane City Council Environmental Weeds (Brisbane City Council)

Species included in the Biosecurity Act – prioritised for the Brisbane LGA (updated December 2022)		
Risk classification	Common name	Species name
Significant	Alligator weed	*Altemanthera philoxeroides*
	Cabomba	*Cabomba caroliniana*
	Horsetails	*Equisetum spp.*
High	Broad-leaved pepper tree	*Schinus terebinthifolius*
	Cat's claw creeper	*Dolichandra unguis-cati*
	Hymenachne	*Hymenachne amplexicaulis*
	Kudzu	*Pueraria lobate*
	Parthenium	*Parthenium hysterophorus*
	Rat's tail grass/giant rat's tail grass	*Sporobulus pyramidalis and S.natalensis*
	Salvinia	*Salvinia molesta*
	Senegal tea	*Gymnocoronis spilanthoides*
	Water hyacinth	*Eichhornia crassipes*
	Water lettuce	*Pistia stratiotes*
	Water mimosa	*Neptunia oleracea (and N. plena)*
Moderate	Asparagus ferns	*Asparagus aethiopicus 'Sprengeri' A. africanus*
	Balloon vine	*Cardiospermum grandiflorum*
	Bridal creeper	*Asparagus asparagoides*
	Broadleaf privet	*Ligustrum lucidum*
	Giant Parramatta grass/rat's tail grasses/Parramatta grass	*Sporobolus fertilis, S. africanus, S. jacquemontii*
	Groundsel bush	*Baccharis halimifolia*
	Hygrophila/glush weed	*Hygrophila costata*
	Kahili ginger	*Hedychium gardnerianum*
	Madeira vine	*Anredera cordifolia*
	Willows	*Salix spp. other than S. babylonica, S. x calodendron, S. xreichardtii and S. chilensis; syn. S. humboldtiana = pencil willow (Chilean willow)*
Low	Annual ragweed	*Ambrosia artemisiifolia*
	Bitou bush	*Chrysanthemoides monilifera subsp. rotundata*

Species included in the Biosecurity Act – prioritised for the Brisbane LGA (updated December 2022)		
Risk classification	Common name	Species name
	Boneseed	*Chrysanthemoides monilifera ssp. monilifera*
	Camphor laurel	*Cinnamomum camphora*
	Chinese celtis	*Celtis sinensis*
	Dutchman's pipe	*Aristolochia elegans*
	Fireweed	*Senecio madagascariensis*
	Honey locust	*Gleditsia triacanthos including cultivars and varieties*
	Mexican feather grass	*Nassella tenuissima*
	Rubber vine	*Cryptostegia grandiflora*
	Tropical soda apple	*Solanum viarum*
	Yellow ginger	*Hedychium flavescens*
Very low	African fountain grass	*Pennisetum setaceum (Cenchrus setaceus)*
	African tulip tree	*Spathodea campanulata*
	Athel pine	*Tamarix aphylla*
	Belly-ache bush/cotton leaf/physic nut	*Jatropha gossypiifolia*
	Bitterweed	*Helenium amarum*
	Blackberry	*Rubus anglocandicans, Rubus fruticosus agg.*
	Chilean needle grass	*Nasella neesiana*
	Elephant ear vine	*Philodendron spp. Argyreia nervosa*
Very low	Harrisia cactus	*Harrisia martinii*
	Lantana (all species)	*Lantana spp.*
	Mexican bean tree	*Cecropia. palmata and C. peltata*
	Miconia	*Miconia calvescens, M. racemosa and M. nervosa*
	Mother of millions hybrid	*Bryophyllum × houghtonii*
	Pond apple	*Annona glabra*
	Prickly pear/tiger pear/ drooping tree pear/westwood pear/velvety tree pear	*Opuntia spp. (O. elata and O. microdasys – cat.2,3,4,5)*
	Sagittaria	*Sagittaria platyphylla*
	Singapore daisy	*Sphagneticola trilobata*
	Small-leaved privet/ Chinese privet	*Ligustrum sinense*

Species included in the Biosecurity Act – prioritised for the Brisbane LGA (updated December 2022)		
Risk classification	Common name	Species name
	Telegraph weed	*Heterotheca grandiflora*
	Yellow bells	*Tecoma stans*
	Yellow oleander/Captain Cook tree	*Cascabela thevetia syn. Thevetia peruviana*

Species in the Biosecurity Act – but assessed as having little impact in the Brisbane LGA	
Common Name	Scientific Name
Acacias non-indigenous to Australia	*Acacia spp.* other than *Acacia nilotica* and *Acacia farnesiana*
African boxthorn	*Lycium ferocissimum*
Anchored water hyacinth	*Eichhornia azurea*
Annual thunbergia	*Thunbergia annua*
Badhara bush	*Gmelina elliptica*
Candleberry myrtle/candleberry myrth	*Myrica faya*
Candyleaf	*Stevia ovata*
Chinee apple	*Ziziphus mauritiana*
Cholla cactus/coral cactus/devil's rope pear/snake cactus/Hudson pear	*Cylindropuntia spp.* and their hybrids, other than *C. spinosior, C. fulgida* and *C. imbricata*
Christ's thorn	*Ziziphus spina-christi*
Eurasian water milfoil	*Myriophyllum spicatum*
Floating water chestnuts	*Trapa spp.*
Gamba grass	*Andropogon gayanus*
Giant sensitive plant	*Mimosa diplotricha* (prev. *Mimosa invisa)*
Giant sensitive tree	*Mimosa pigra*
Gorse	*Ulex europaeus*
Harungana	*Harungana madagascariensis*
Kochia	*Kochia scoparia syn Bassia scoparia*
Koster's curse	*Clidemia hirta*
Lagarosiphon	*Lagarosiphon major*
Laurel clock vine, fragrant thunbergia	*Thunbergia laurifolia, (syn grandiflora)*
Limnocharis/yellow burrhead	*Limnocharis flava*
Madras thorn	*Pithecellobium dulce*

Species in the Biosecurity Act – but assessed as having little impact in the Brisbane LGA	
Common Name	Scientific Name
Mesquites	All *Prosopis spp*. and hybrids other than *Prosopis glandulosa, P. pallida* and *P. velutina*
Mikania vine	*Mikania spp.*
Parkinsonia	*Parkinsonia aculeata*
Peruvian primrose	*Ludwigia peruviana*
Prickly acacia	*Acacia nilotica syn(Vachellia nilotica)*
Red sesbania	*Sesbania punicea*
Serrated tussock	*Nassella trichotoma*
Sicklepod/hairy cassia/foetid cassia	*Senna obtusifolia, S. hirsuta* and *S. tora* and *obtusifolia*
Spiked pepper	*Piper aduncum*
Tobacco weed	*Elephantopus mollis*
Water soldiers	*Stratiotes aloides*
White ginger	*Hedychium coronarium*
Witch weeds	*Striga spp.* other than native species

Species NOT in the Biosecurity Act but that are regulated under the Natural Assets Local Law	
Common Name	Scientific Name
Agave	*Agave spp.*
Amazon frogbit	*Limnobium laevigatum*
Anzac tree daisy	*Montanoa hibiscifolia*
Arrowhead vine	*Syngonium spp.*
Arsenic bush	*Senna septemtrionalis*
Arum lily	*Zantedeschia aethiopica*
Bahia grass	*Paspalum notatum*
Balsam (busy Lizzie)	*Impatiens spp.*
Bamboos	*Phyllostachys aurea* and *nigra*
Black eyed Susan	*Thunbergia alata*
Blackberry nightshade	*Solanum nigrum*
Blade apple, lemon vine, Barbados gooseberry	*Pereskia aculeata*
Blue trumpet vine	*Thunbergia grandiflora*
Brazilian nightshade	*Solanum seaforthianum*
Cadaga or cadaghi	*Corymbia torelliana*

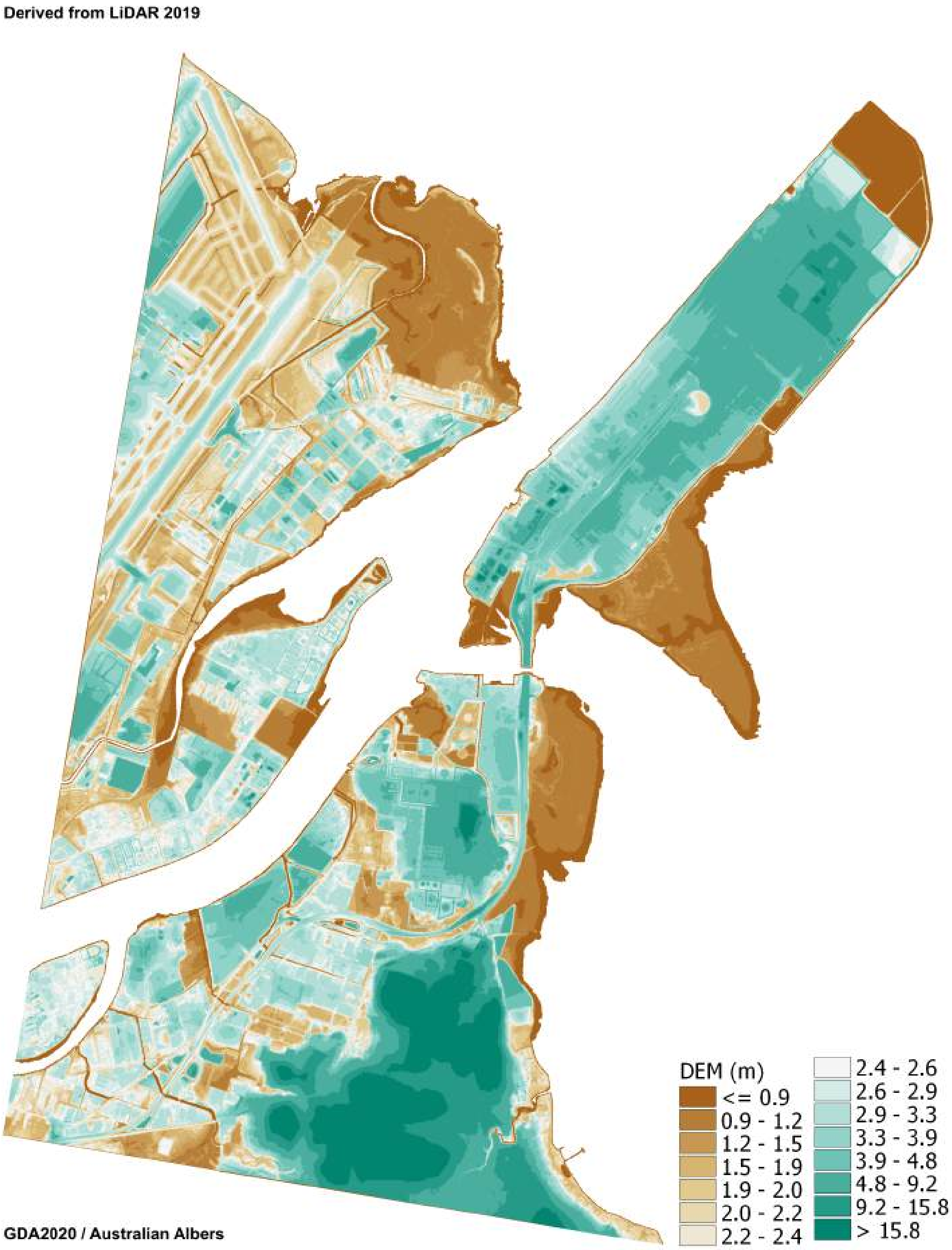
Species NOT in the Biosecurity Act but that are regulated under the Natural Assets Local Law	
Common Name	Scientific Name
Cape ivy	*Senecio angulatus*
Cape spinach	*Emex australis*
Capeweed	*Arctotheca calendula*
Castor oil plant	*Ricinus communis*
Chinese tallow	*Triadica sebifera*
Cockspur coral tree	*Erythrina crista-galli*
Cocos palm or Queen palm	*Syagrus romanzoffiana*
Common Indian hawthorn	*Rhaphiolepis indica*
Condamine couch/lippia	*Phyla canescens*
Coral berry or Indian currant	*Ardisia crenata, Rivina humilis* or *Symphoricarpos orbiculatus*
Coral creeper	*Barleria repens*
Passionflower	*Passiflora spp.*
Cotoneaster	*Cotoneaster lacteus*
Creeping lantana	*Lantana montevidensis*
Crofton weed	*Eupatorium adenophorum*
Dense water weed	*Egeria densa*
Devil's fig	*Solanum torvum*
Duranta	*Duranta erecta syn. D. repens* and *D. plumieri*
Dyschoriste	*Dyschoriste depressa*
Easter cassia	*Senna pendula var. glabrata*
Elephant grass	*Pennisetum purpureum*
Feathertop Rhodes grass	*Chloris virgata*
Fire flag	*Thalia geniculata*
Fishbone fern	*Nephrolepis cordifolia*
Foxglove	*Digitalis purpurea*
Giant devil's fig	*Solanum hispidum*
Giant reed	*Arundo donax*
Glory lily	*Gloriosa superba*
Glycine	*Neonotonia wightii*
Golden chain tree	*Laburnum anagyroides*
Golden rain tree	*Koelreuteria elegans ssp. formosana*

Species NOT in the Biosecurity Act but that are regulated under the Natural Assets Local Law	
Common Name	**Scientific Name**
Golden rod	*Solidago altissima*
Green cestrum	*Cestrum parqui*
Guinea grass	*Megathyrsus maximus*
Hemlock	*Conium maculatum*
Himalayan ash	*Fraxinus griffithii*
Hiptage	*Hiptage benghalensis*
Indian rubber tree	*Ficus elastica*
Ivy gourd	*Coccinia grandis*
Jacaranda	*Jacaranda mimosifolia*
Japanese/Mexican sunflower	*Tithonia diversifolia, T.sp*
Japanese honeysuckle	*Lonicera japonica*
Johnson grass	*Sorghum halepense*
Khaki weed	*Alternanthera pungens*
Kidney leaf mud plantain	*Heteranthera reniformis*
Leucaena	*Leucaena leucocephala (all spp.)*
Little bluestem	*Schizachyrium microstachyum*
Live plant, Resurrection plant	*Bryophyllum pinnatum*
Mile a minute	*Ipomoea cairica*
Mist flower	*Ageratina riparia*
Mock orange	*Murraya paniculata*
Molasses grass	*Melinis minutiflora*
Monkey's comb	*Pithecoctenium crucigerum*
Morning glory	*Ipomoea indica*
Mossman river grass	*Cenchrus echinatus*
Mother-in-law's tongue	*Sansevieria trifasciata*
Needle burr or spiny amaranth	*Amaranthus spinosus*
Noon flower	*Merremia dissecta*
Ochna	*Ochna serrulata*
Oleander	*Nerium oleander*
Pampas grass	*Cortaderia selloana*
Paper mulberry	*Broussonetia papyrifera*
Para grass	*Urochloa mutica*

Species NOT in the Biosecurity Act but that are regulated under the Natural Assets Local Law	
Common Name	Scientific Name
Parrot feather	*Myriophyllum aquaticum*
Perennial horse gram	*Macrotyloma axillare*
Perennial ragweed	*Ambrosia psilostachya*
Pongamia tree	*Millettia pinnata*
Praxelis	*Praxelis clematidea*
Prickly poppy or Mexican poppy	*Argemone ochroleuca*
Purple succulent	*Callisia fragrans*
Red-head cotton bush	*Asclepias curassavica*
Rhodes grass	*Chloris gayana*
Rhus	*Toxicodendron succedaneum*
Ruellia	*Ruellia tweediana*
Shoebutton ardisia	*Ardisia elliptica*
Sicklebush	*Dichrostachys cinerea*
Signal grass	*Urochloa decumbens*
Silver leaf desmodium or velcro plant	*Desmodium uncinatum*
Siratro	*Macroptilium atropurpureum*
Slash pine	*Pinus elliotii*
South African pigeon grass	*Setaria sphacelata*
Stinking roger	*Tagetes minuta*
Taro	*Colocasia esculenta*
Thorn apples	*Datura spp*
Tipuana	*Tipuana tipu*
Tropical pickeral weed	*Pontederia rotundifolia*
Umbrella tree	*Schefflera actinophylla*
Wandering Jew	*Tradescantia fluminensis, T. pallida and T. spathacea*
Water lily	*Nymphaea caerulea ssp. zanzibarensis*
Whiskey grass	*Andropogon virginicus*
White moth plant	*Araujia sericifera and A. hortorum*
White mulberry	*Morus alba*
Wait-a while	*Caesalpinia decapetala*
Wild aster	*Aster subulatus*
Wild tobacco tree	*Solanum mauritianum*

Species NOT in the Biosecurity Act but that are regulated under the Natural Assets Local Law	
Common Name	Scientific Name
Zebrina	*Tradescantia zebrina*

Annex D Site Characteristics (DEM, Slope, Aspect)



Title:
Digital Elevation Model (DEM)

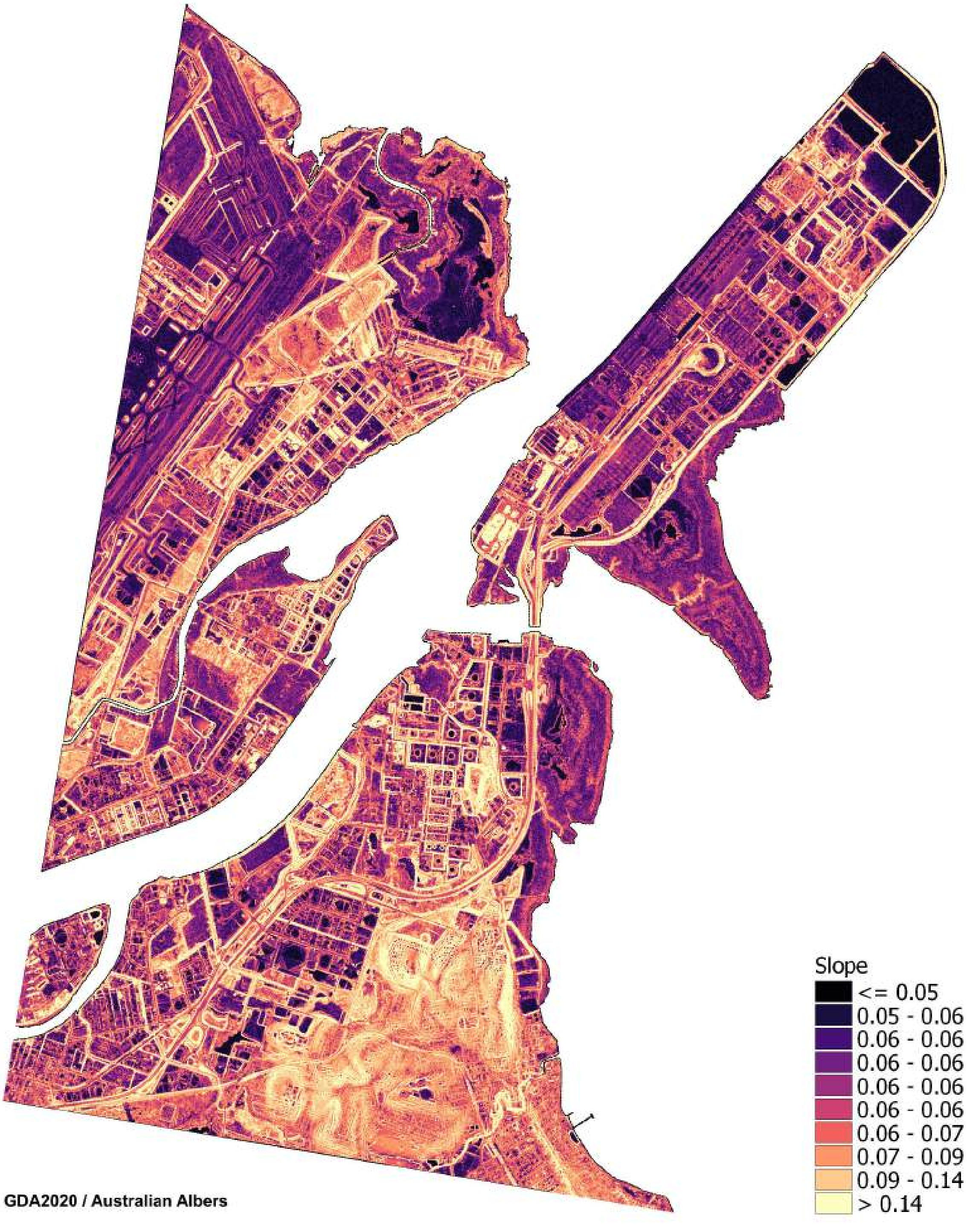
Figure:

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\EVVs.qgz



Title:
Slope

Figure:

Rev:
A

N

0 1 2 km

www.bmt.org

Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\EVVs.qgz

Title:
Aspect

Figure:

Rev: A

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

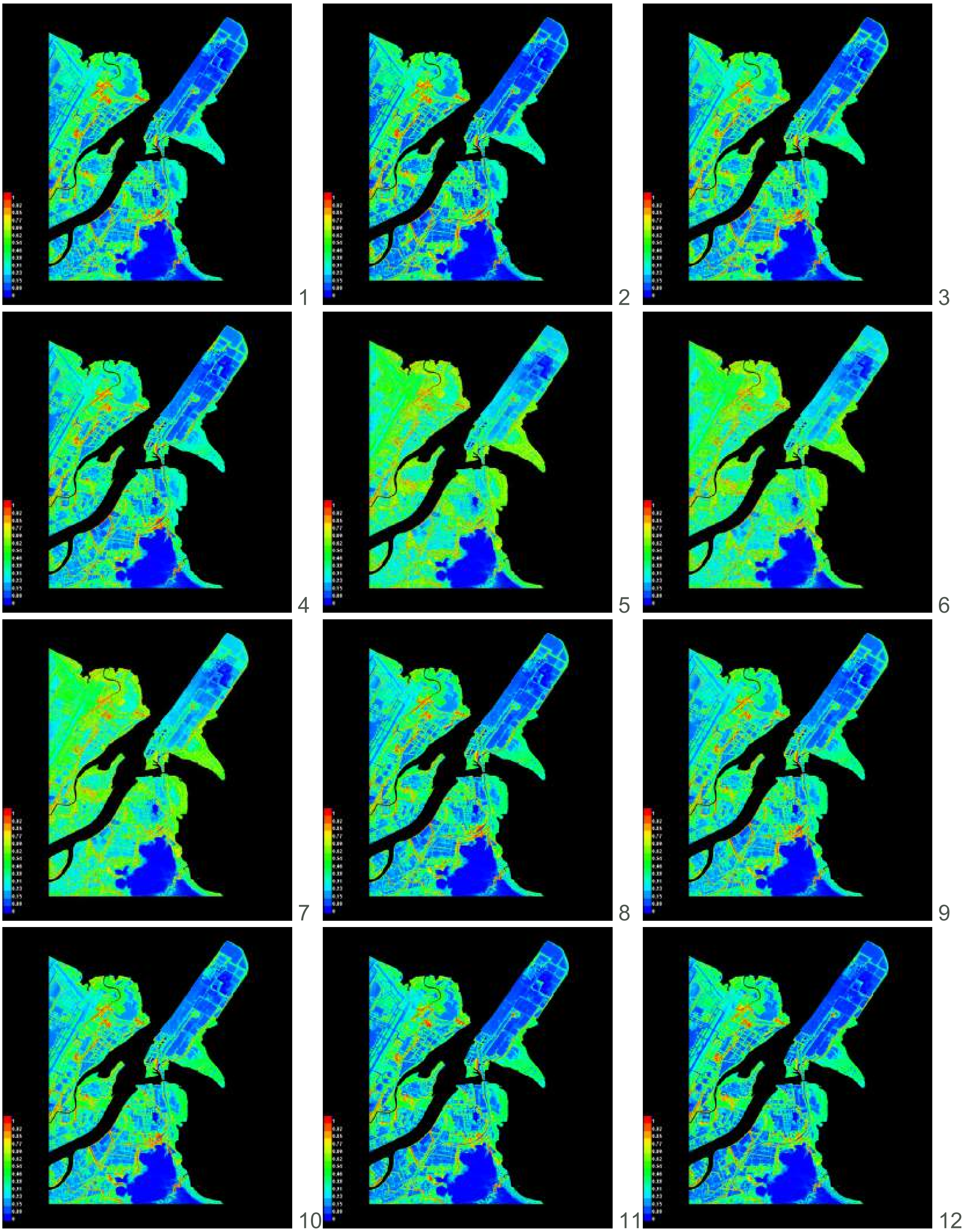
N 0 1 2 km

www.bmt.org

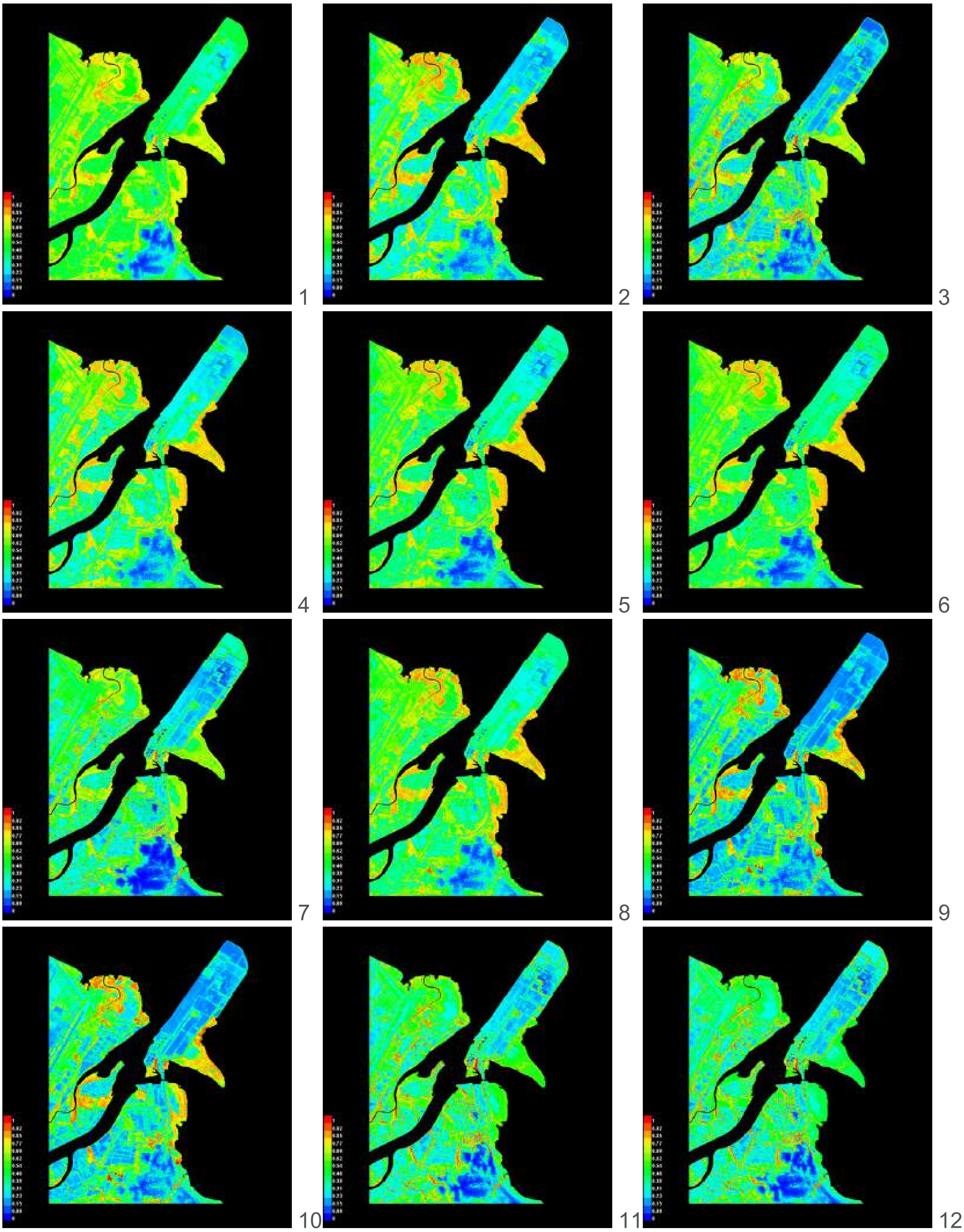
Filepath: I:\B23621.PoB Monitoring 2019-25\2024\Invasive_Plants|QGIS\EVVs.qgz

Annex E Monthly Species Distribution Models in 2023

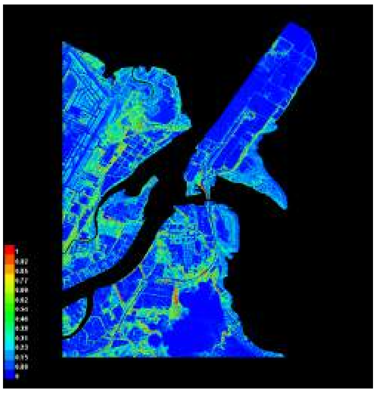
E.1 Castor Oil

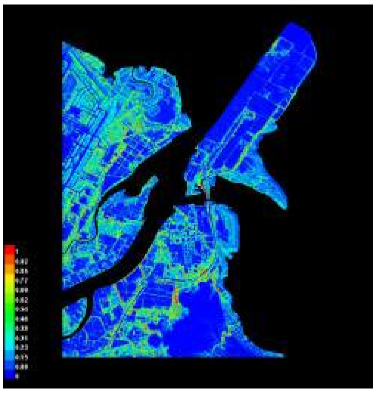


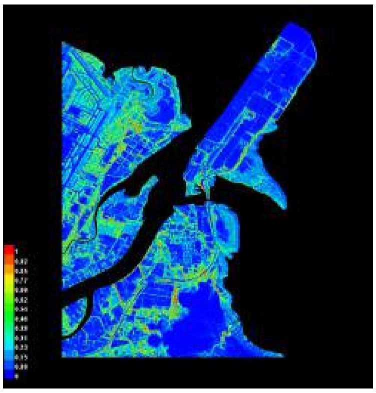
E.2 Coral Berry

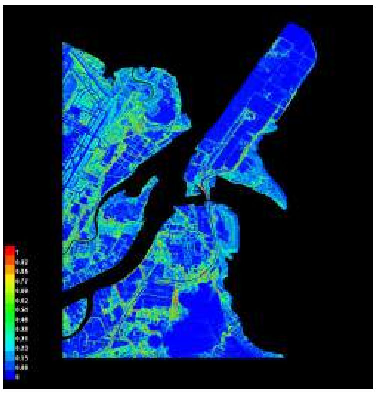


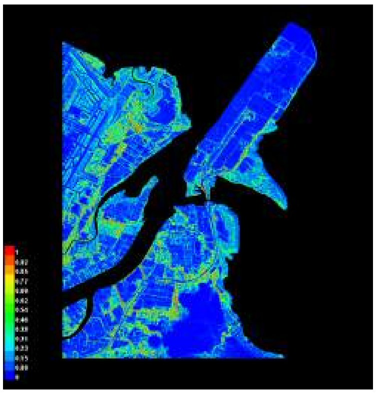
E.3 Easter Cassia

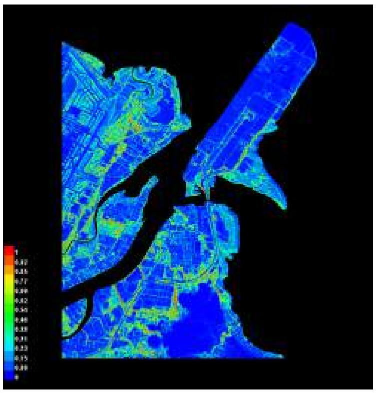

1

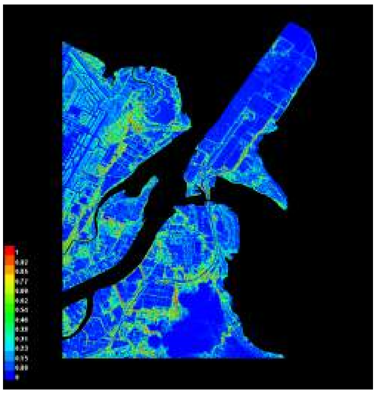

2

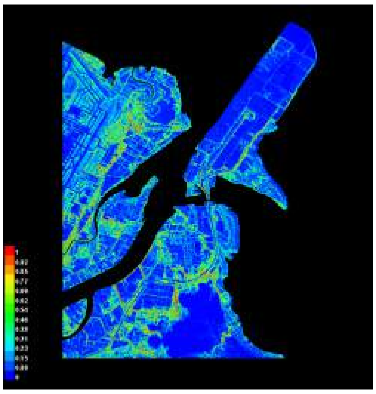

3

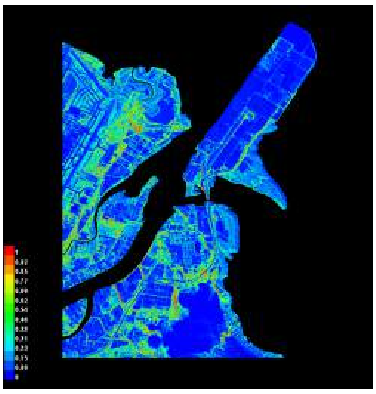

4

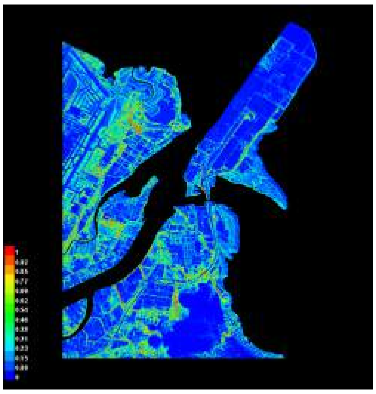

5

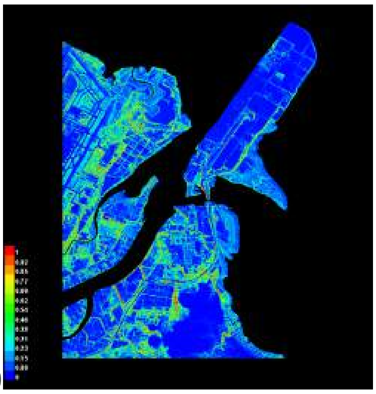

6

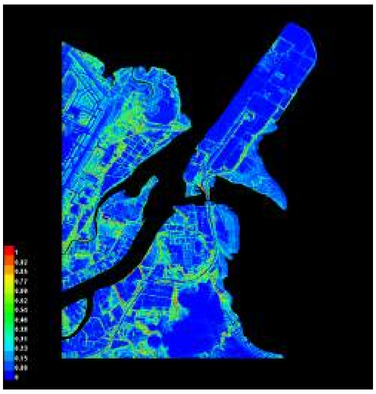

7


8

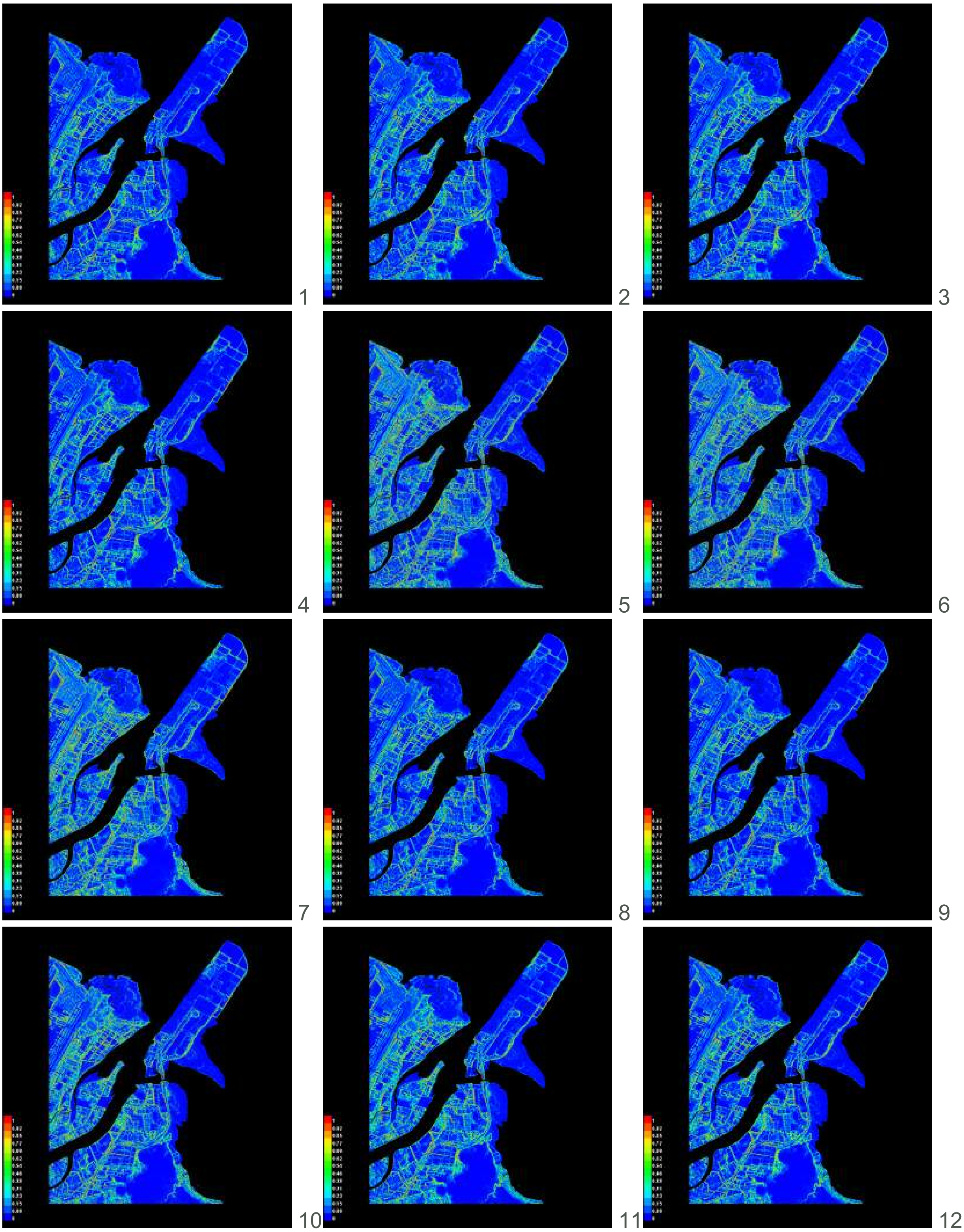

9


10

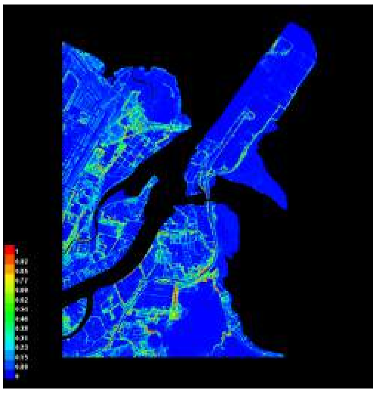
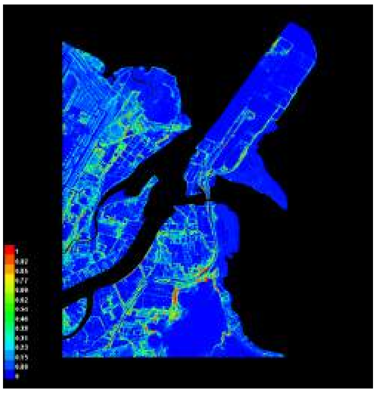
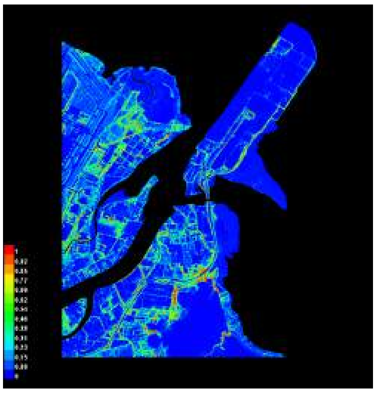
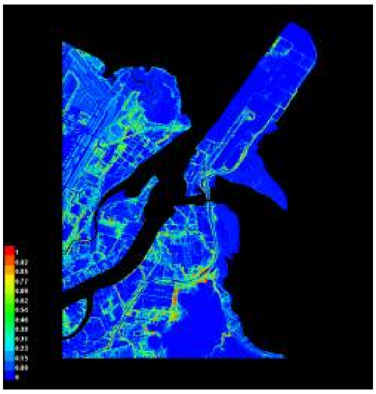
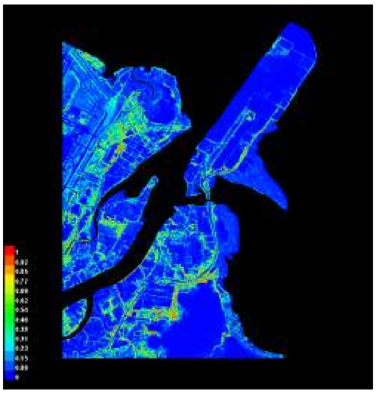
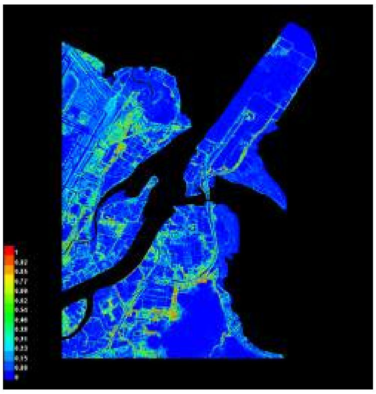
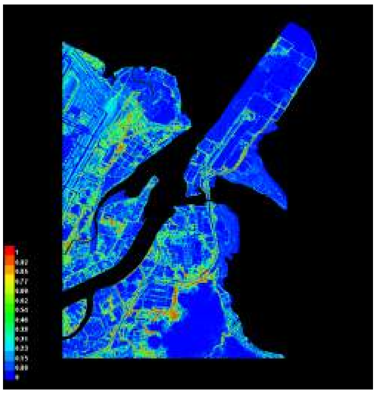
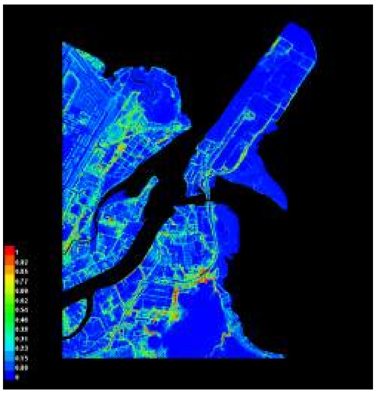
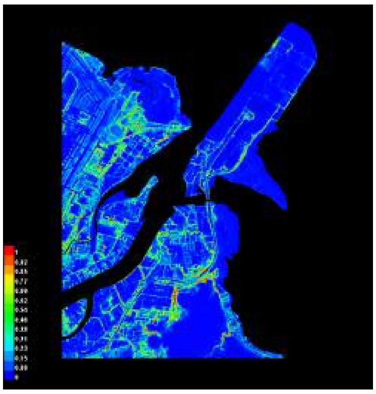
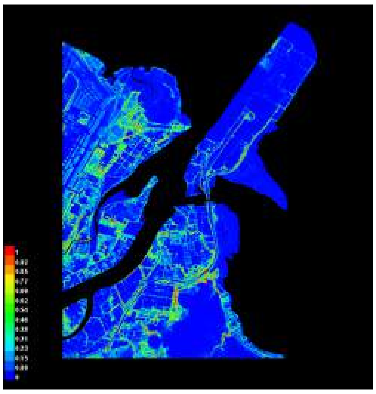
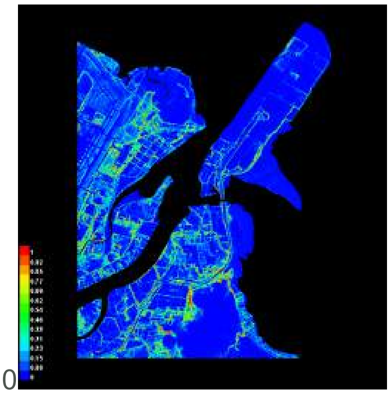
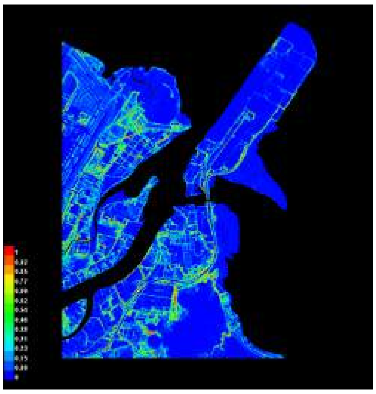

11


12

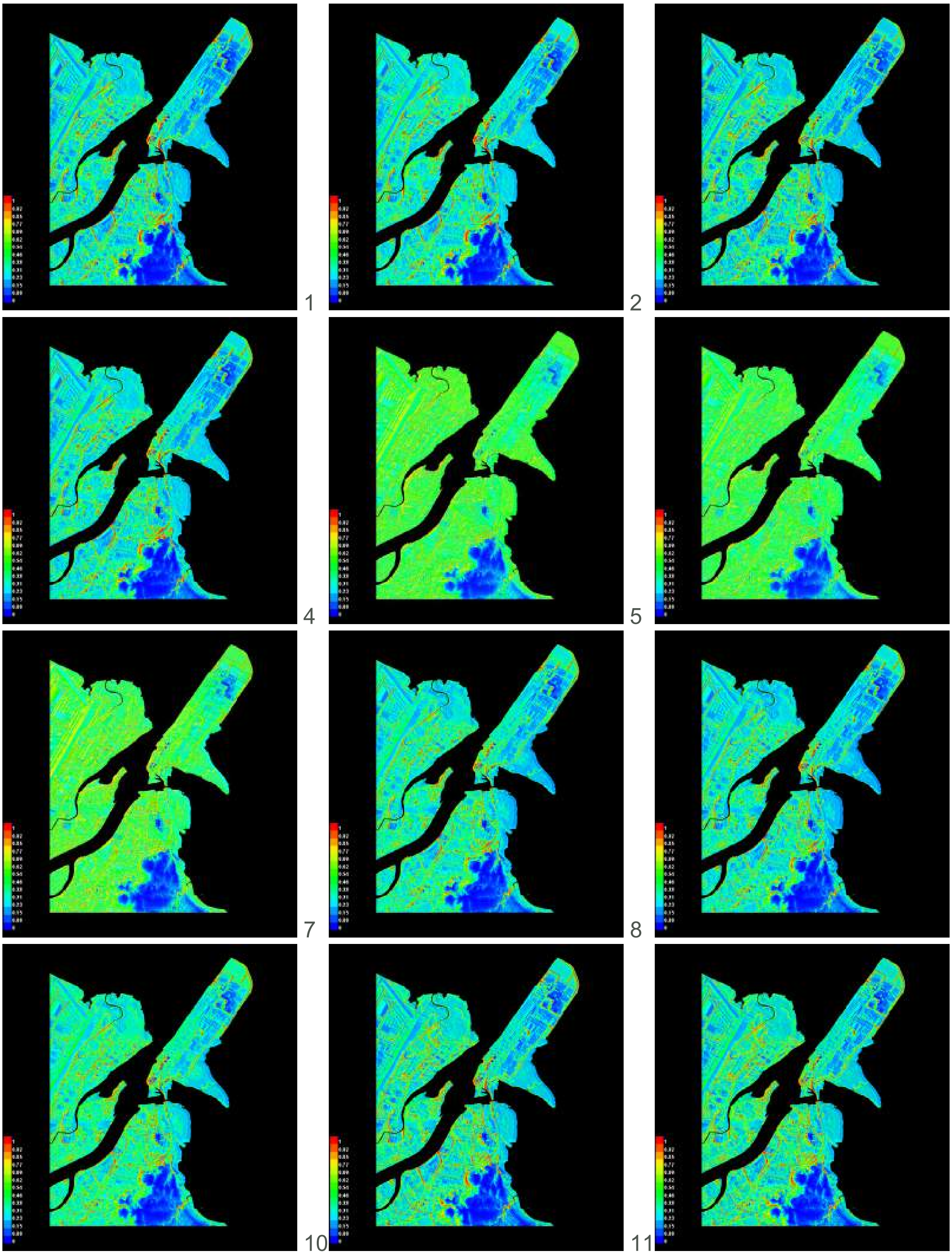
E.4 Groundsel Bush



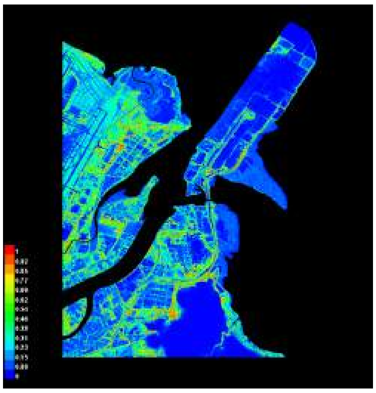
E.5 Lantana

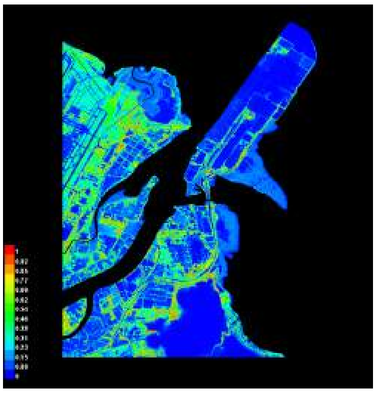

1

2

3

4

5

6

7

8

9

10

11

12

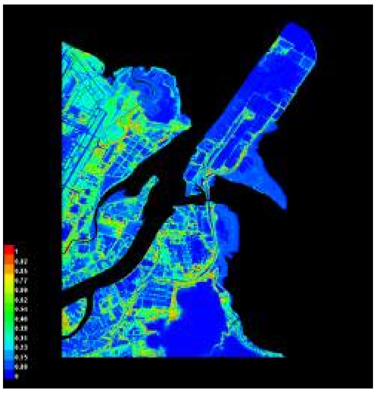
E.6 Leucaena

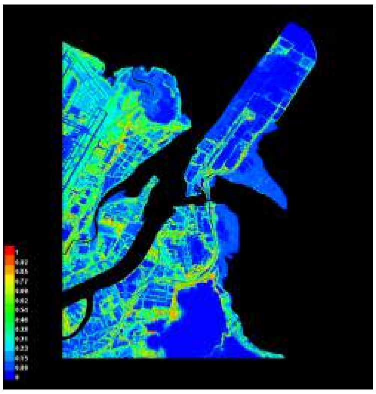


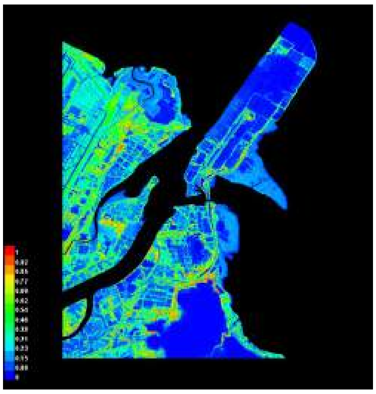
E.7 Mile-A-Minute

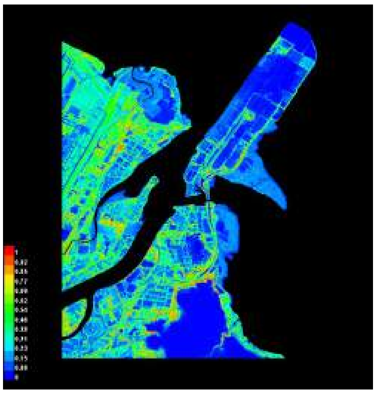

1

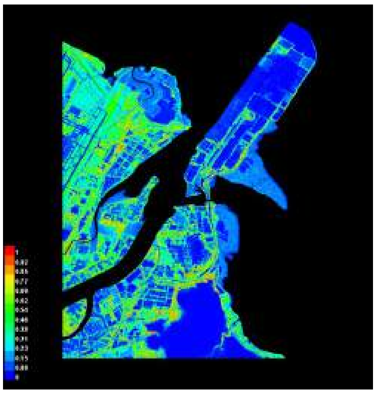

2

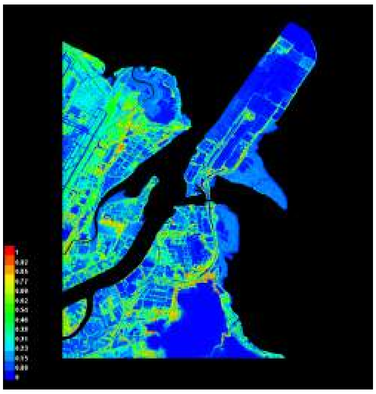

3

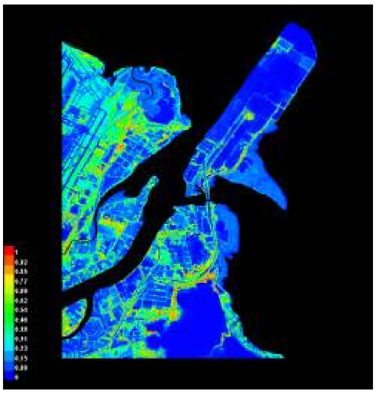

4

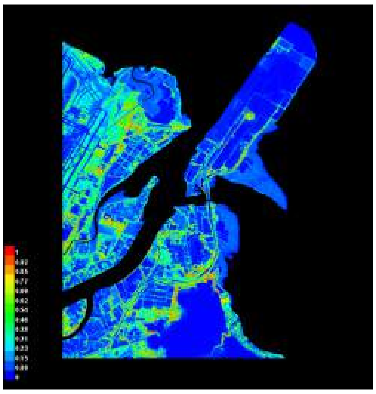

5

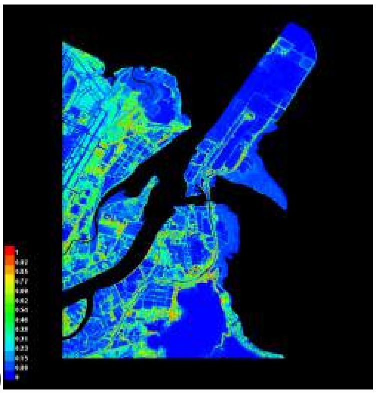

6

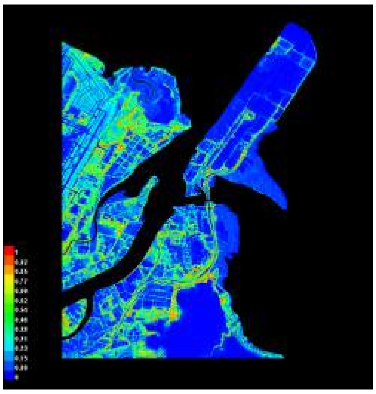

7


8

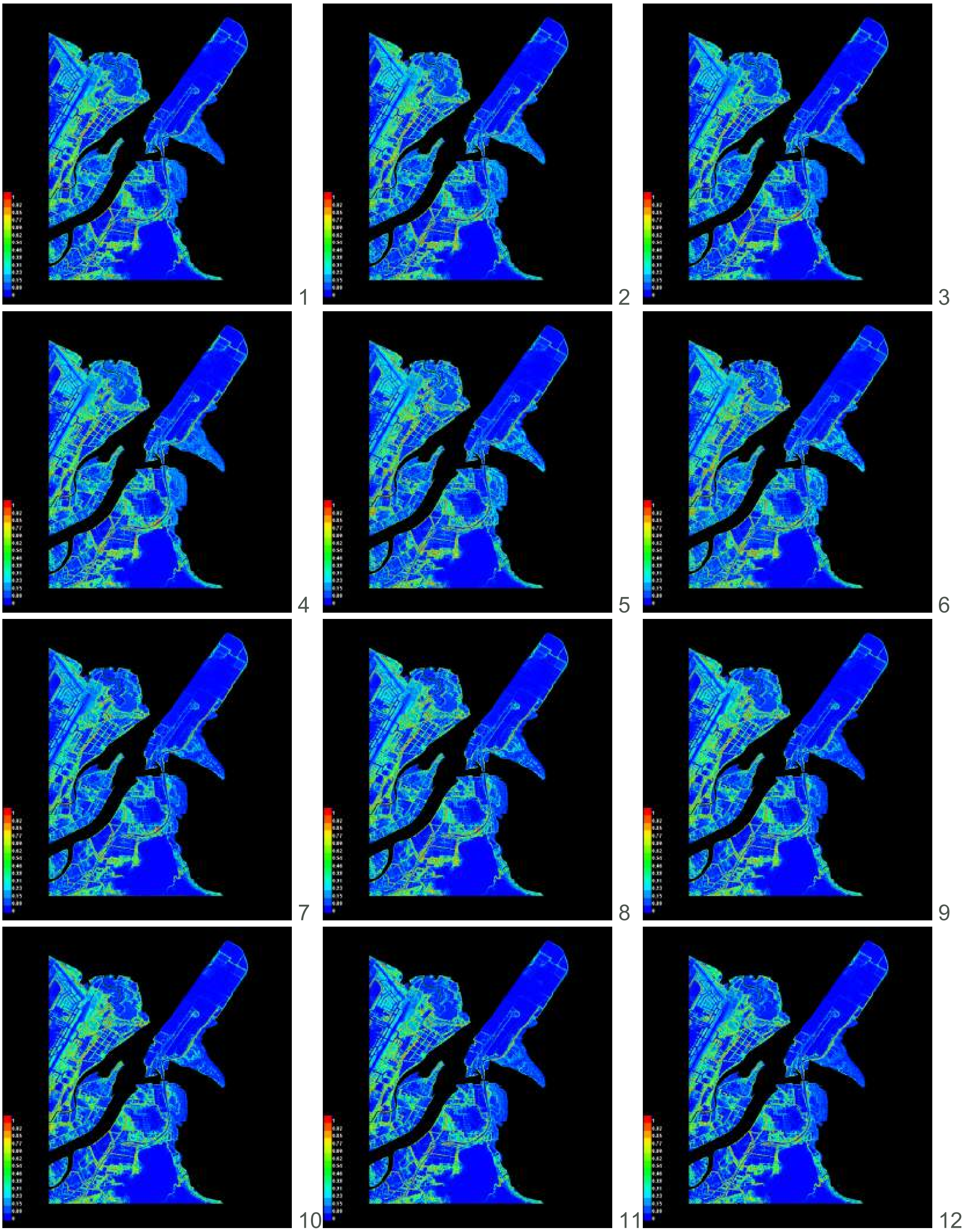

9


10

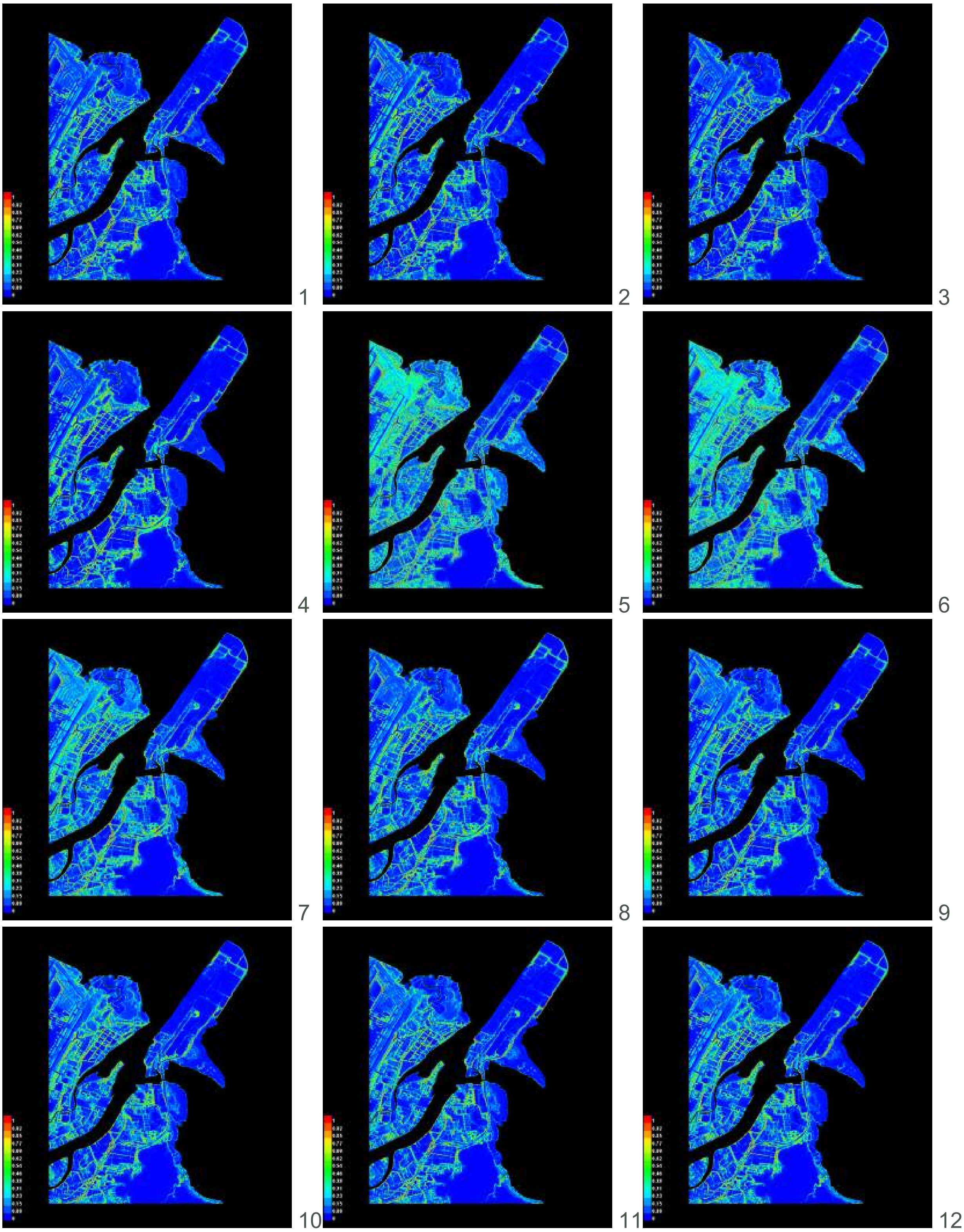

11


12

E.8 Broadleaved Pepper Tree



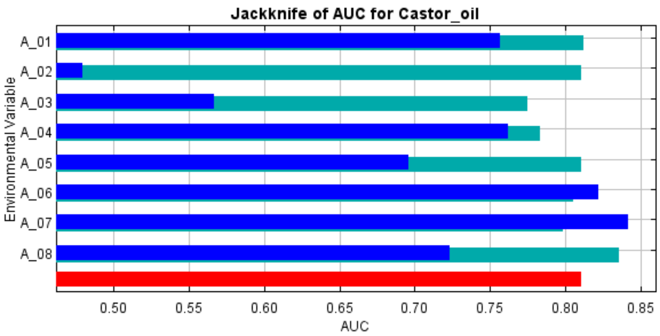
E.9 Sesbania Pea



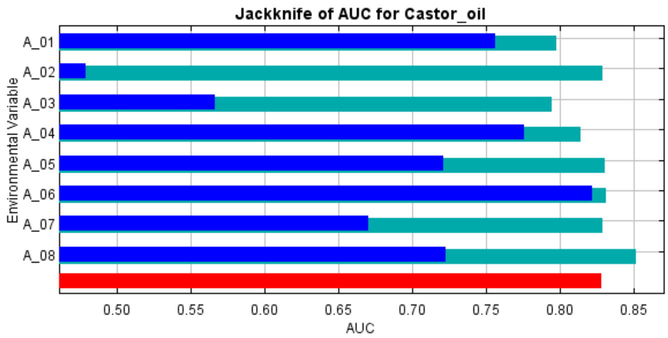
Annex F Jackknife Test Outcomes

The Monthly Contribution of Soil Temperature (A 01), Aspect (A 02), DEM (A 03), LAI (A 04), NDVI (A 05), Slope (A 06), Solar Radiation (A 07), TWI (A 08) for predicting each weed's spatial distribution. Green bar = without variable, blue bar = with only that variable and red bar = all variables

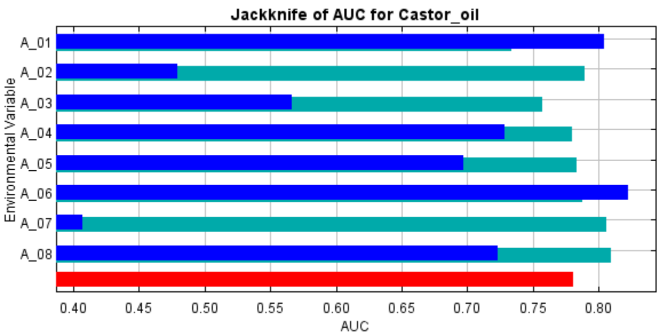
F.1 Castor Oil



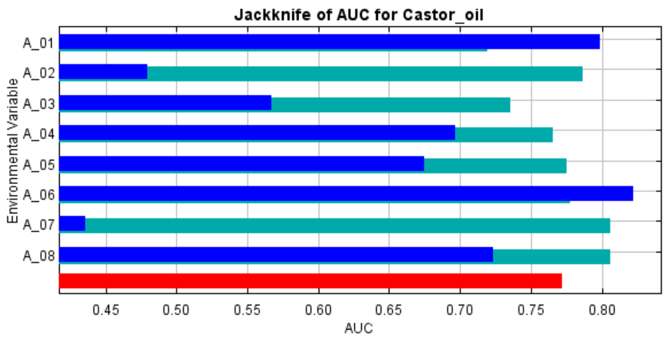
January (Month 1)



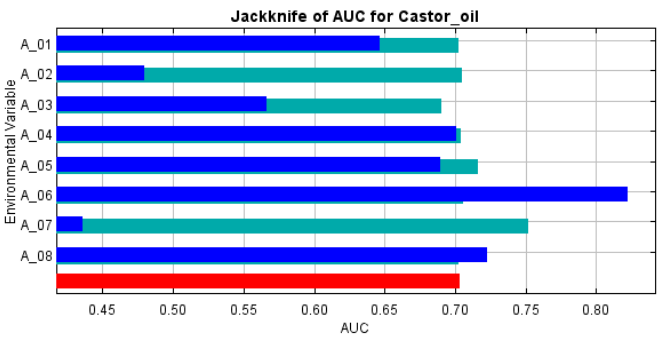
February (Month 2)



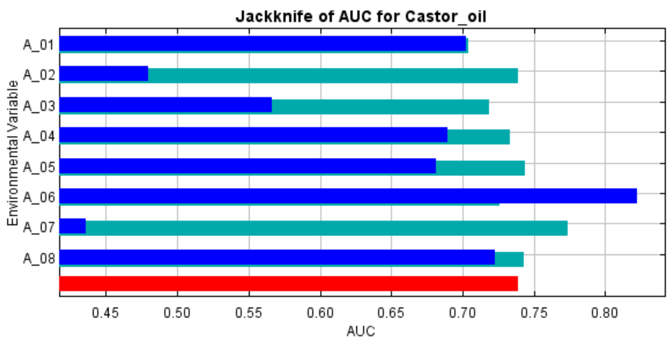
March (Month 3)



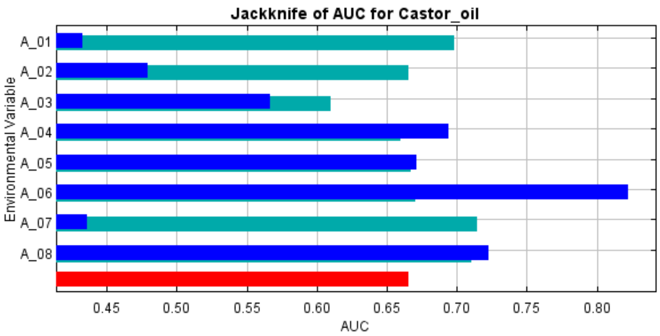
April (Month 4)



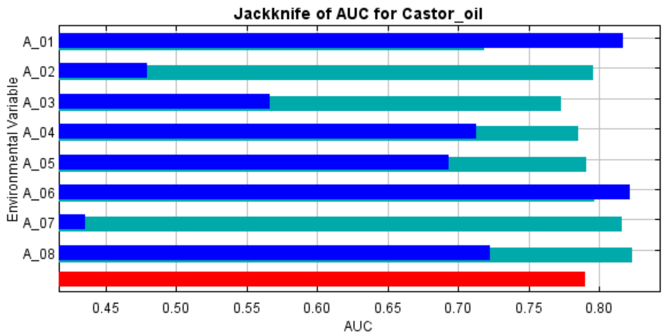
May (Month 5)



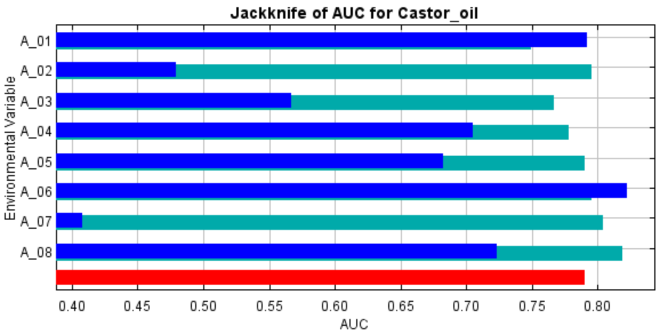
June (Month 6)



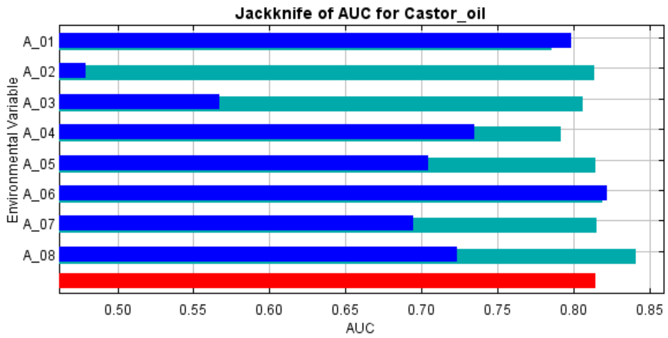
July (Month 7)



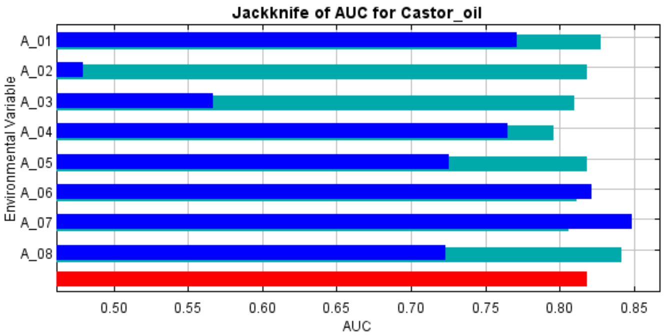
August (Month 8)



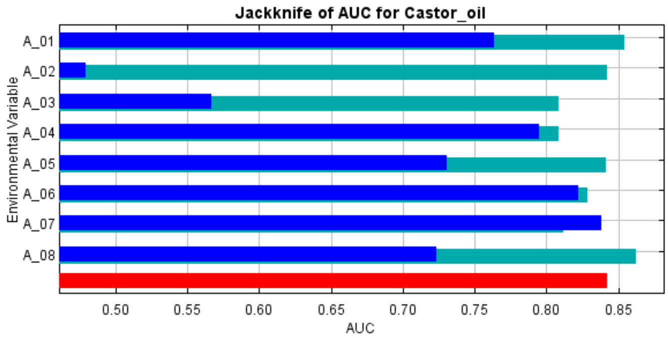
September (Month 9)



October (Month 10)

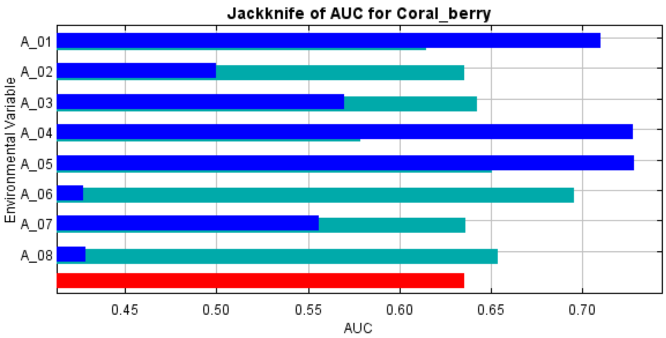


November (Month 11)

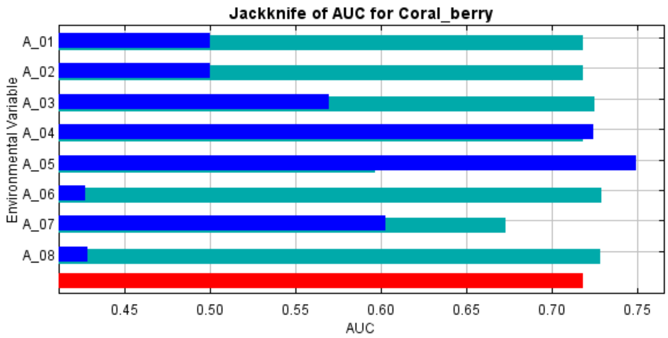


December (Month 12)

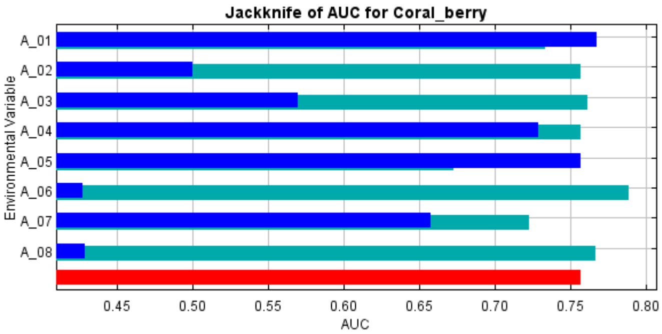
F.2 Coral Berry



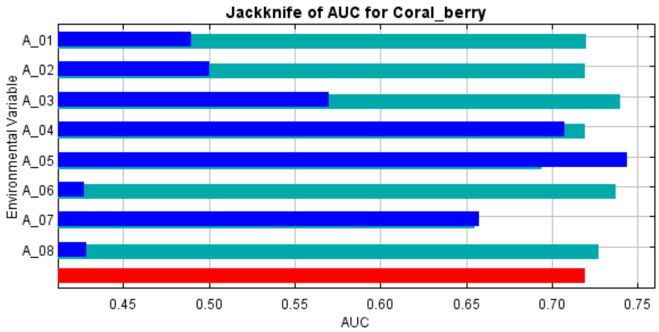
January (Month 1)



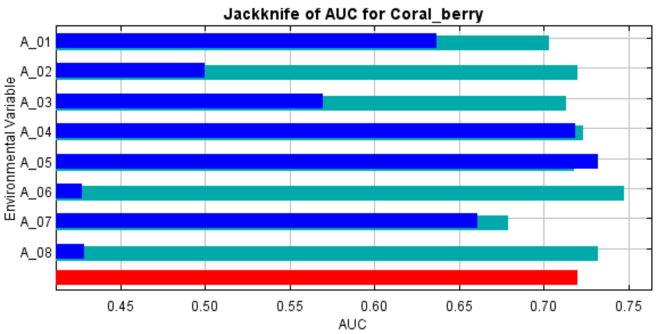
February (Month 2)



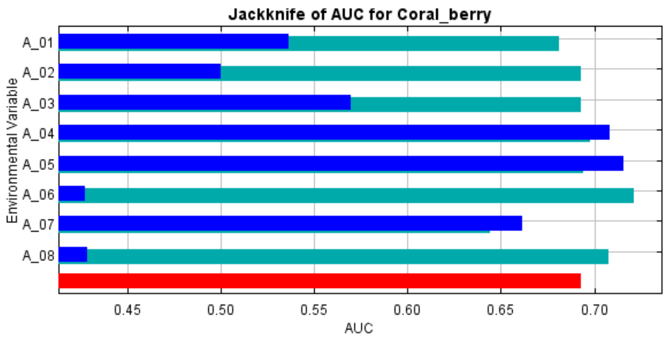
March (Month 3)



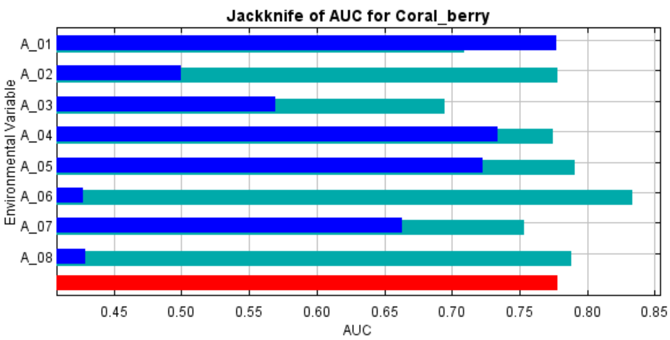
April (Month 4)



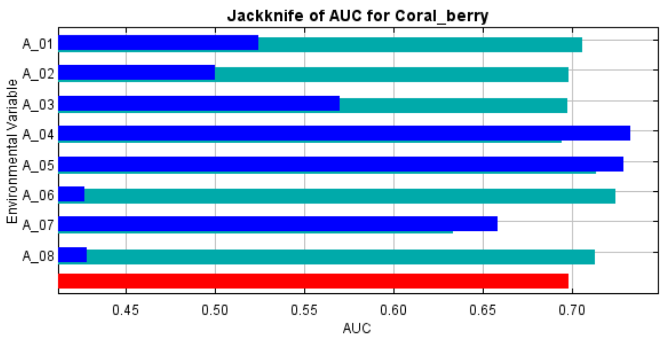
May (Month 5)



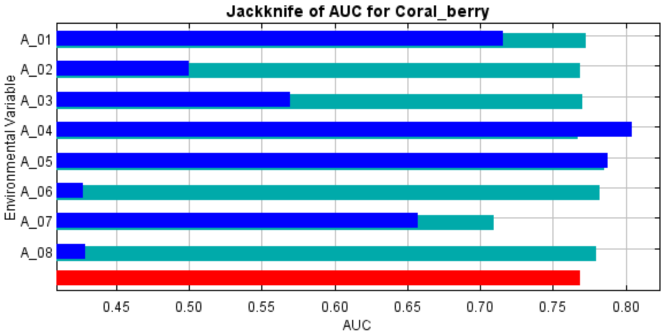
June (Month 6)



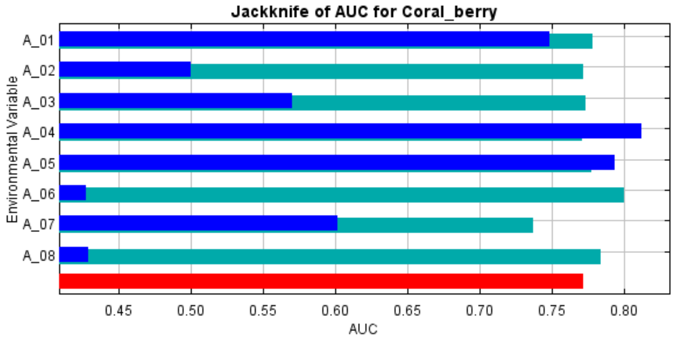
July (Month 7)



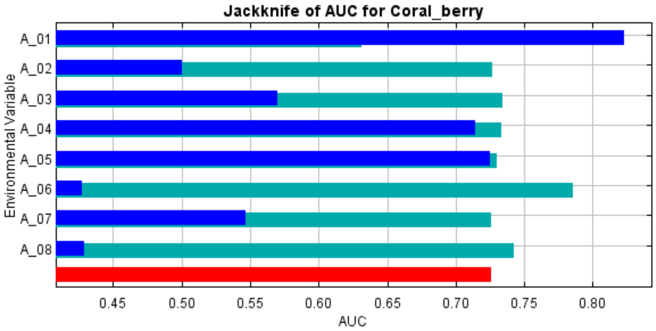
August (Month 8)



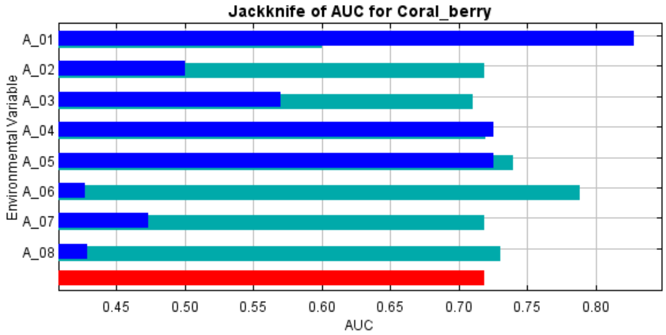
September (Month 9)



October (Month 10)

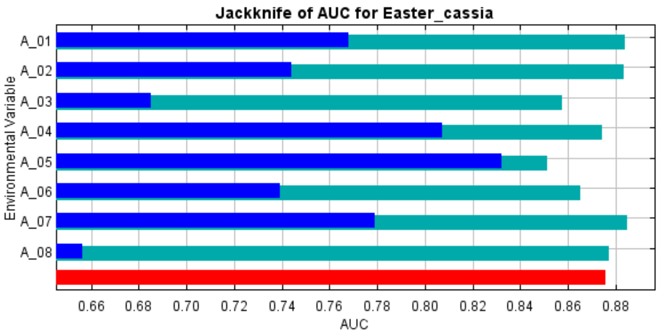


November (Month 11)

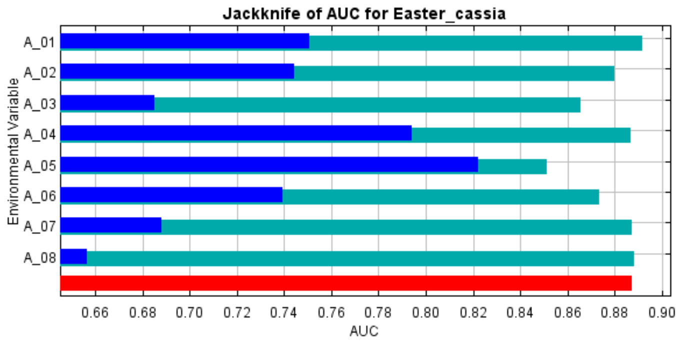


December (Month 12)

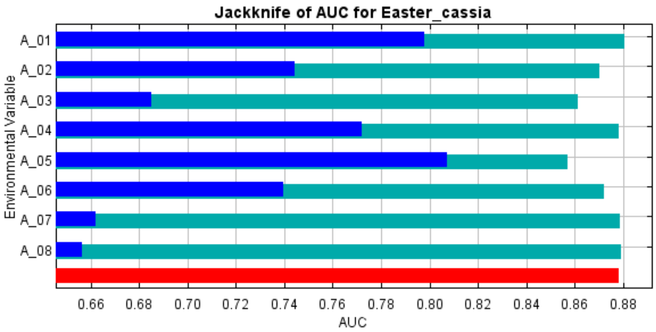
F.3 Easter Cassia



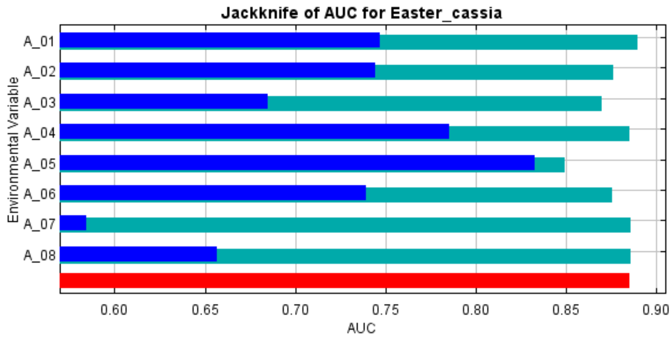
January (Month 1)



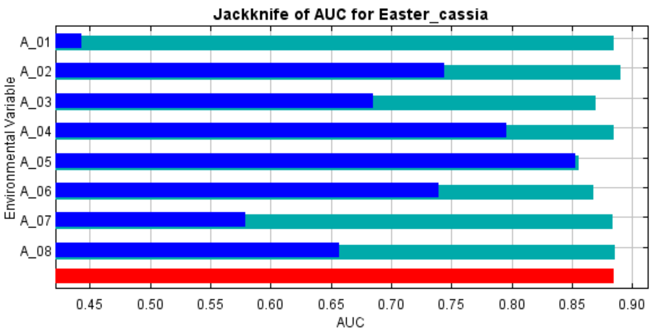
February (Month 2)



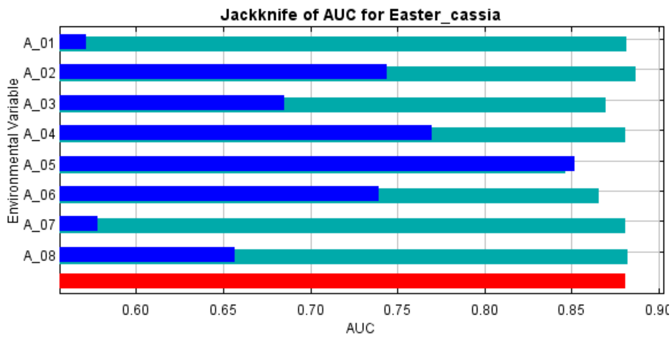
March (Month 3)



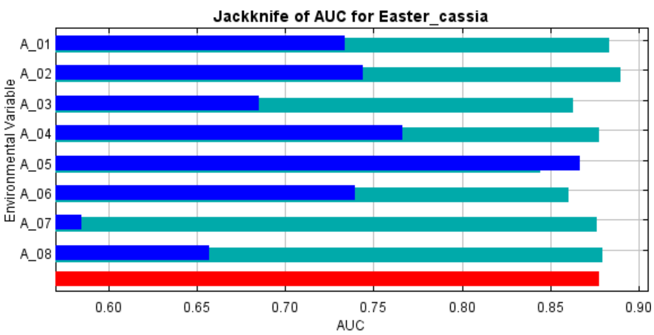
April (Month 4)



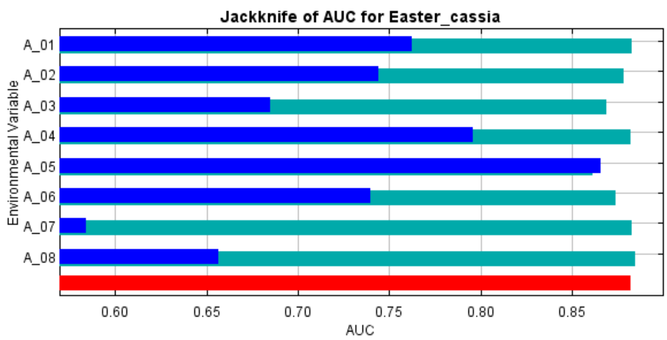
May (Month 5)



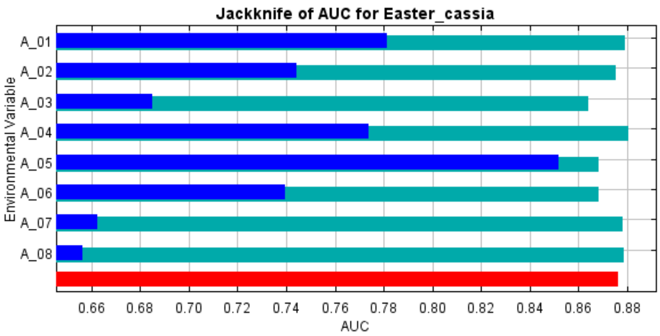
June (Month 6)



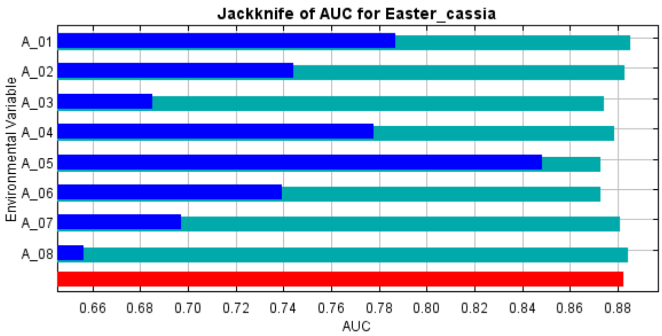
July (Month 7)



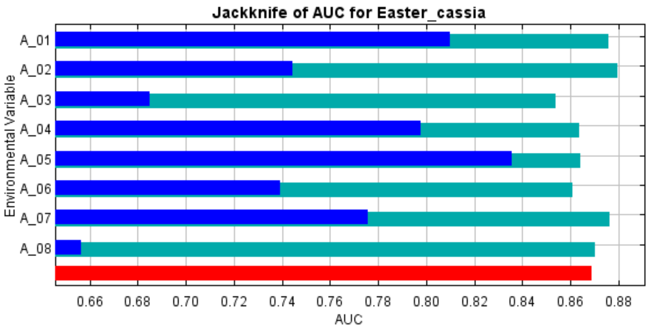
August (Month 8)



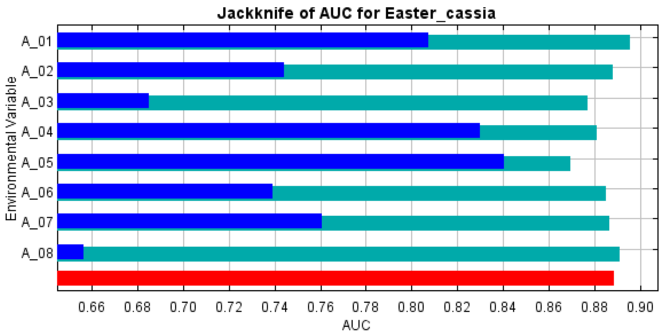
September (Month 9)



October (Month 10)

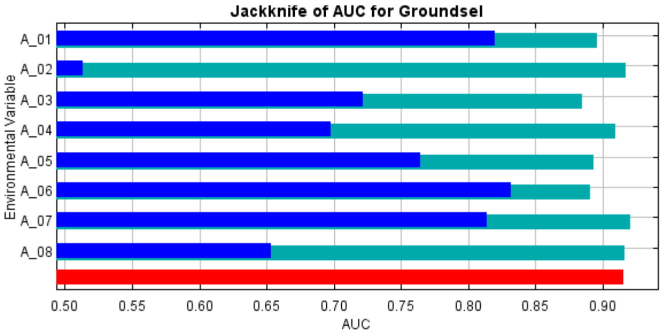


November (Month 11)

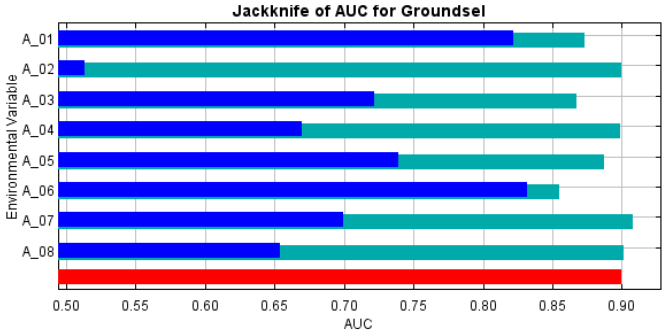


December (Month 12)

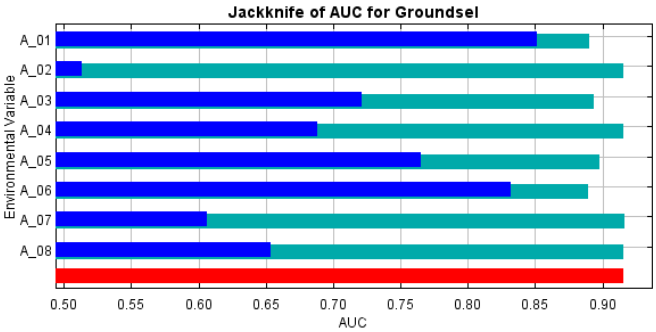
F.4 Groundsel Bush



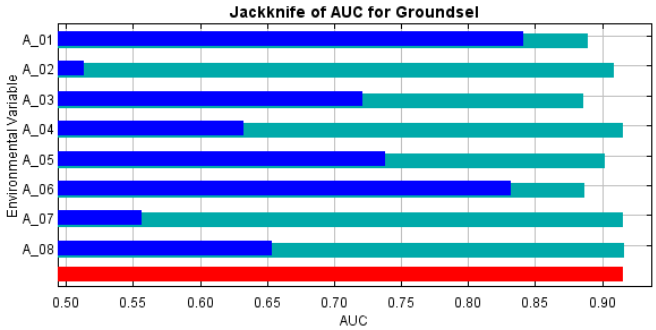
January (Month 1)



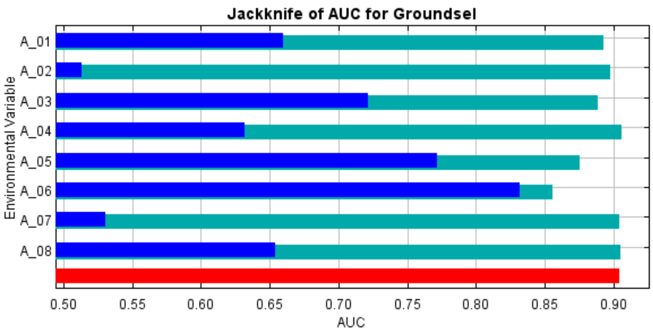
February (Month 2)



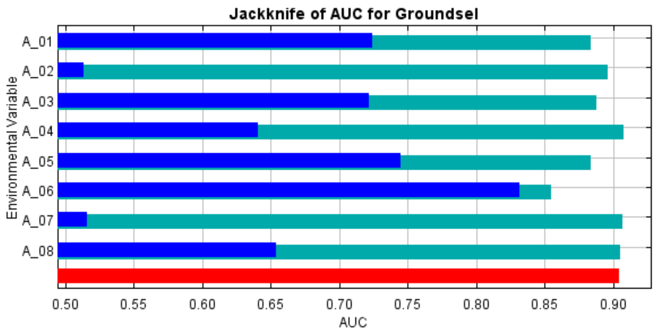
March (Month 3)



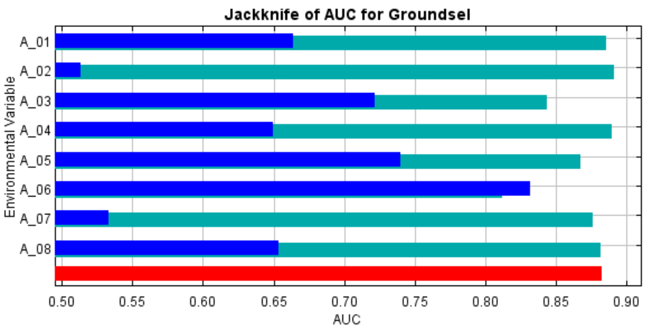
April (Month 4)



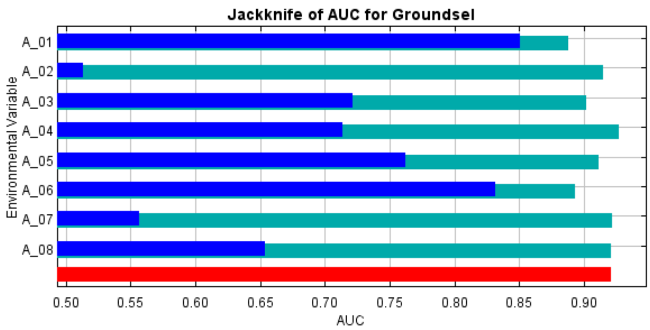
May (Month 5)



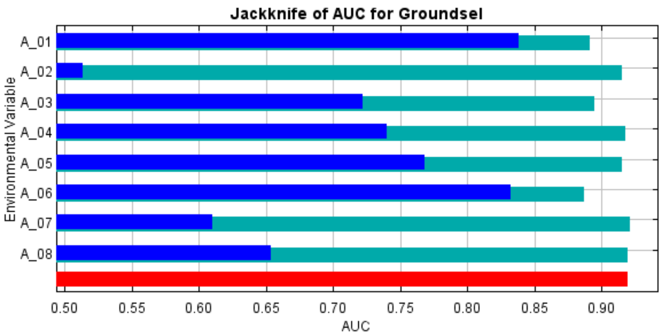
June (Month 6)



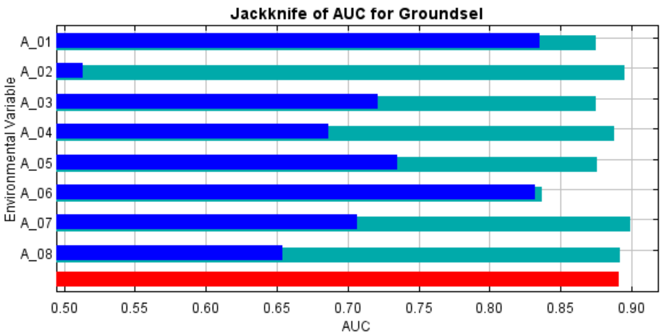
July (Month 7)



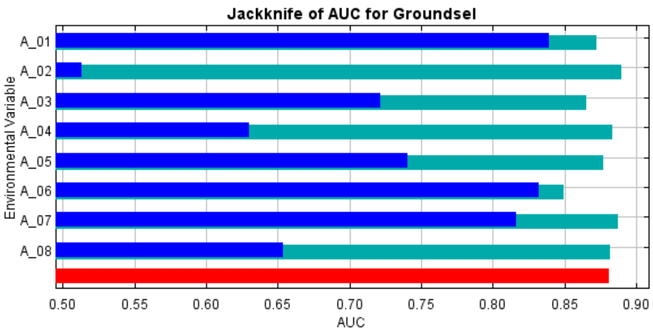
August (Month 8)



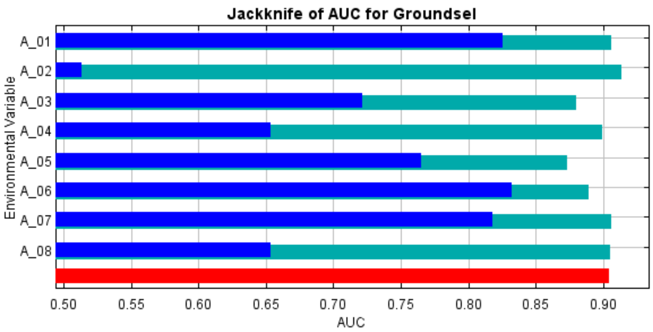
September (Month 9)



October (Month 10)

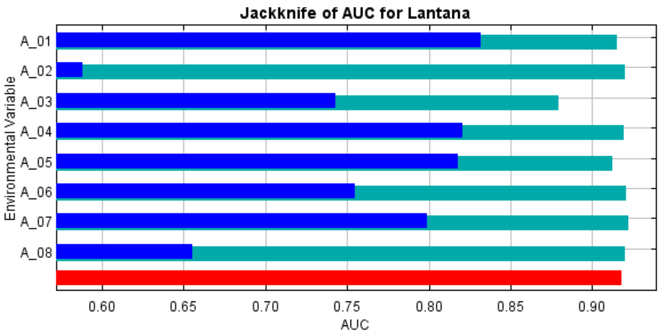


November (Month 11)

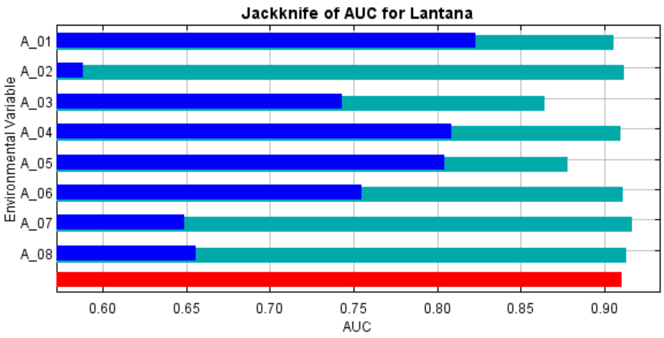


December (Month 12)

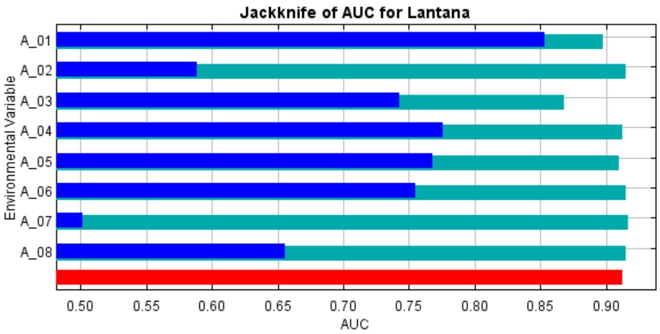
F.5 Lantana



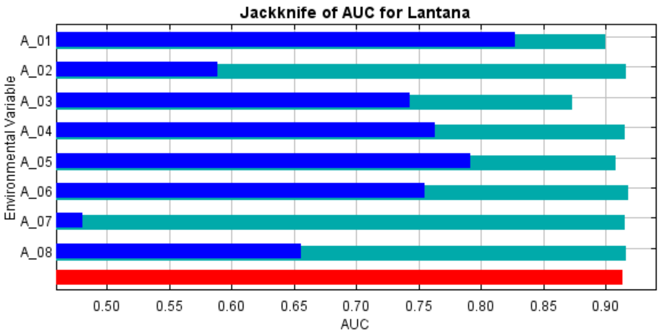
January (Month 1)



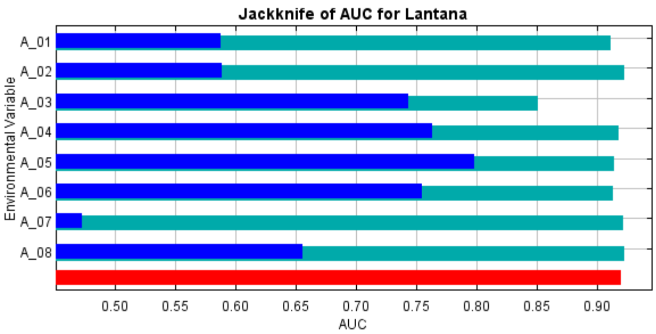
February (Month 2)



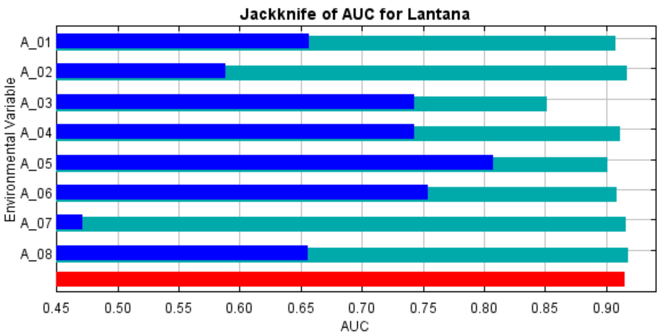
March (Month 3)



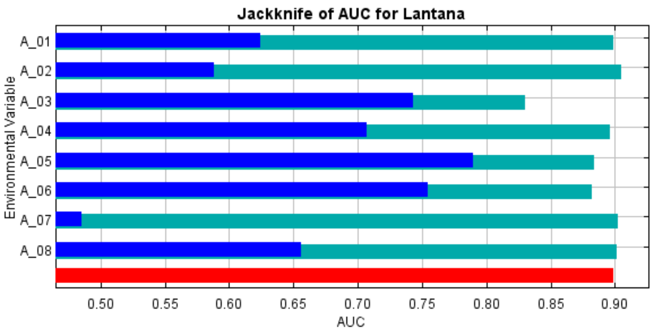
April (Month 4)



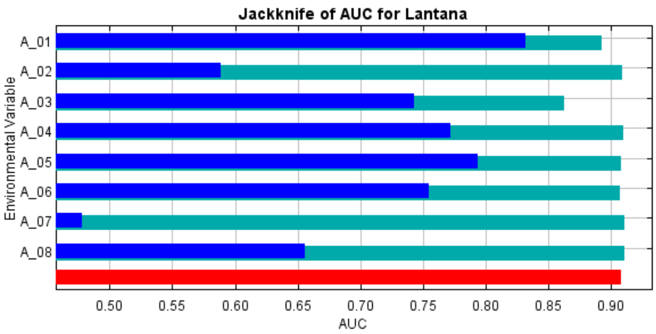
May (Month 5)



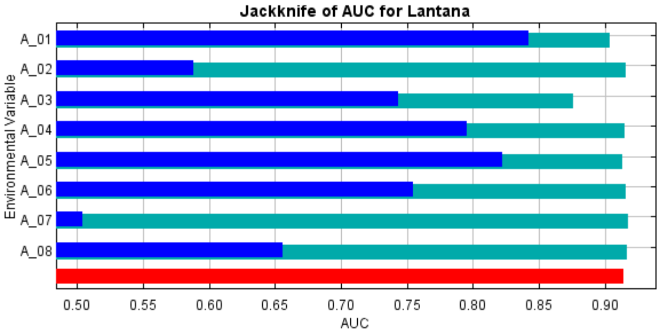
June (Month 6)



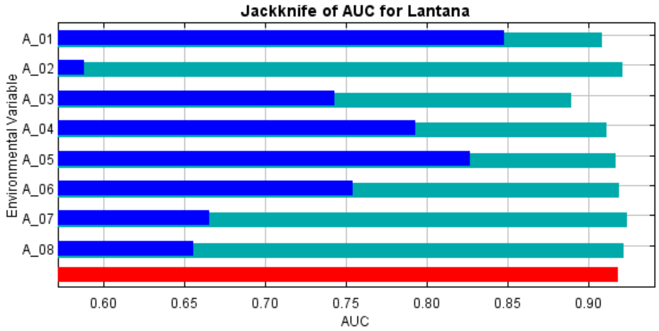
July (Month 7)



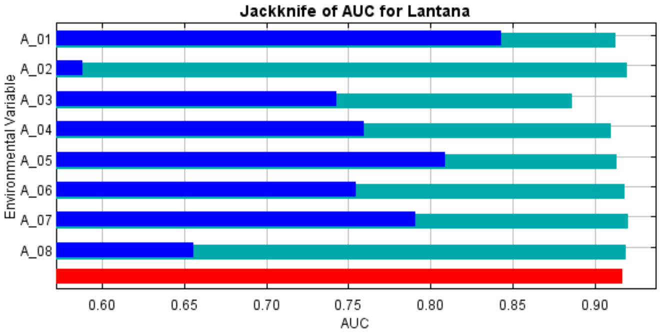
August (Month 8)



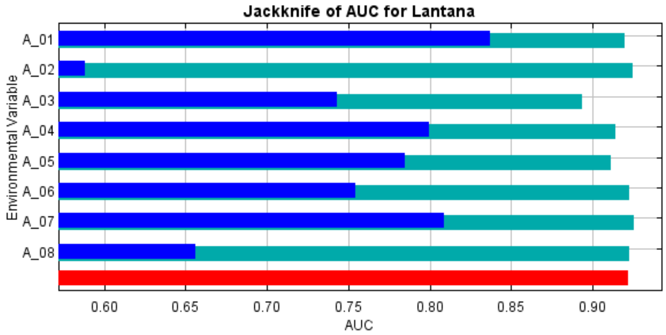
September (Month 9)



October (Month 10)

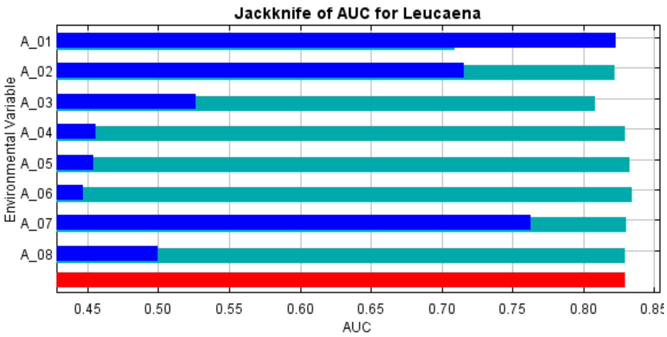


November (Month 11)

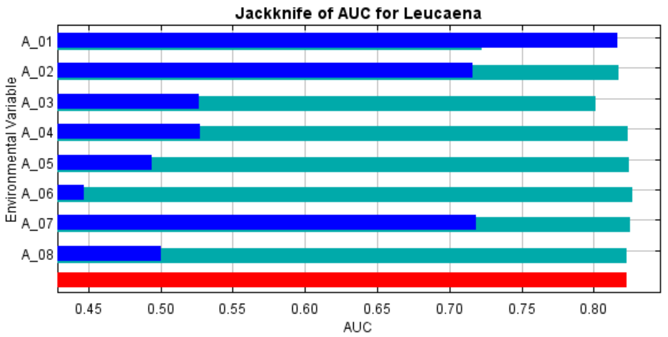


December (Month 12)

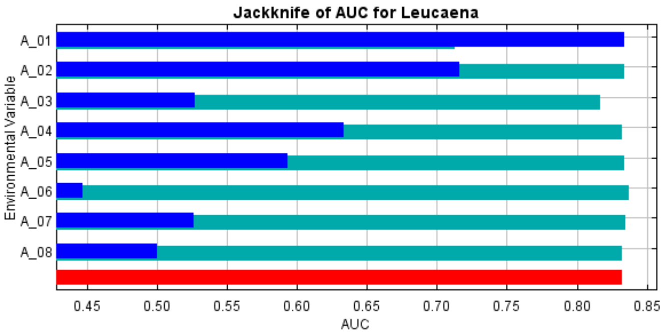
F.6 Leucaena



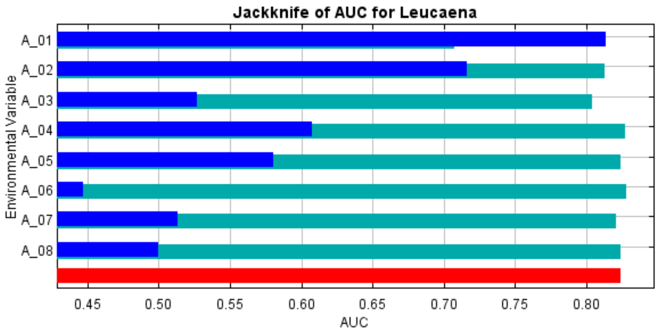
January (Month 1)



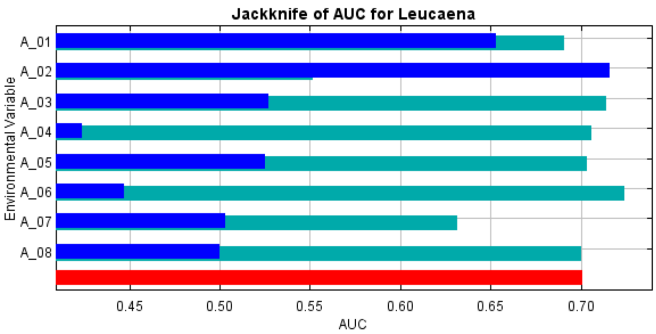
February (Month 2)



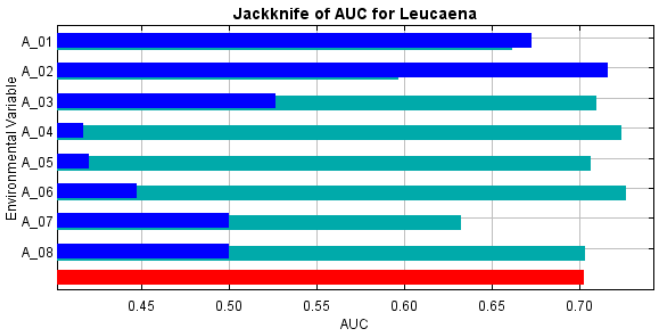
March (Month 3)



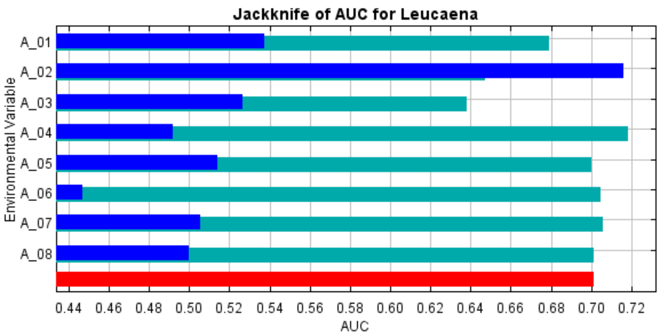
April (Month 4)



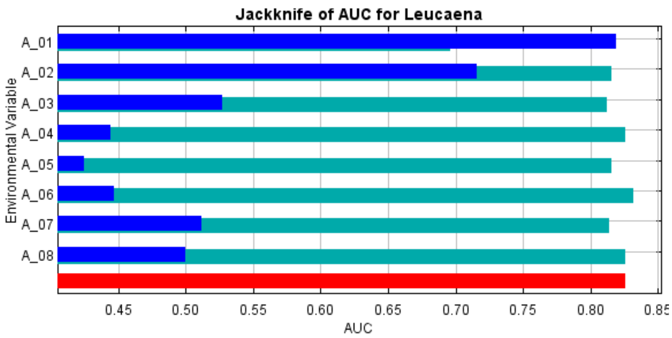
May (Month 5)



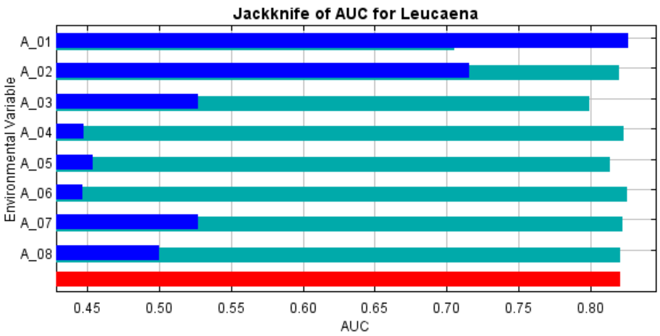
June (Month 6)



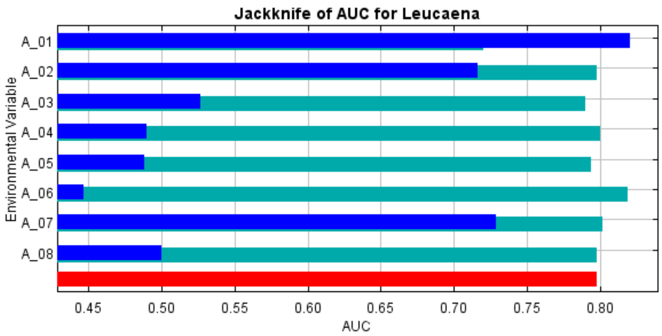
July (Month 7)



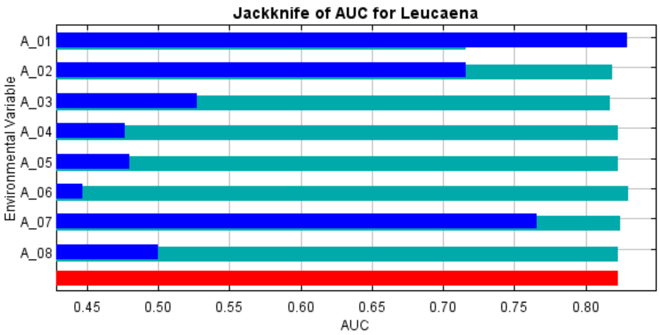
August (Month 8)



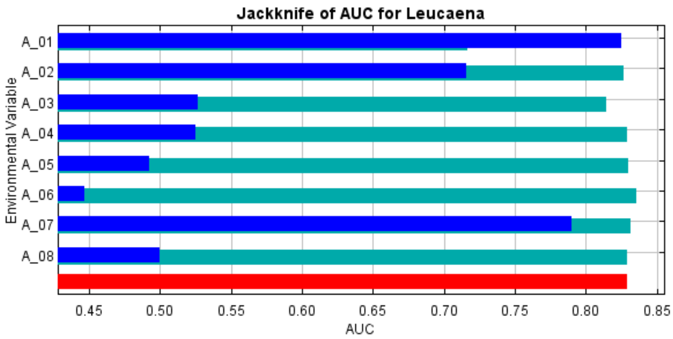
September (Month 9)



October (Month 10)

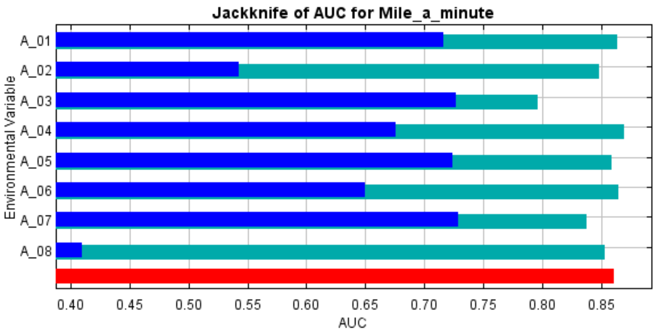


November (Month 11)

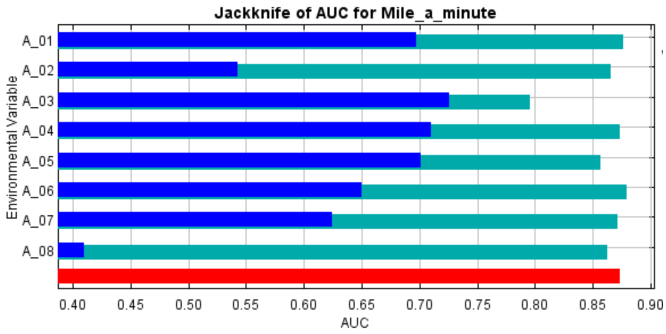


December (Month 12)

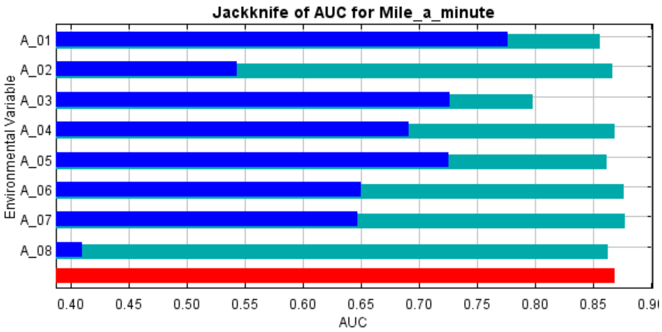
F.7 Mile-A-Minute



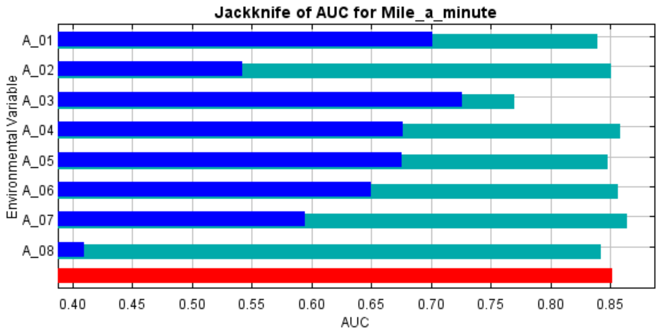
January (Month 1)



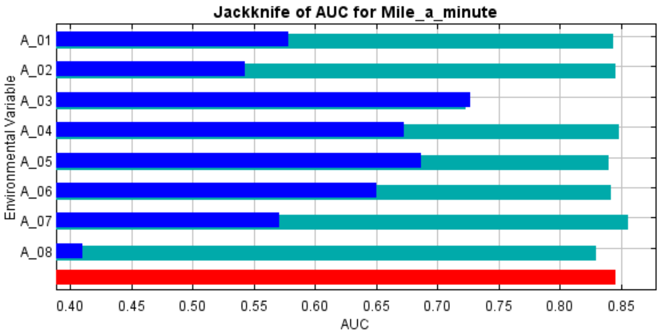
February (Month 2)



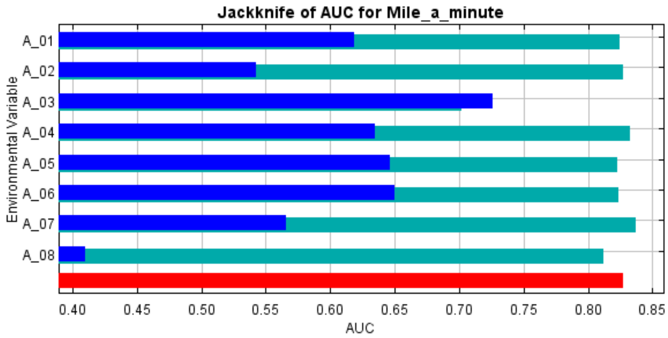
March (Month 3)



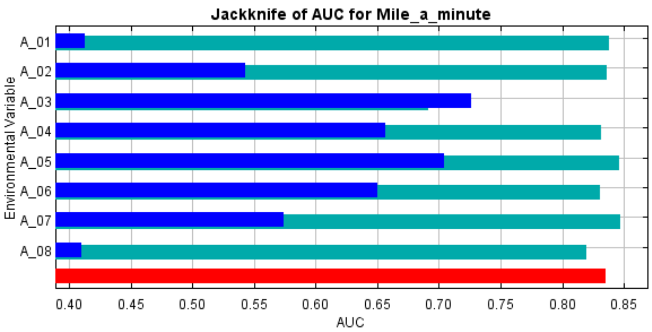
April (Month 4)



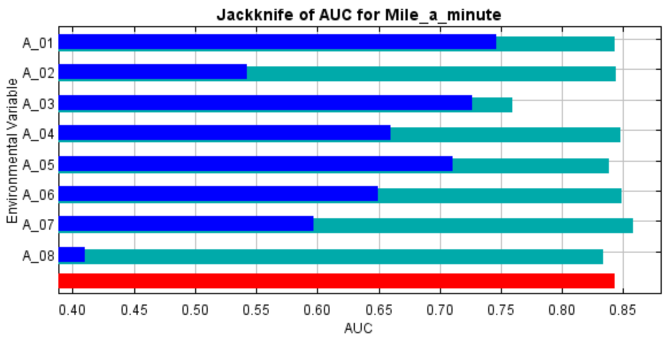
May (Month 5)



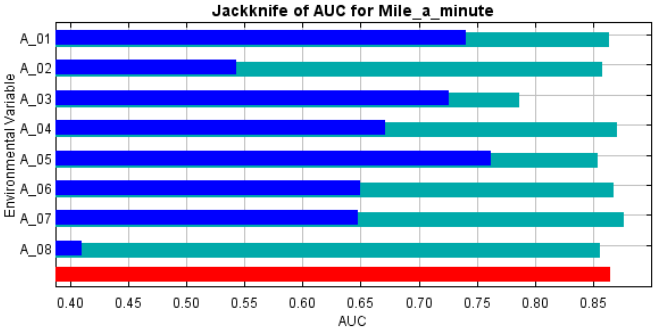
June (Month 6)



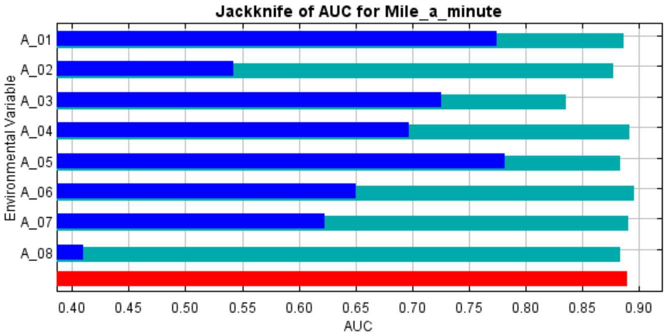
July (Month 7)



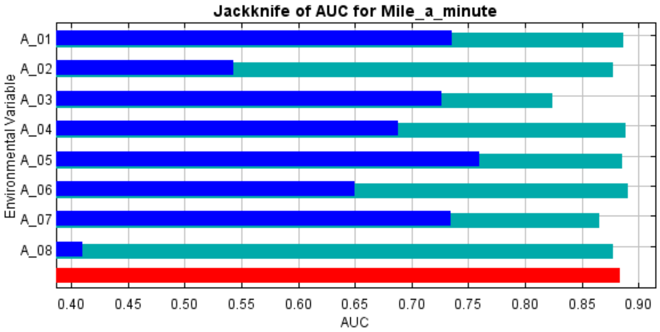
August (Month 8)



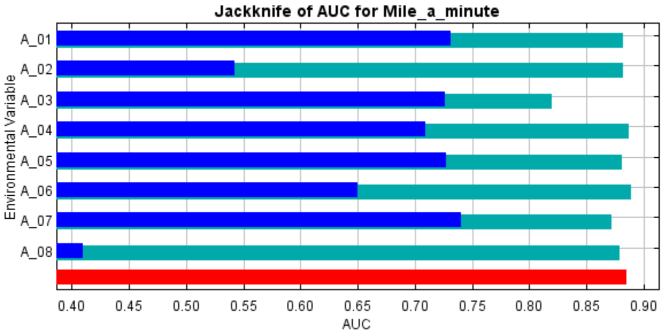
September (Month 9)



October (Month 10)

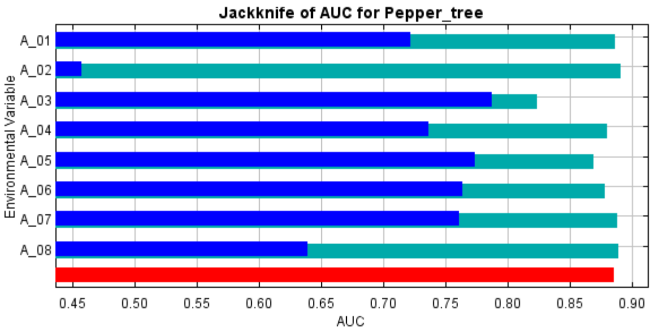


November (Month 11)

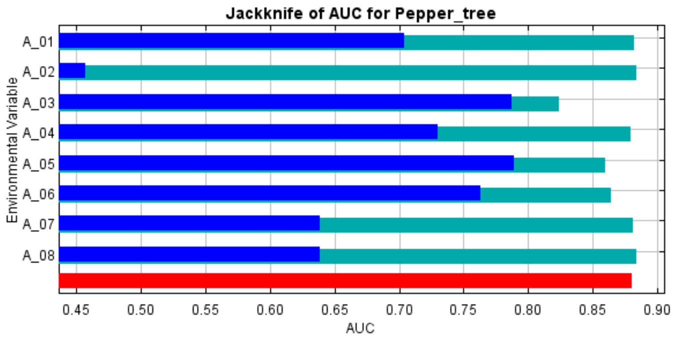


December (Month 12)

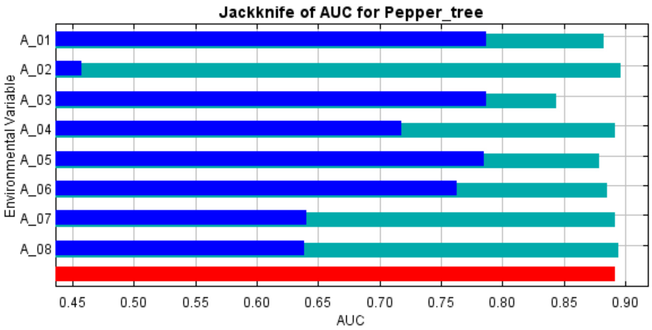
F.8 Broadleaved Pepper Tree



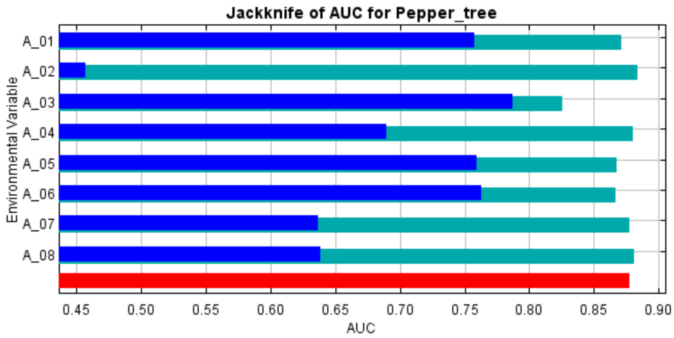
January (Month 1)



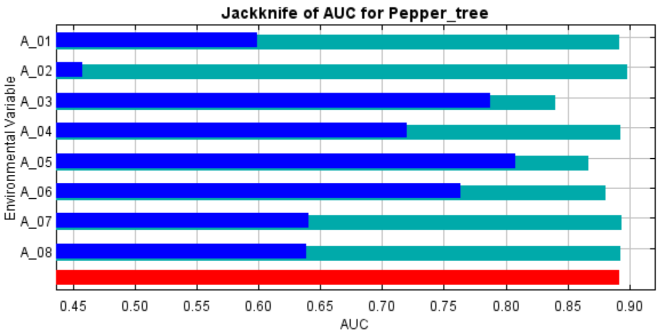
February (Month 2)



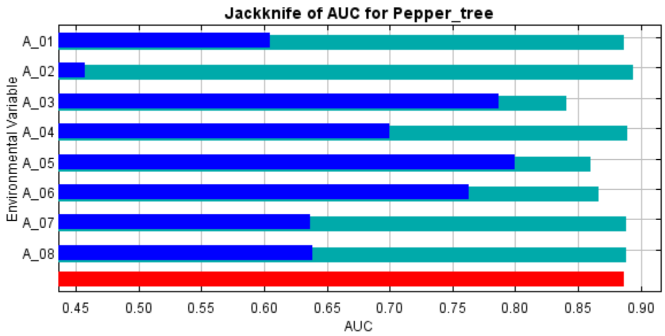
March (Month 3)



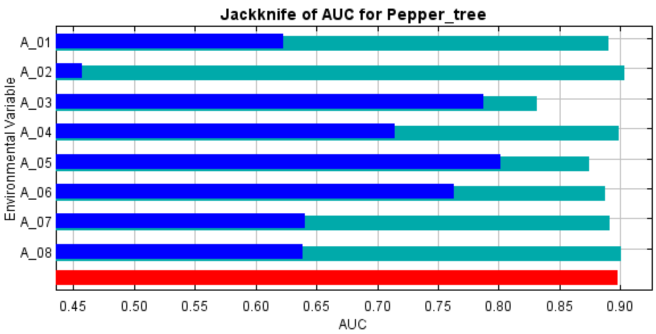
April (Month 4)



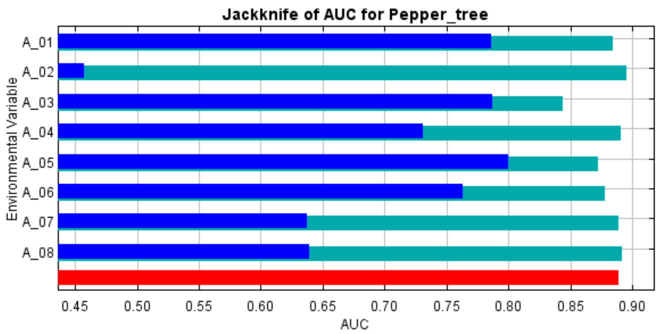
May (Month 5)



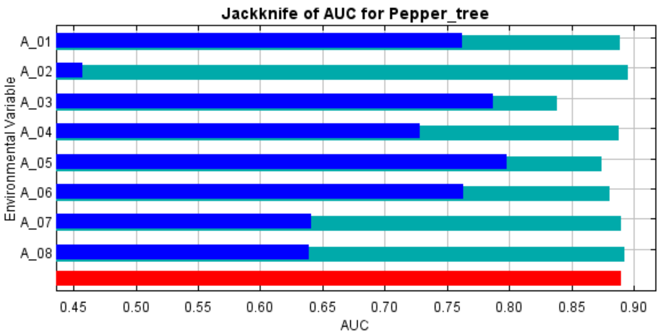
June (Month 6)



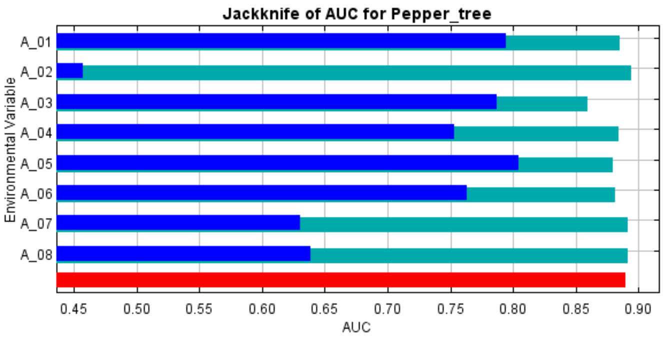
July (Month 7)



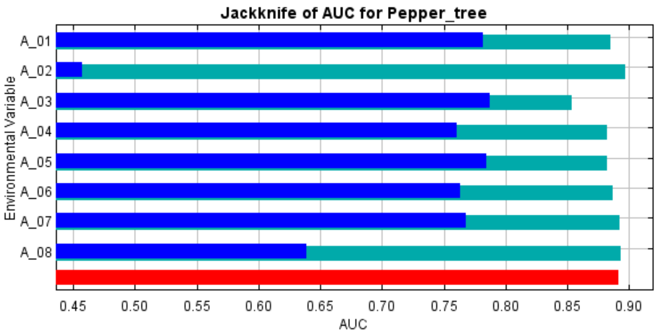
August (Month 8)



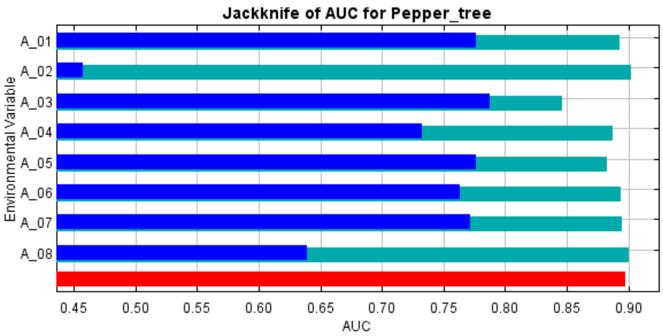
September (Month 9)



October (Month 10)

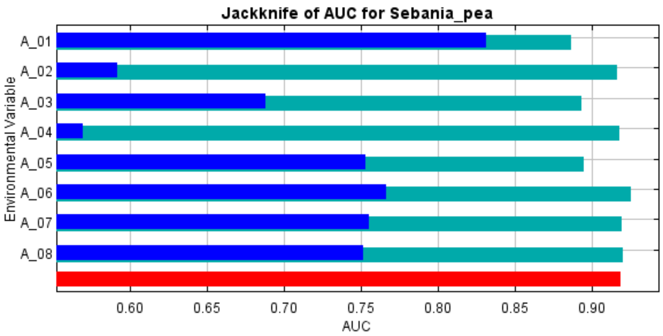


November (Month 11)

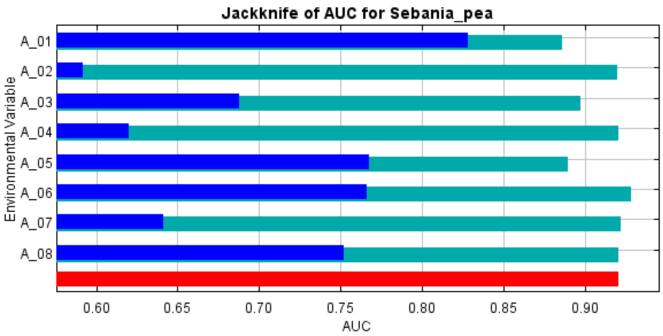


December (Month 12)

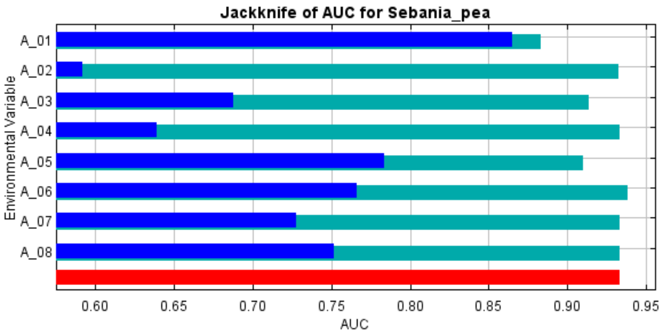
F.9 Sesbania Pea



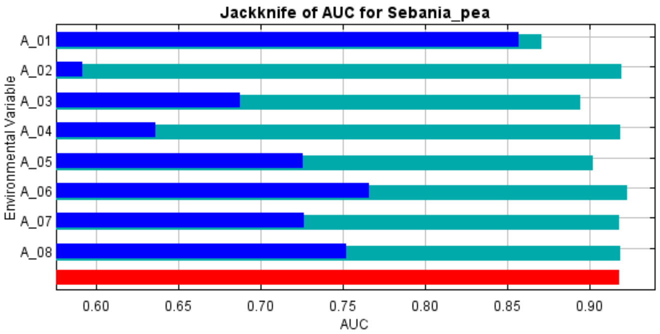
January (Month 1)



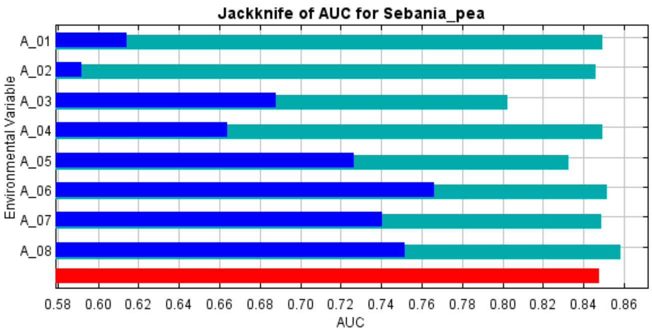
February (Month 2)



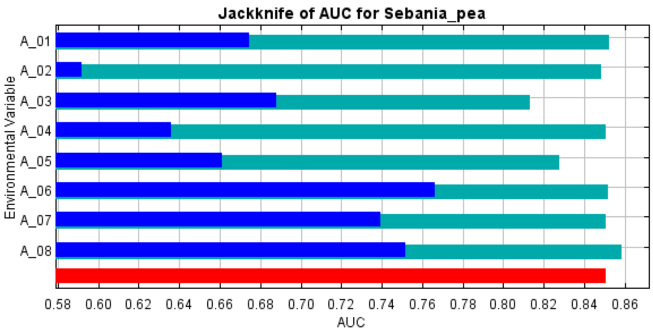
March (Month 3)



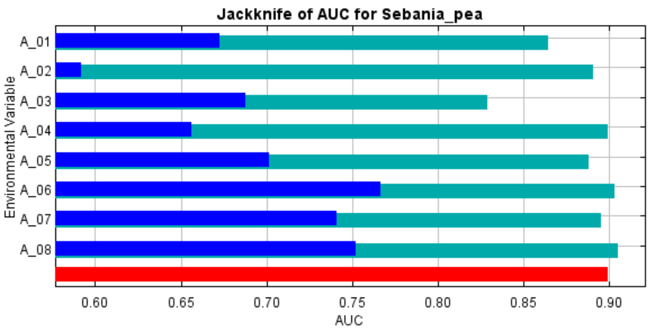
April (Month 4)



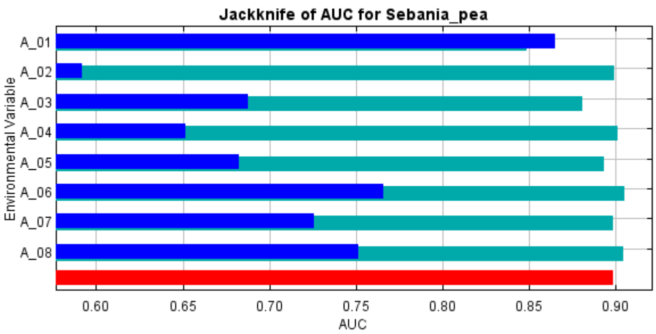
May (Month 5)



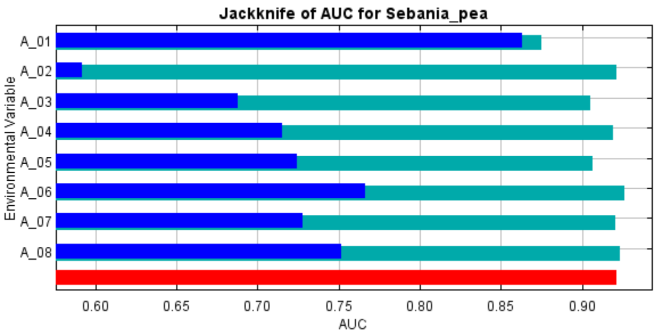
June (Month 6)



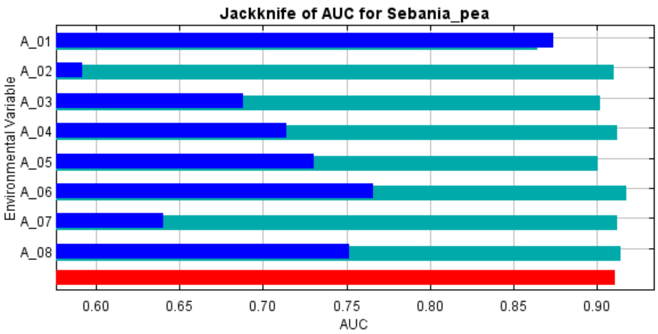
July (Month 7)



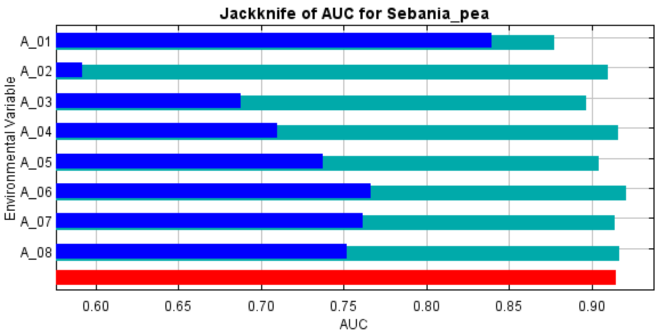
August (Month 8)



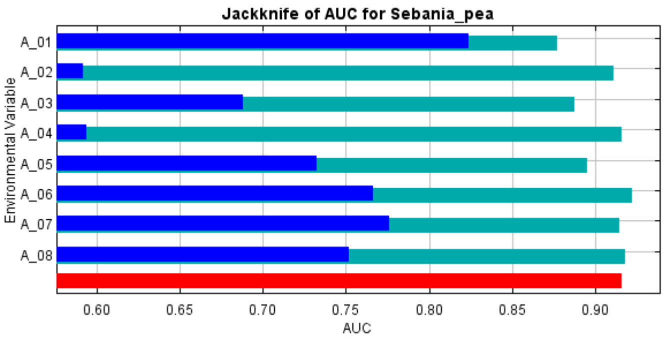
September (Month 9)



October (Month 10)



November (Month 11)

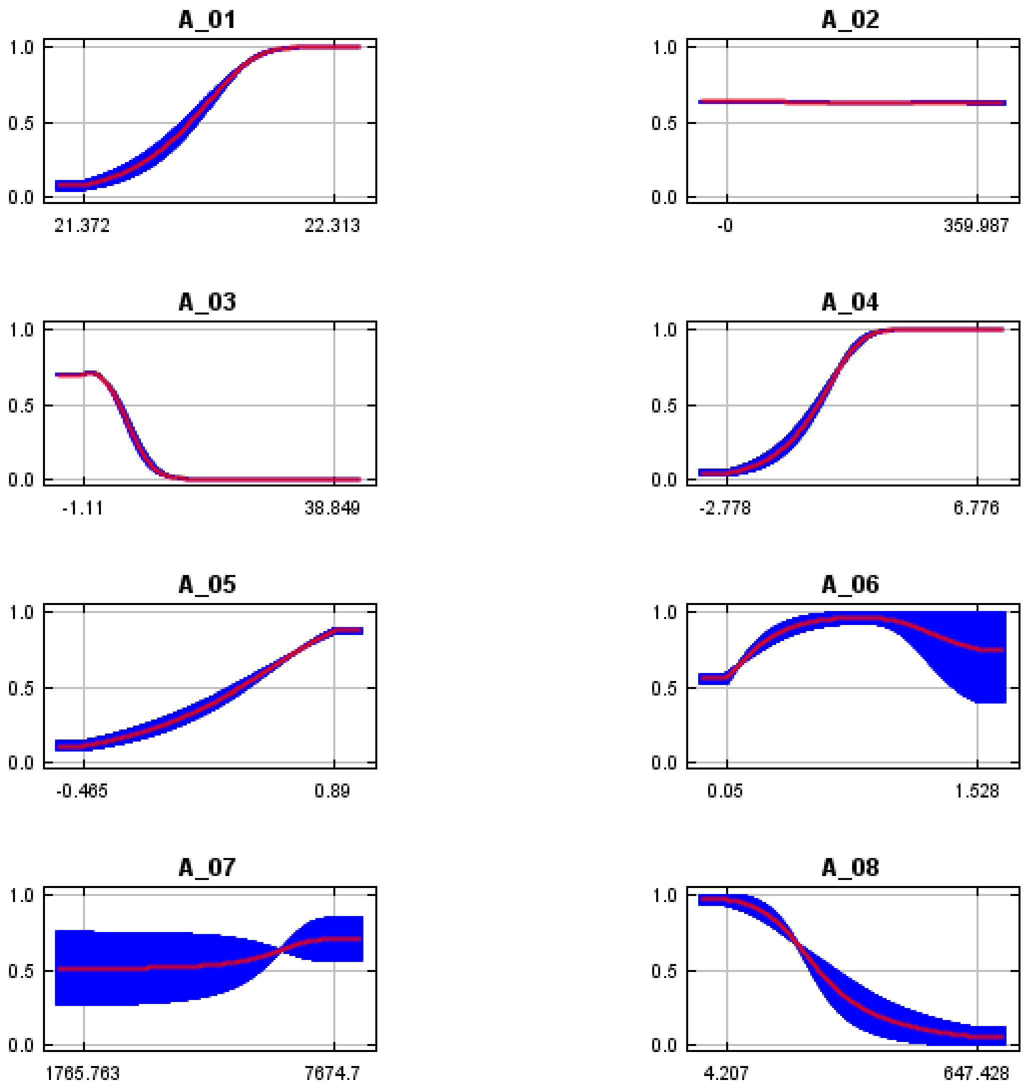


December (Month 12)

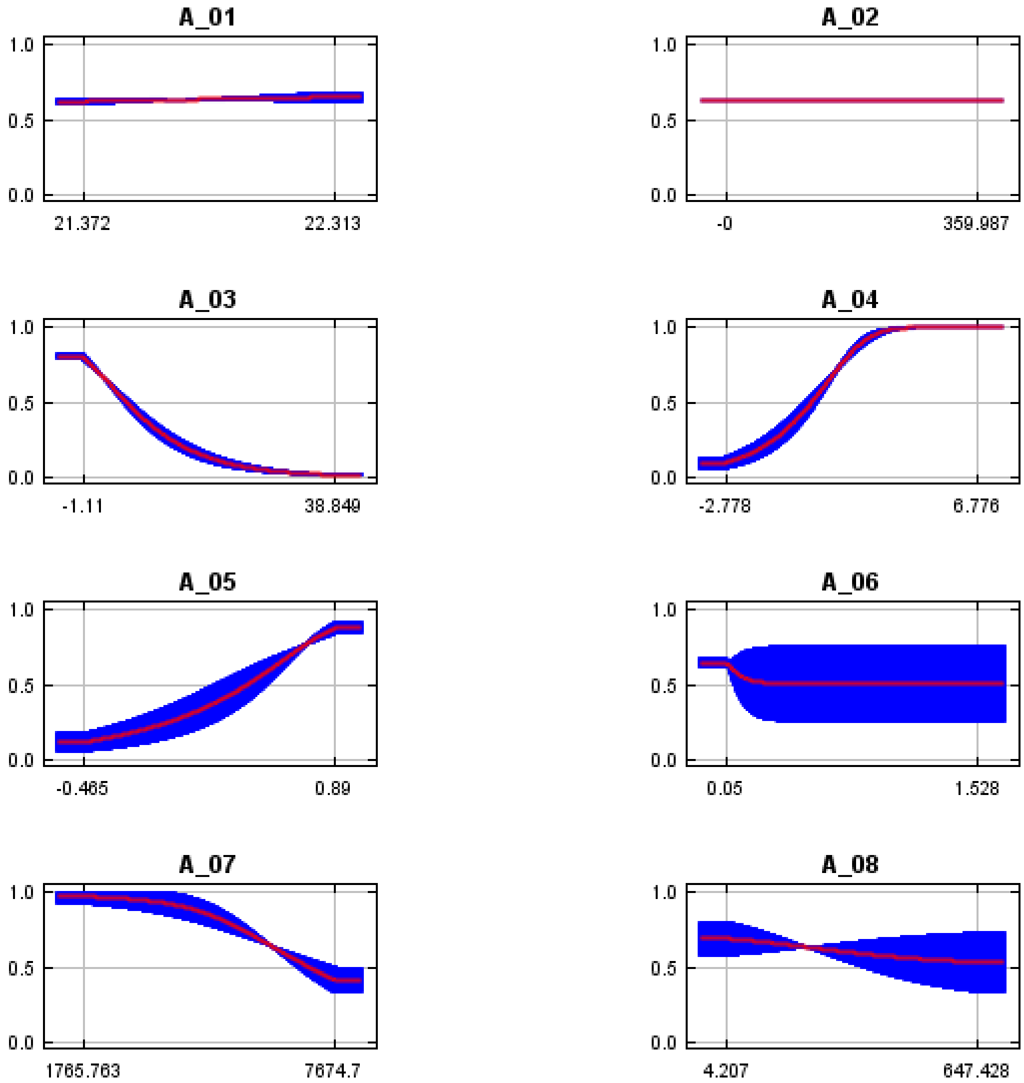
Annex G Response Curves

Curve of Soil Temperature (A 01), Aspect (A 02), DEM (A 03), LAI (A 04), NDVI (A 05), Slope (A 06), Solar Radiation (A 07), TWI (A 08) for predicting weeds in April 2023. The curves show the mean response of the 5 replicate runs (red) and the mean +/- one standard deviation (blue).

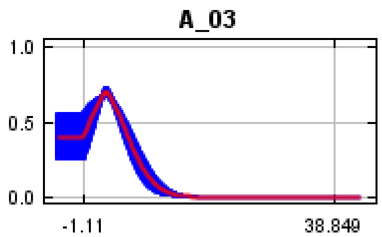
G.1 Castor Oil

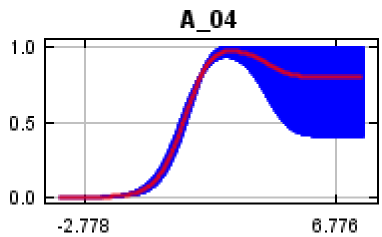


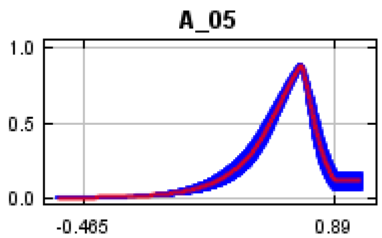
G.2 Coral Berry

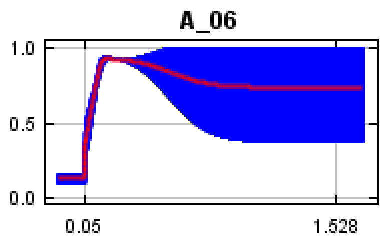


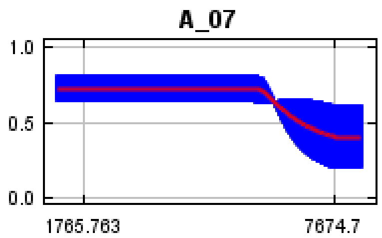
G.3 Easter Cassia

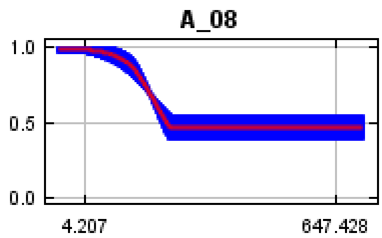




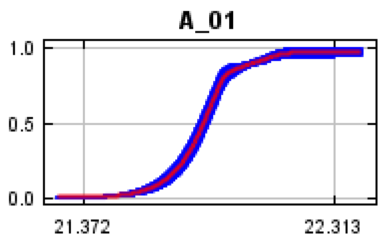


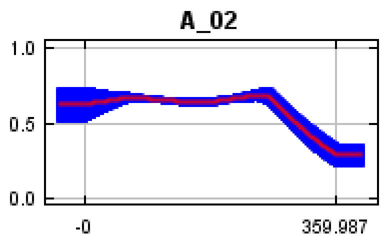


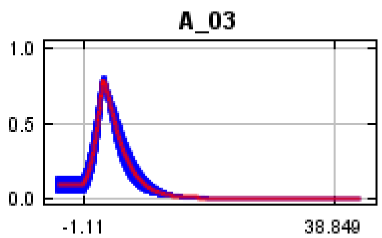


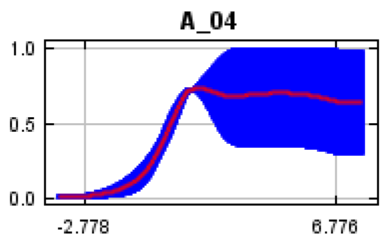


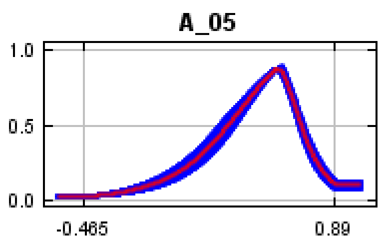
G.4 Groundsel Bush

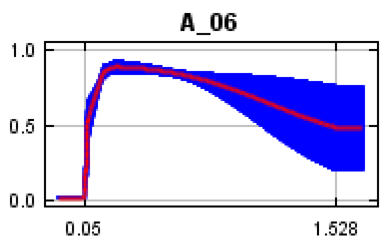


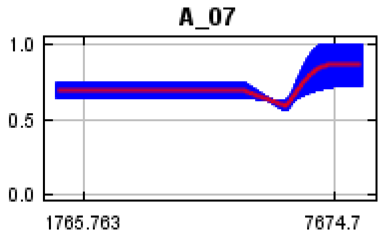


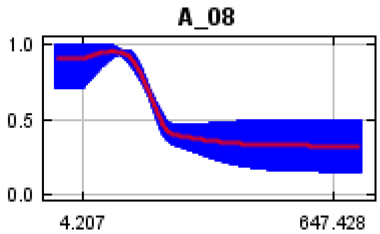




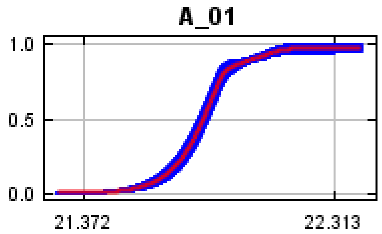


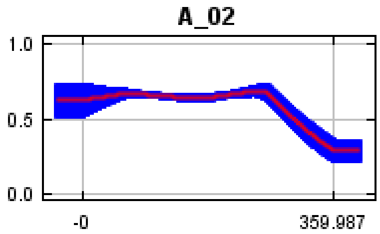


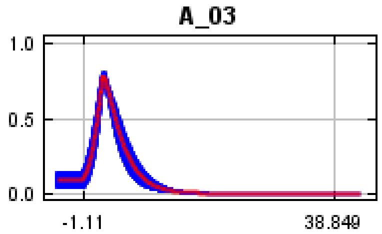

A_07
1.0
0.5
0.0
1765.763
7674.7

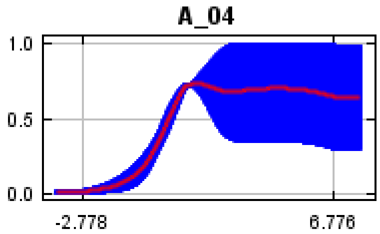

A_08
1.0
0.5
0.0
4.207
647.428

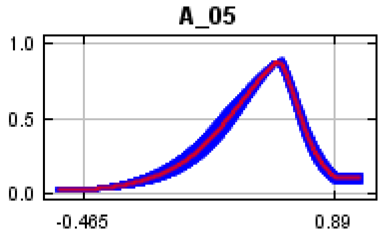
G.5 Lantana

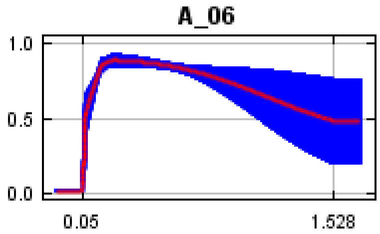

A_01
1.0
0.5
0.0
21.372
22.313

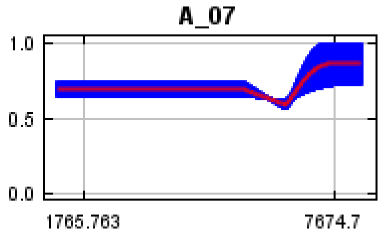

A_02
1.0
0.5
0.0
-0
359.987

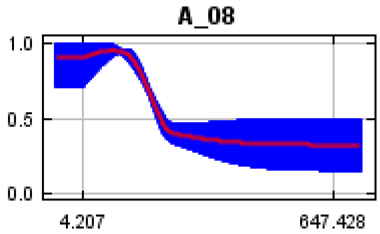

A_03
1.0
0.5
0.0
-1.11
38.849


A_04
1.0
0.5
0.0
-2.778
6.776

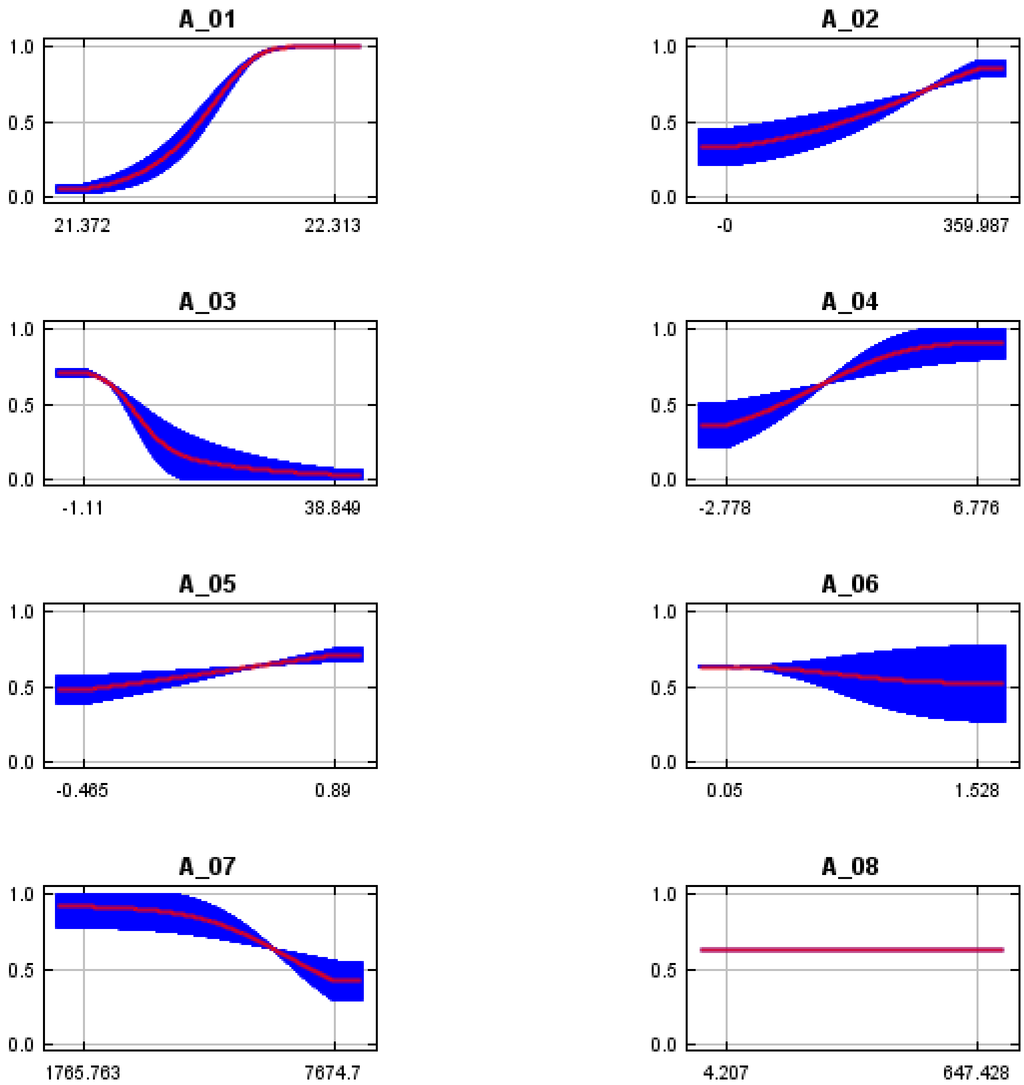

A_05
1.0
0.5
0.0
-0.465
0.89


A_06
1.0
0.5
0.0
0.05
1.528

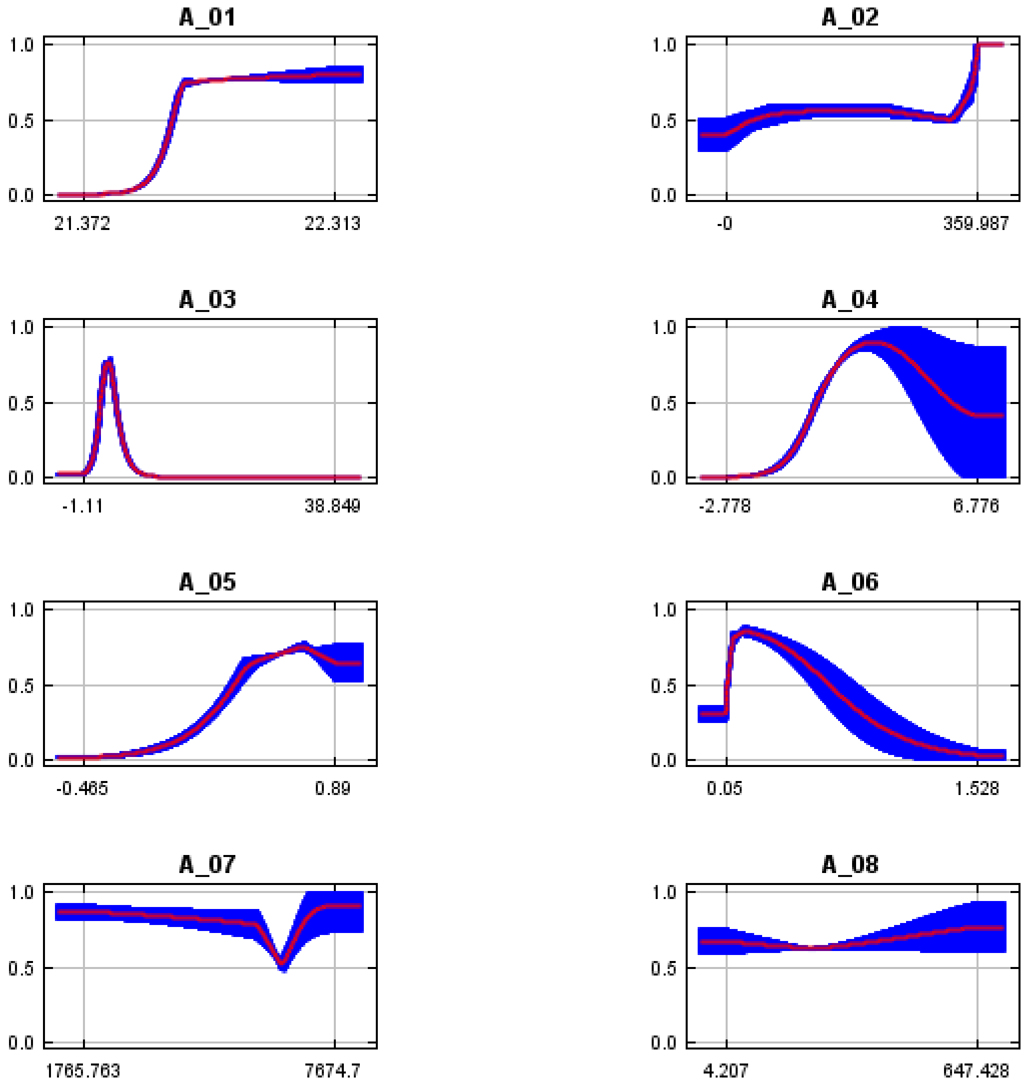

A_07
1.0
0.5
0.0
1765.763
7674.7


A_08
1.0
0.5
0.0
4.207
647.428

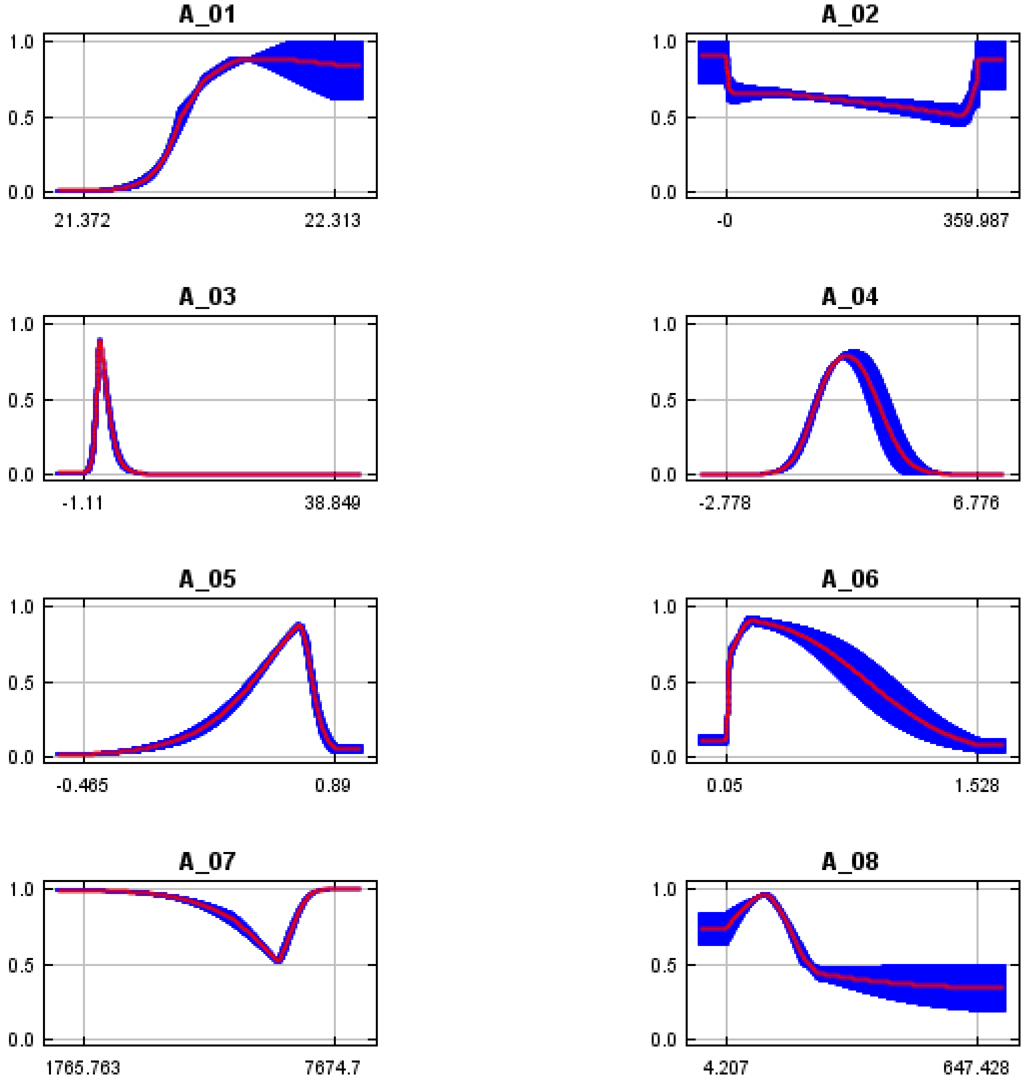
G.6 Leucaena


A_01
1.0
0.5
0.0
21.372
22.313
A_02
1.0
0.5
0.0
-0
359.987
A_03
1.0
0.5
0.0
-1.11
38.849
A_04
1.0
0.5
0.0
-2.778
6.776
A_05
1.0
0.5
0.0
-0.465
0.89
A_06
1.0
0.5
0.0
0.05
1.528
A_07
1.0
0.5
0.0
1765.763
7674.7
A_08
1.0
0.5
0.0
4.207
647.428

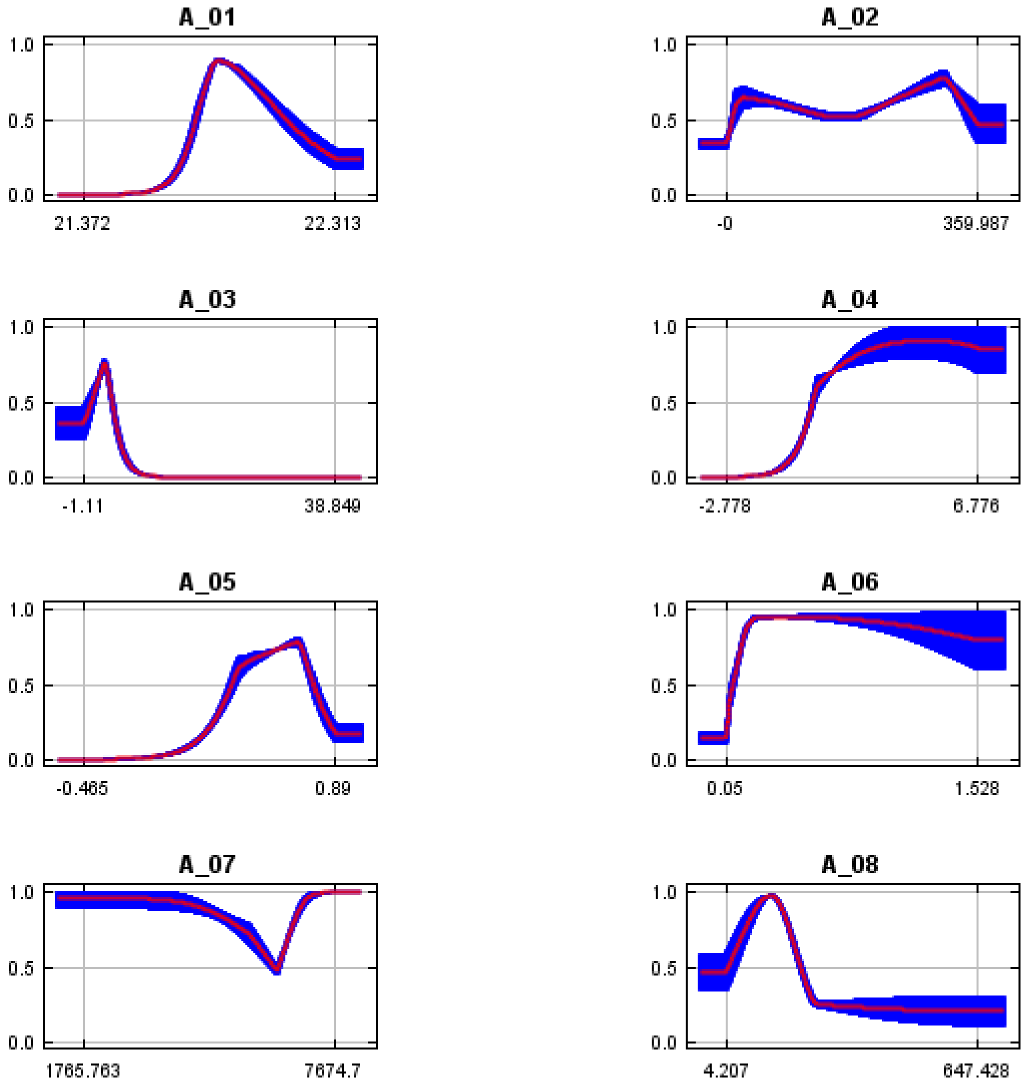
G.7 Mile-A-Minute



G.8 Broadleaved Pepper Tree

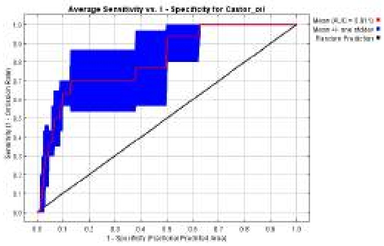


G.9 Sesbania Pea

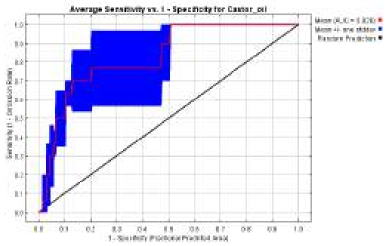


Annex H Monthly ROC

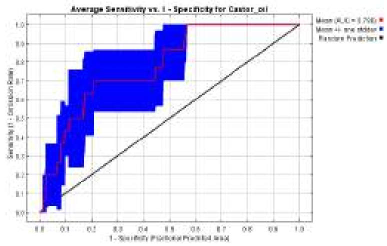
H.1 Castor Oil



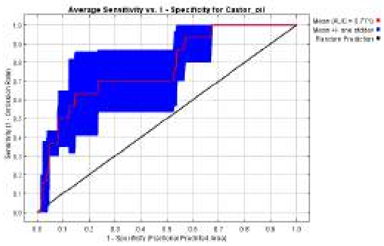
1



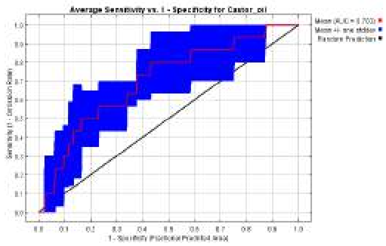
2



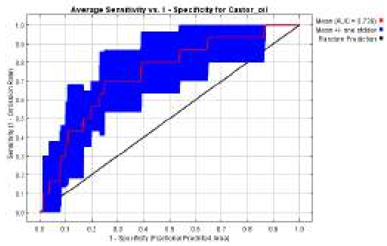
3



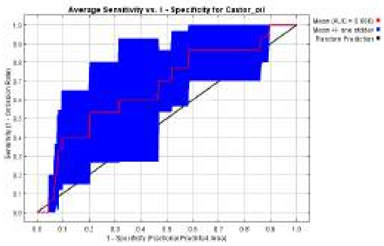
4



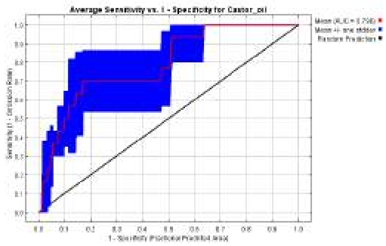
5



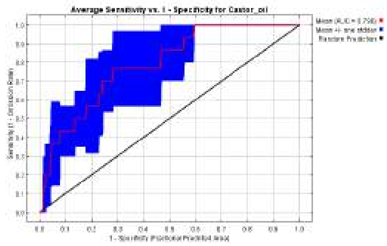
6



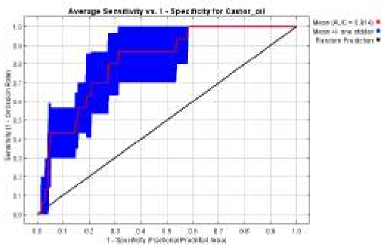
7



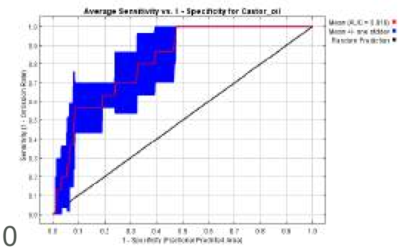
8



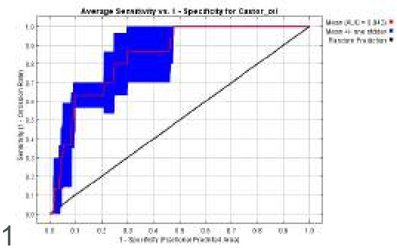
9



10

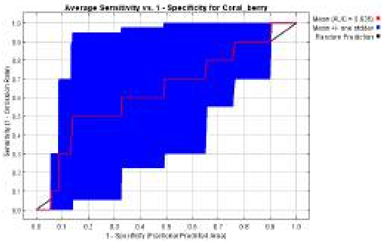


11

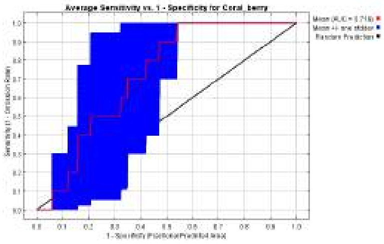


12

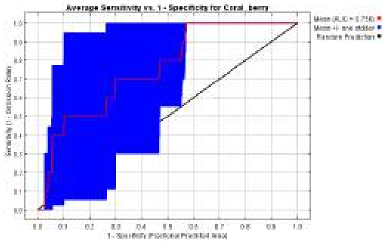
H.2 Coral Berry



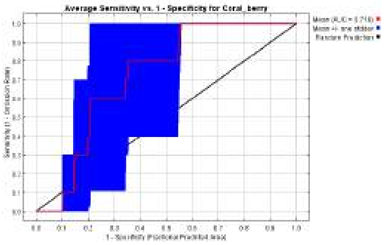
1



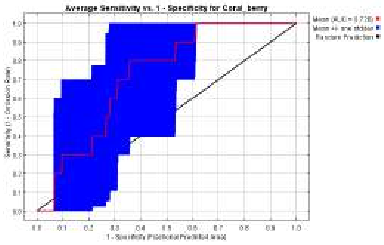
2



3

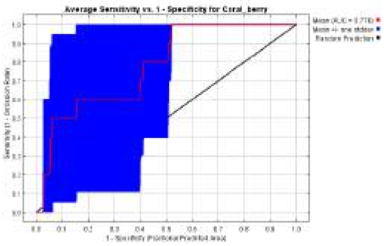


4

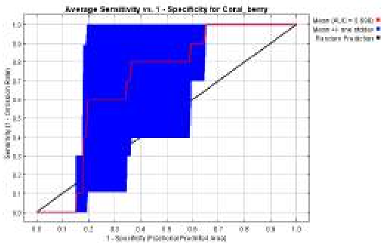


5

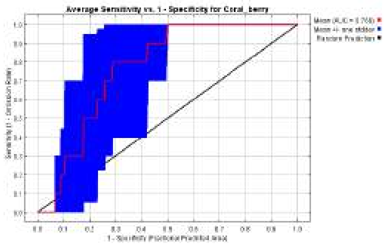
6



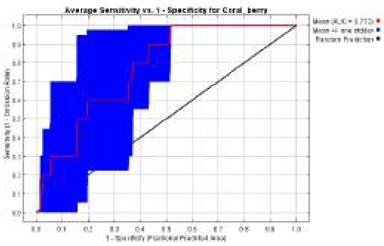
7



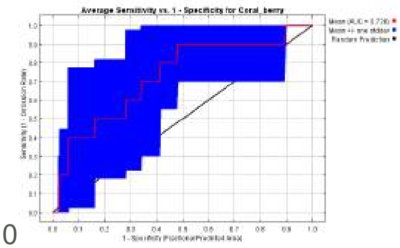
8



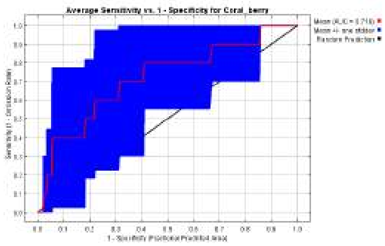
9



10

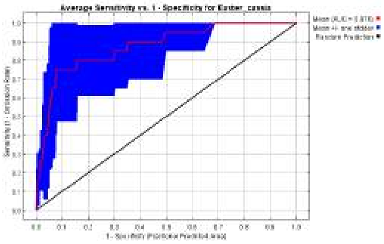


11

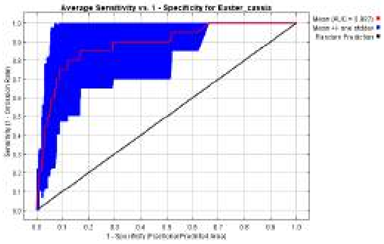


12

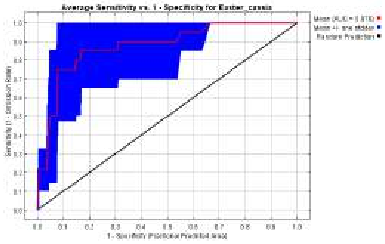
H.3 Easter Cassia



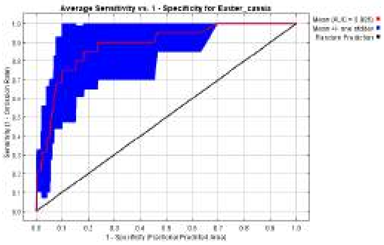
1



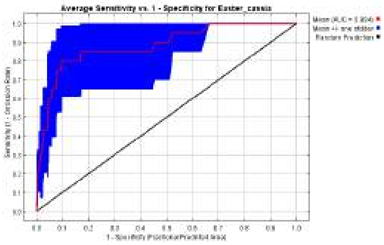
2



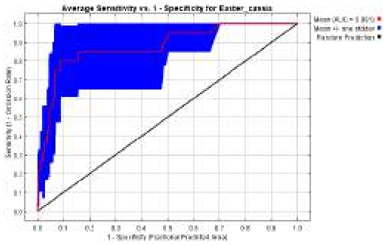
3



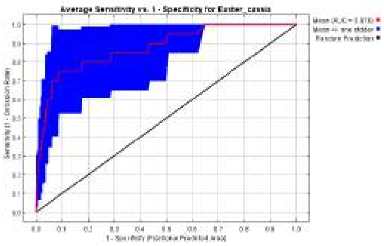
4



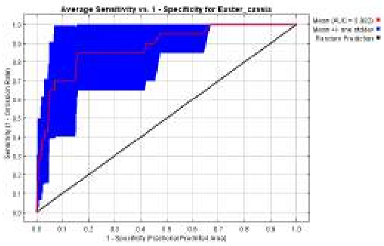
5



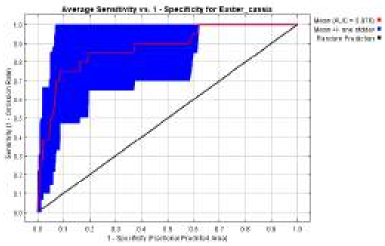
6



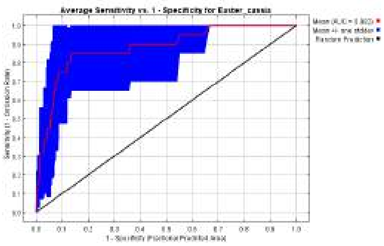
7



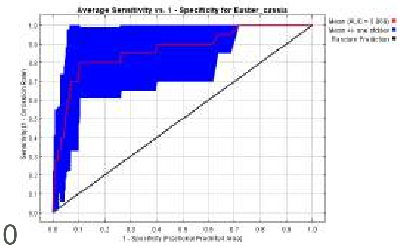
8



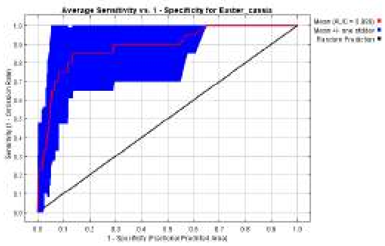
9



10

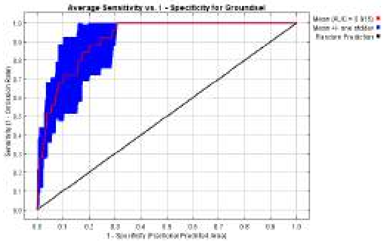


11

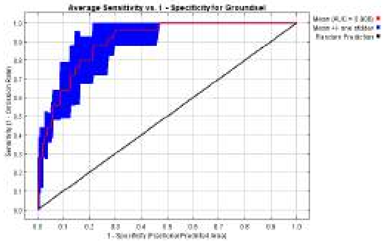


12

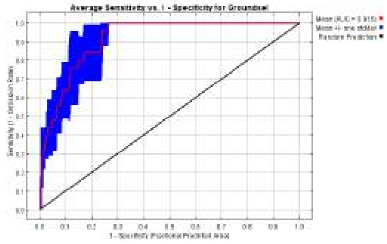
H.4 Groundsel Bush



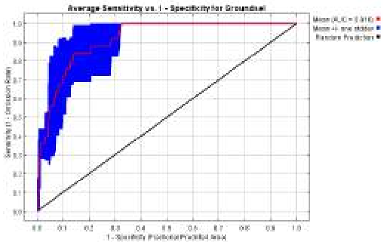
1



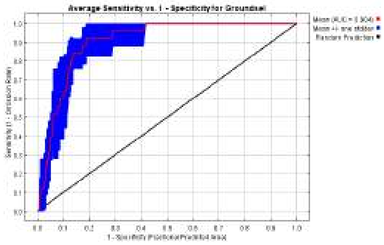
2



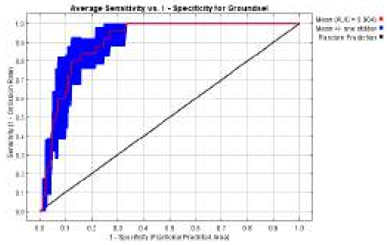
3



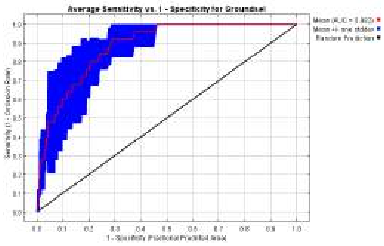
4



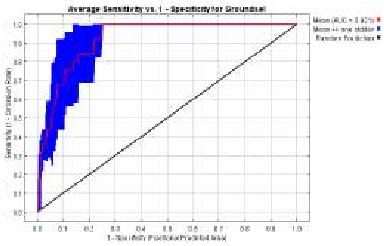
5



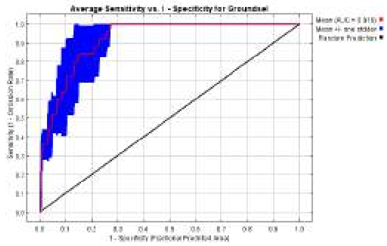
6



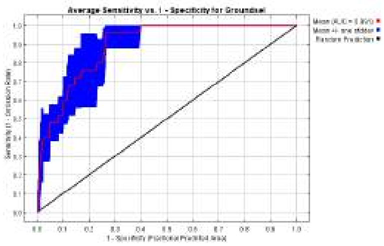
7



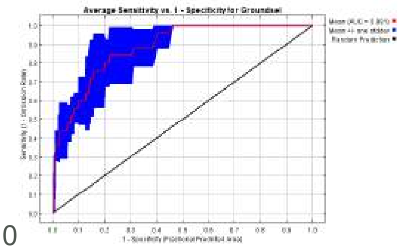
8



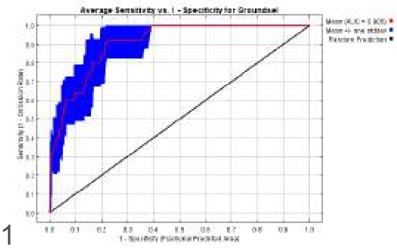
9



10

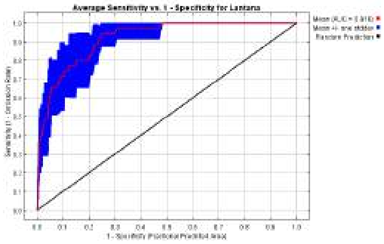


11

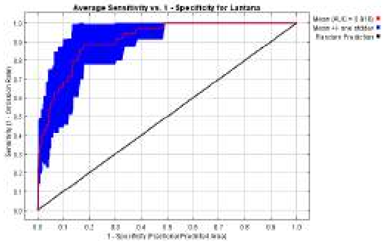


12

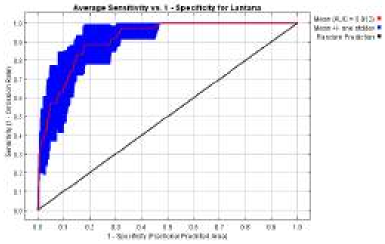
H.5 Lantana



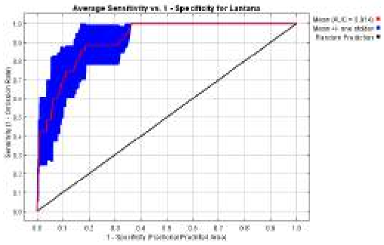
1



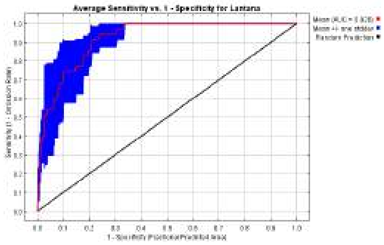
2



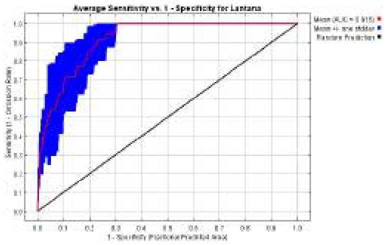
3



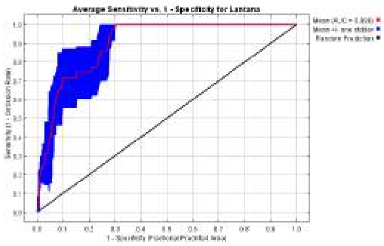
4



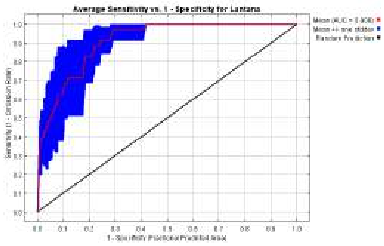
5



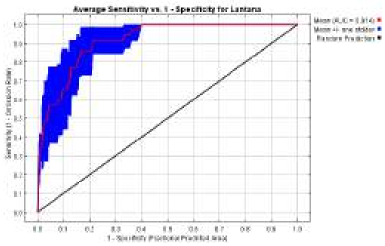
6



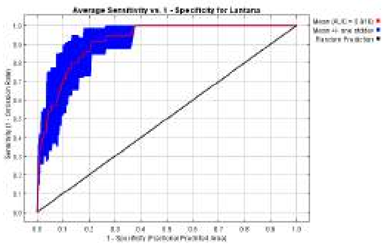
7



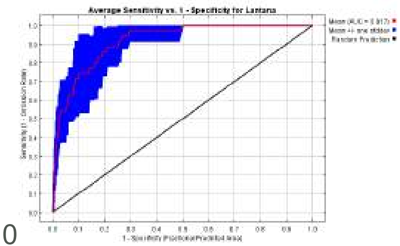
8



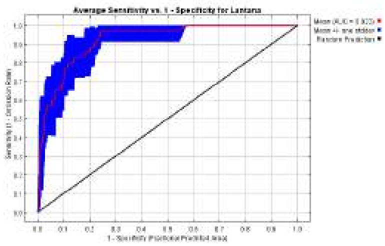
9



10

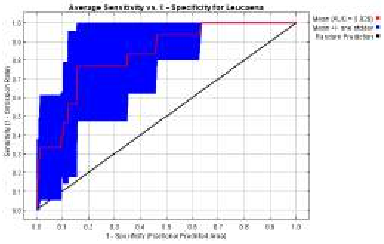


11

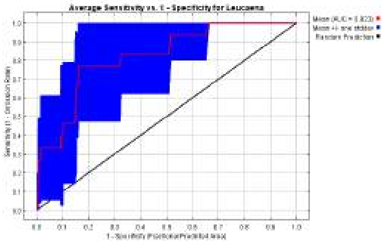


12

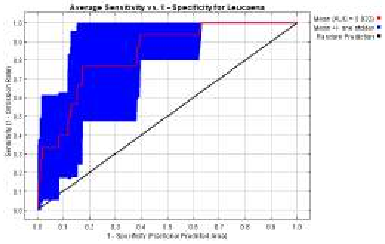
H.6 Leucaena



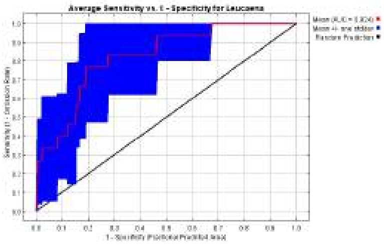
1



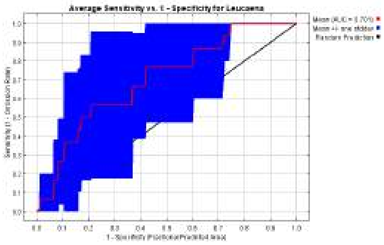
2



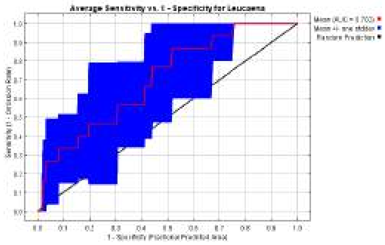
3



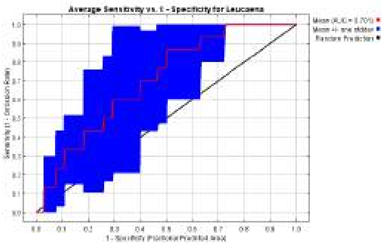
4



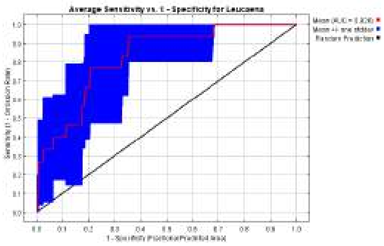
5



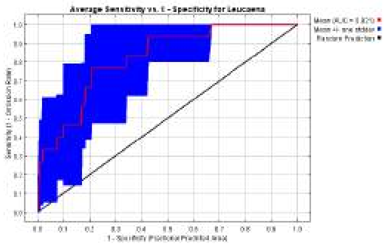
6



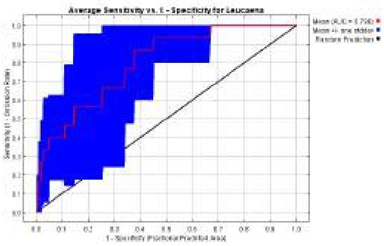
7



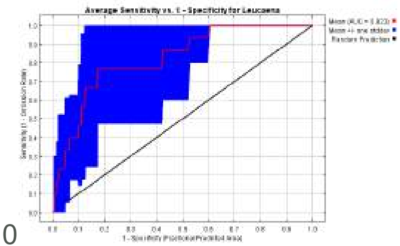
8



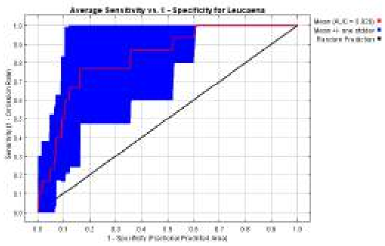
9



10

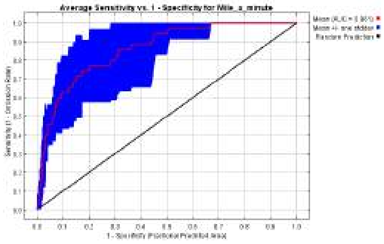


11

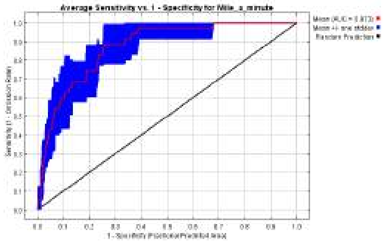


12

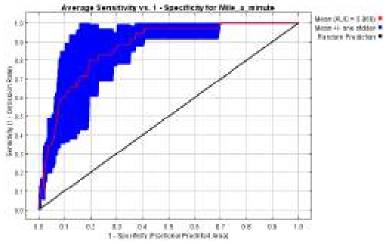
H.7 Mile-A-Minute



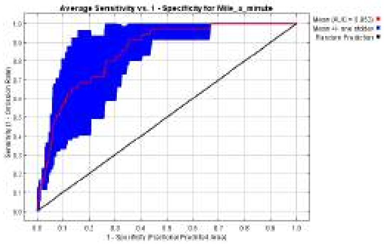
1



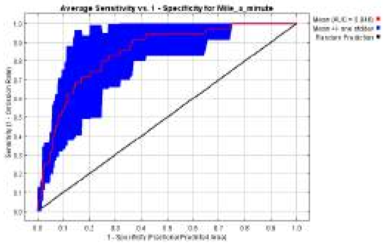
2



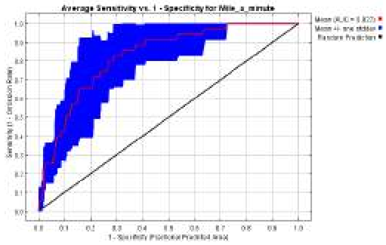
3



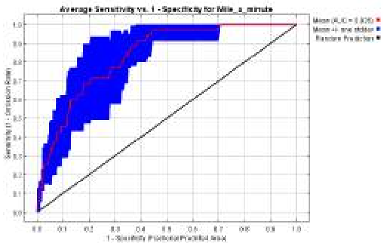
4



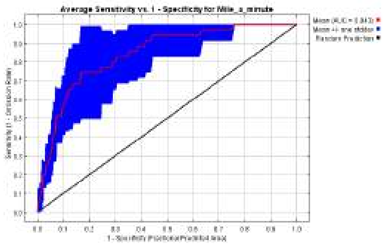
5



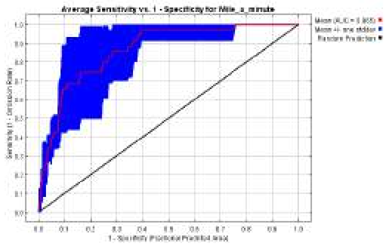
6



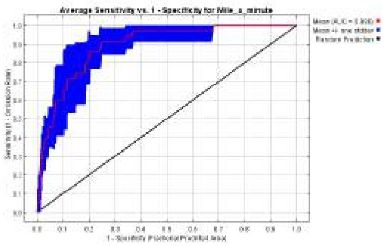
7



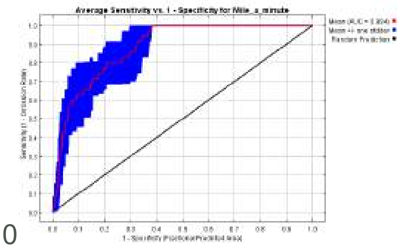
8



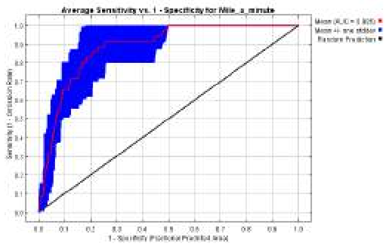
9



10

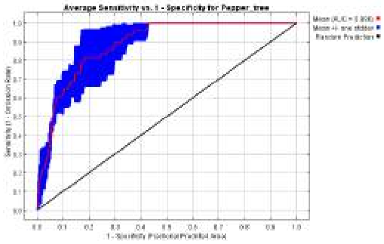


11

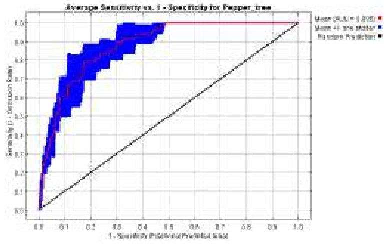


12

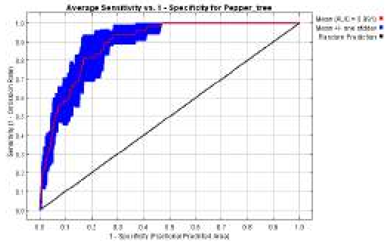
H.8 Broadleaved Pepper Tree



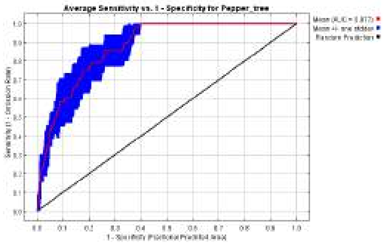
1



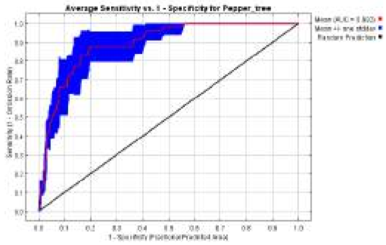
2



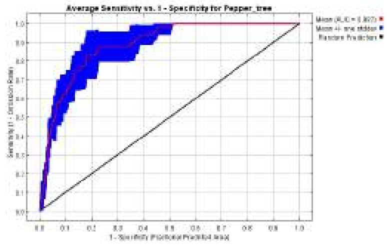
3



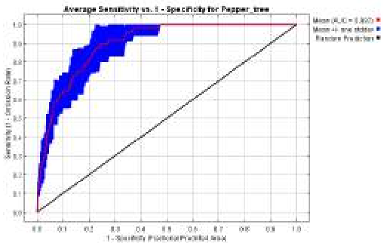
4



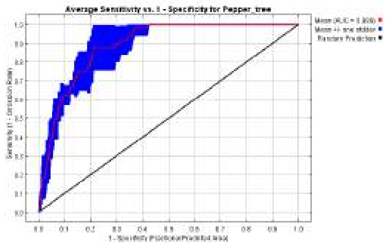
5



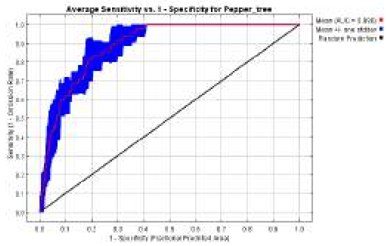
6



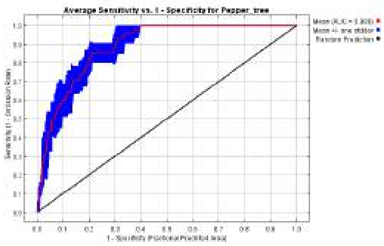
7



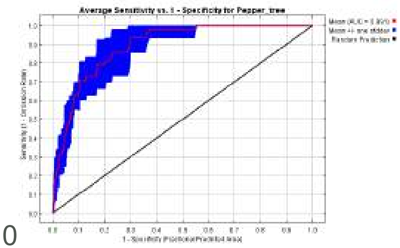
8



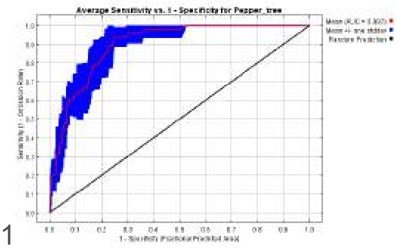
9



10

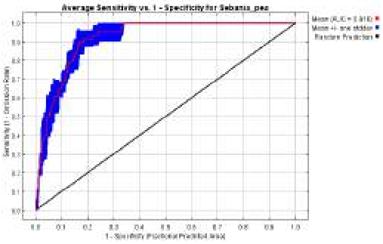


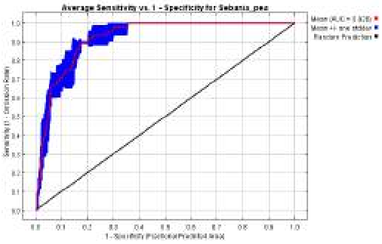
11

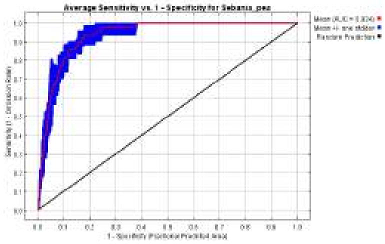


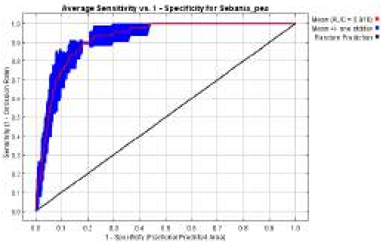
12

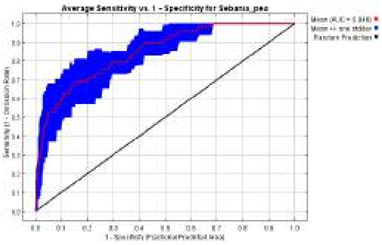
H.9 Sesbania Pea

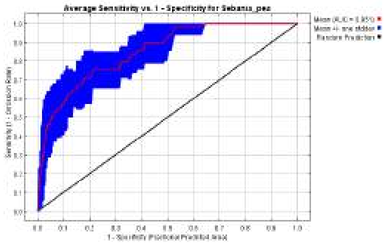

1

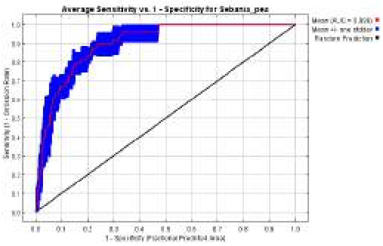

2

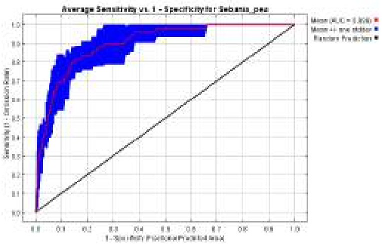

3

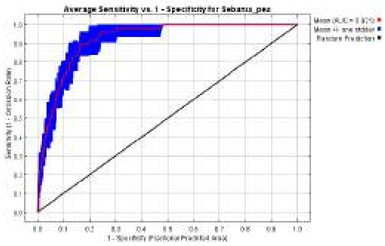

4

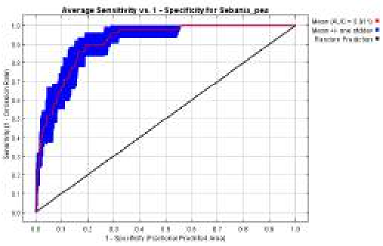

5

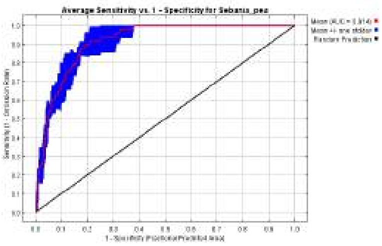

6

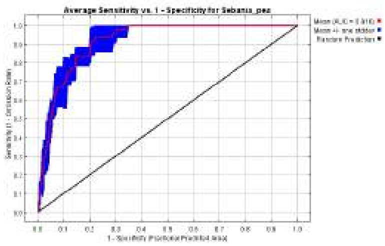

7


8


9

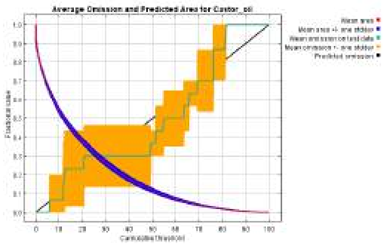

10


11

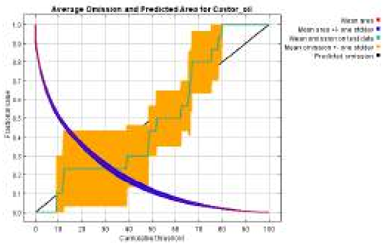

12

Annex I Monthly Omission

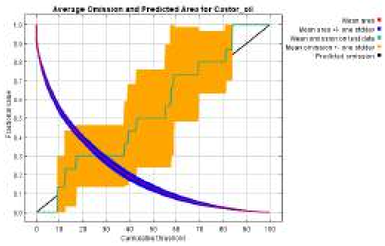
I.1 Castor Oil



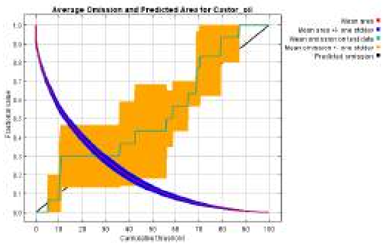
1



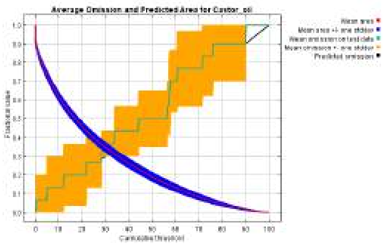
2



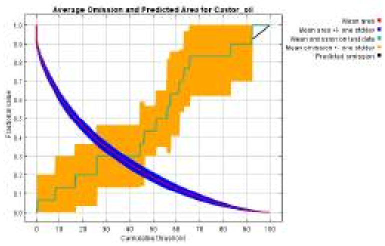
3



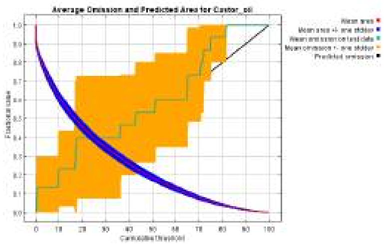
4



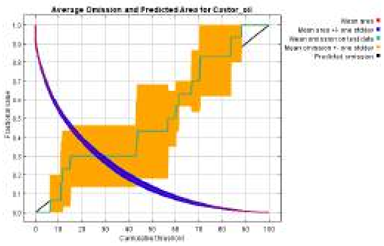
5



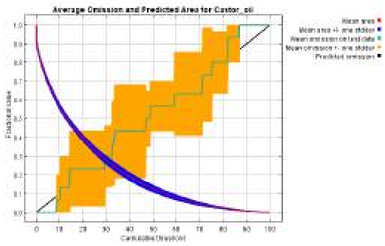
6



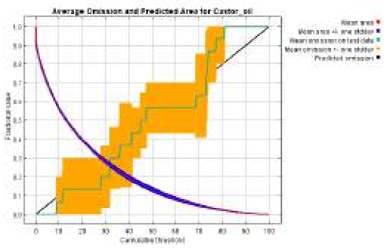
7



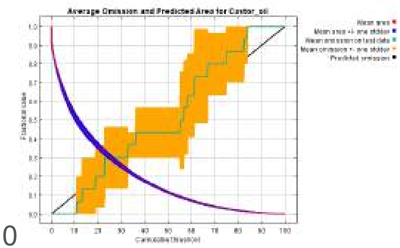
8



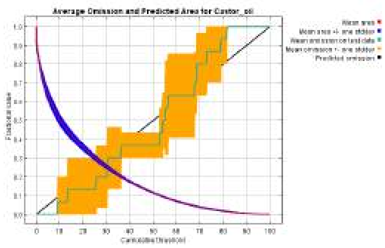
9



10

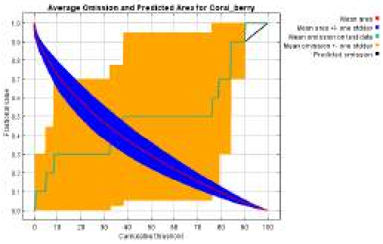


11

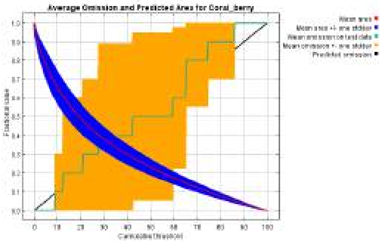


12

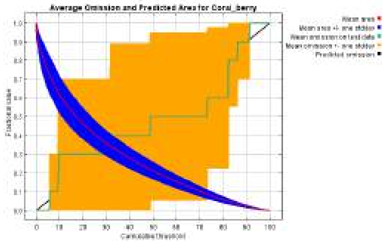
I.2 Coral Berry



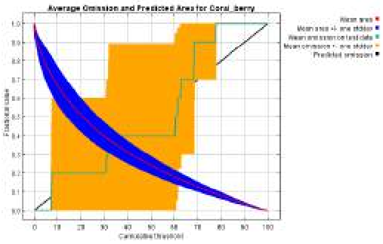
1



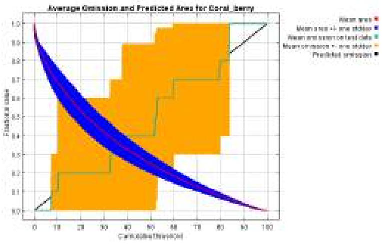
2



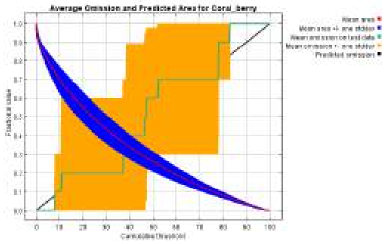
3



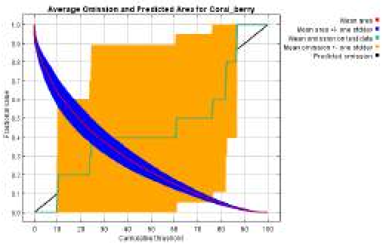
4



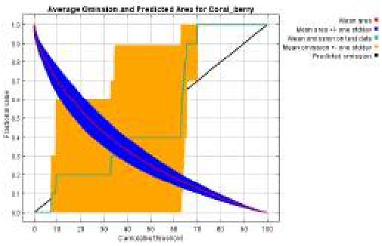
5



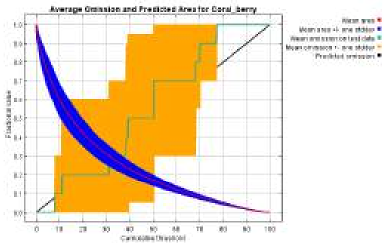
6



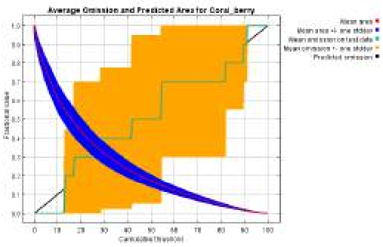
7



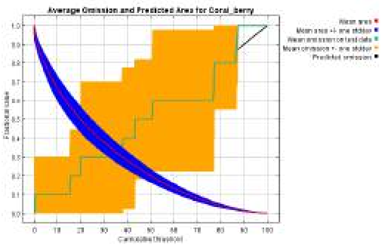
8



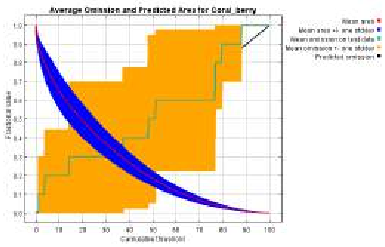
9



10

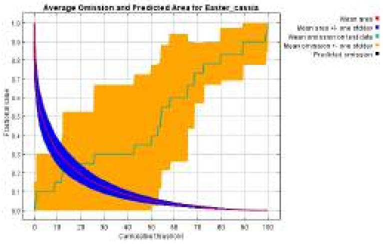


11

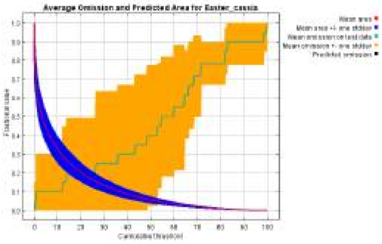


12

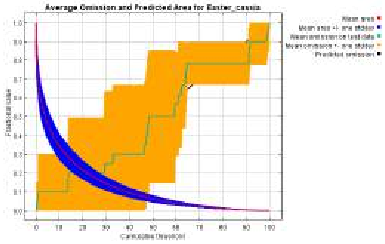
I.3 Easter Cassia



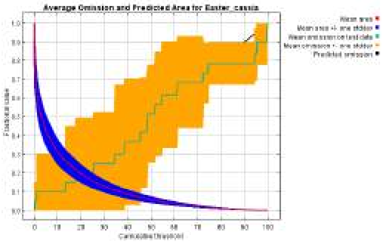
1



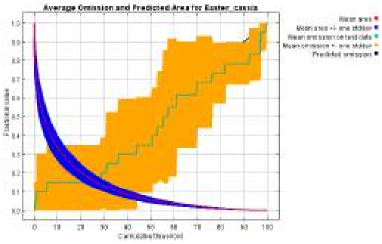
2



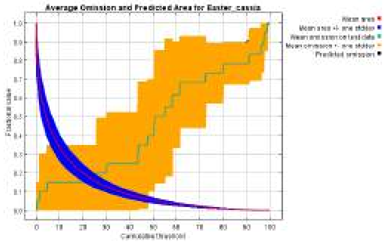
3



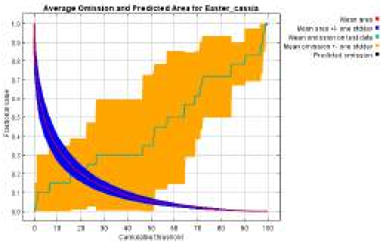
4



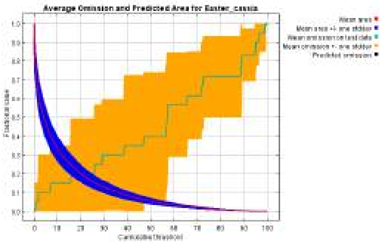
5



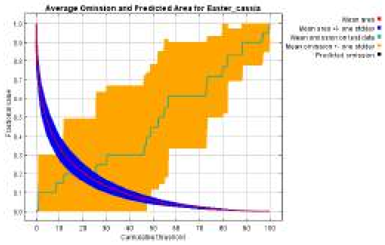
6



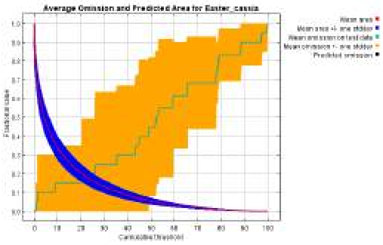
7



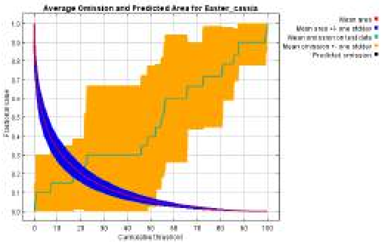
8



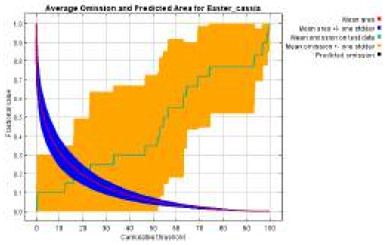
9



10

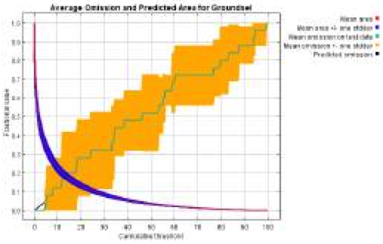


11

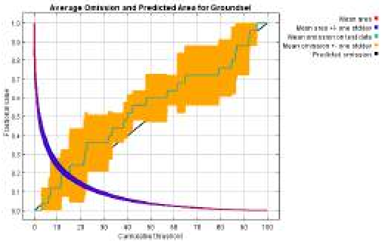


12

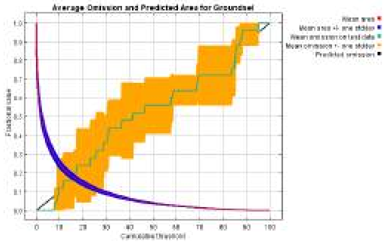
I.4 Groundsel Bush



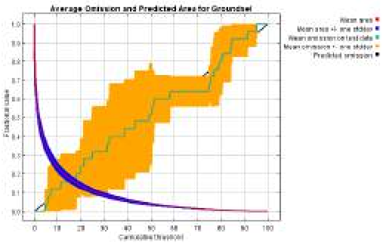
1



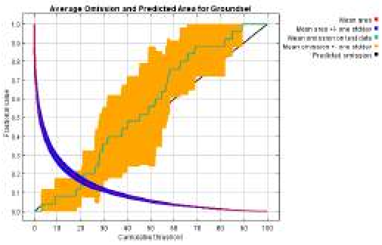
2



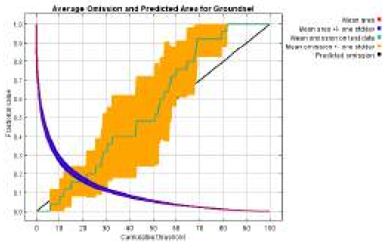
3



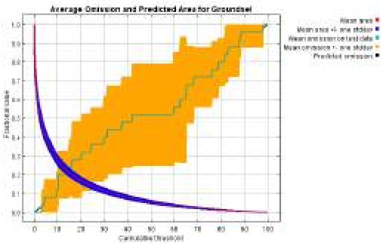
4



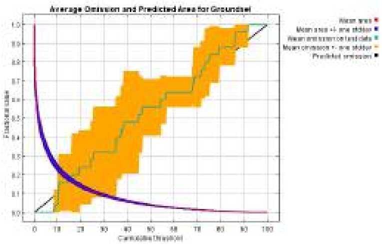
5



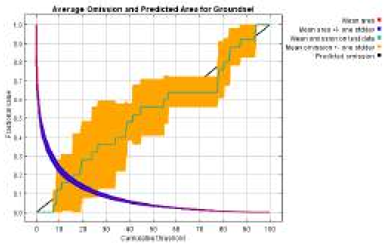
6



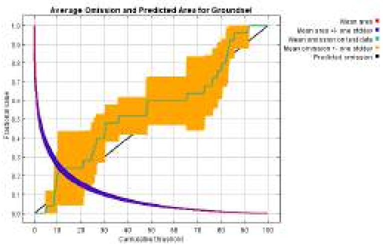
7



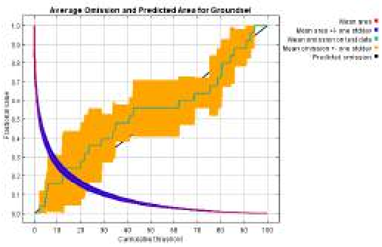
8



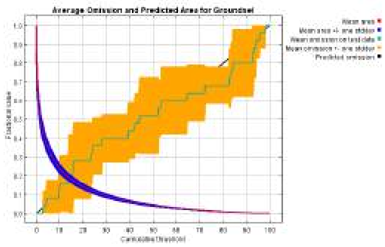
9



10

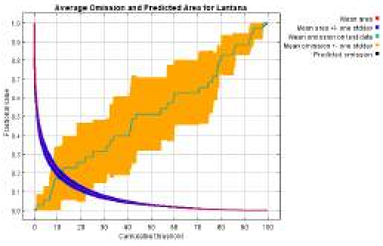


11

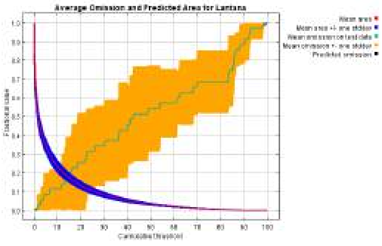


12

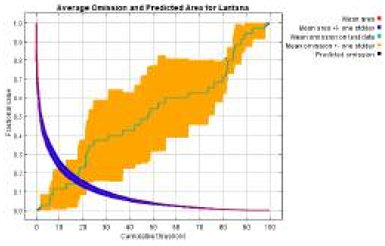
I.5 Lantana



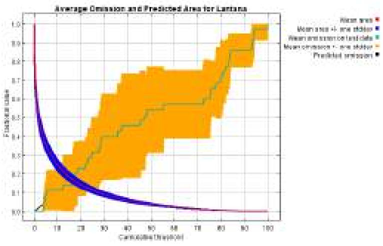
1



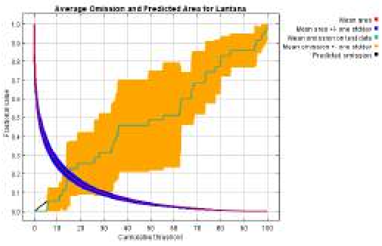
2



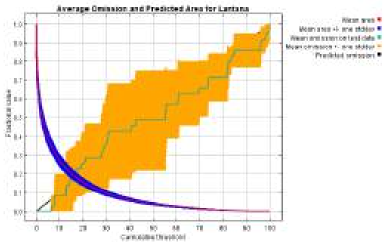
3



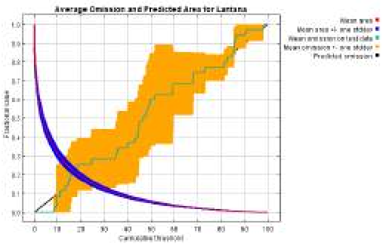
4



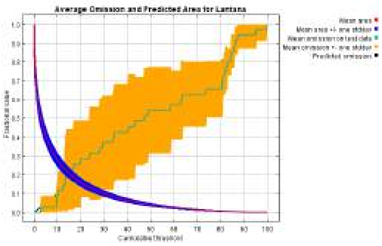
5



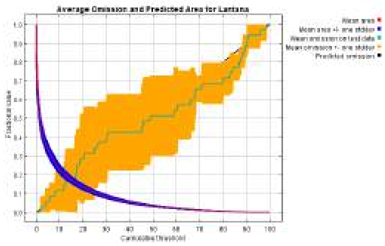
6



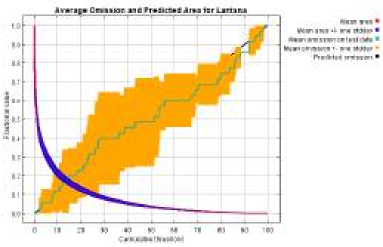
7



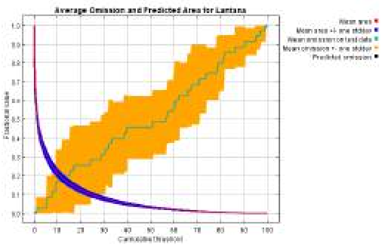
8



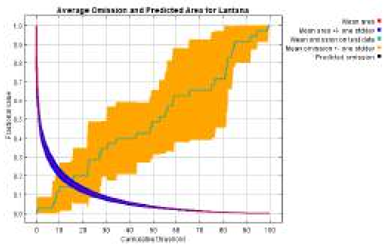
9



10

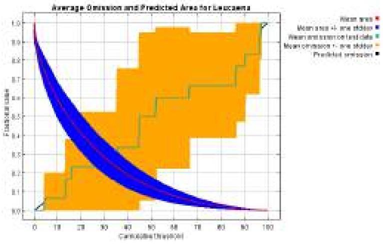


11

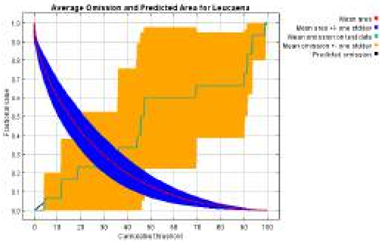


12

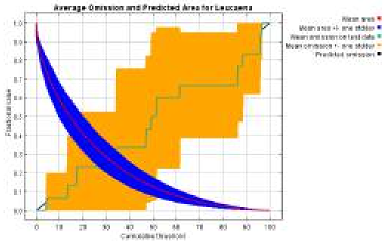
I.6 Leucaena



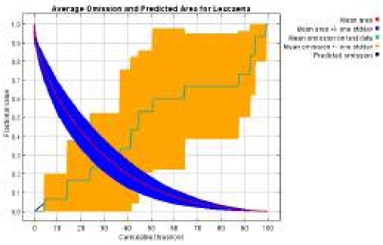
1



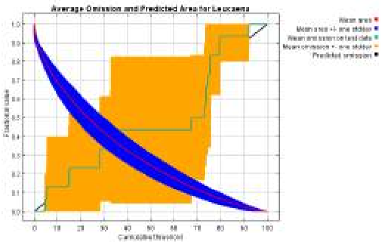
2



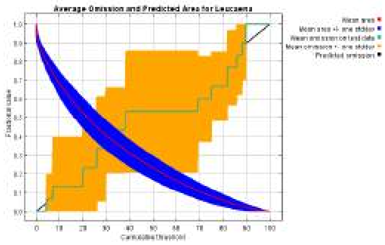
3



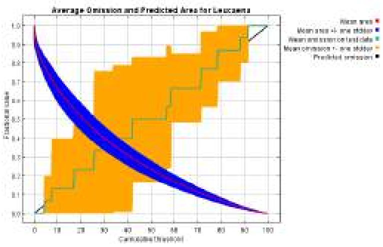
4



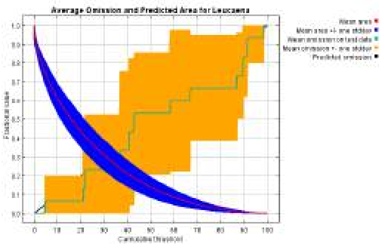
5



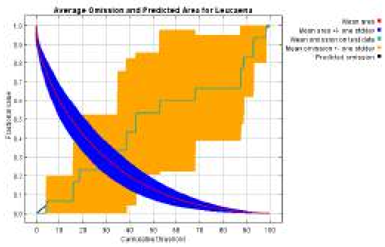
6



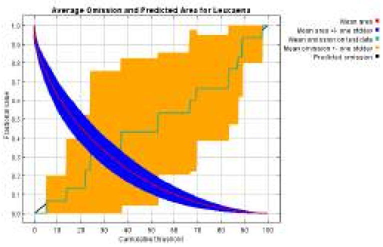
7



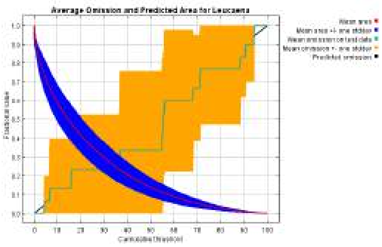
8



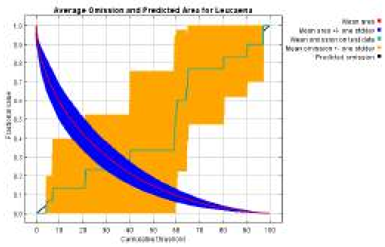
9



10

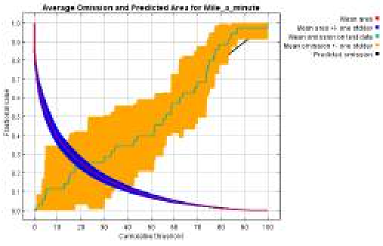


11

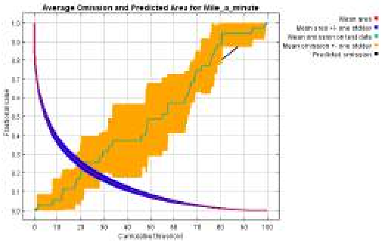


12

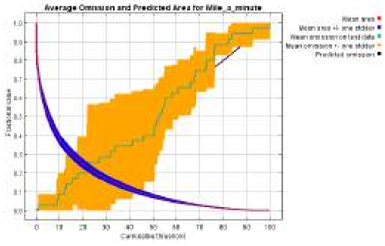
I.7 Mile-A-Minute



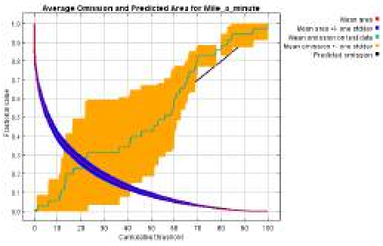
1



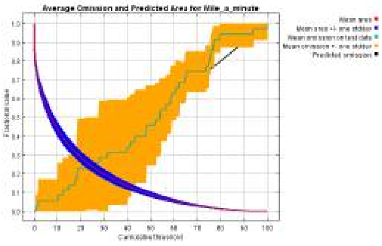
2



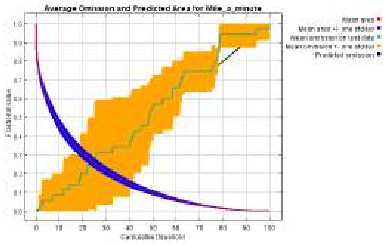
3



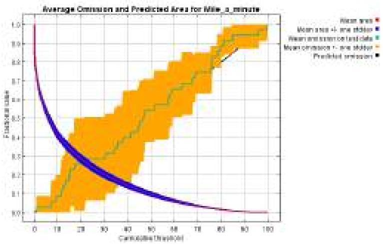
4



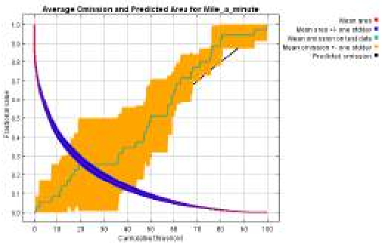
5



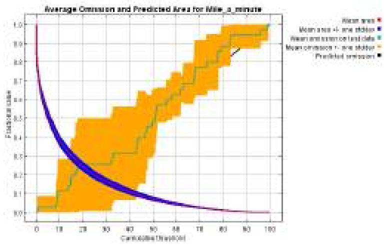
6



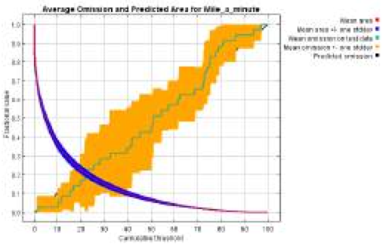
7



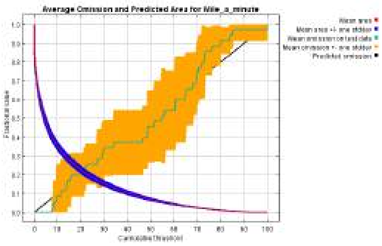
8



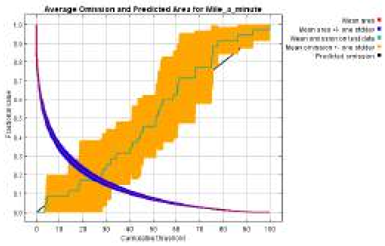
9



10

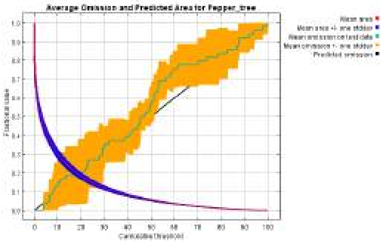


11

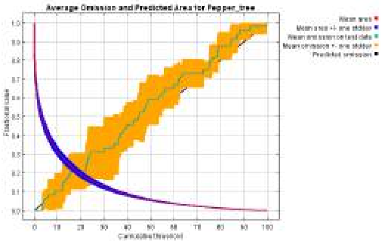


12

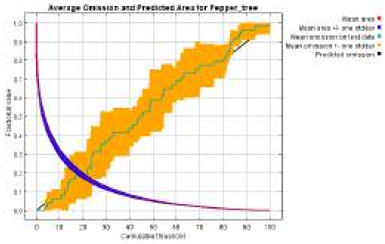
I.8 Broadleaved Pepper Tree



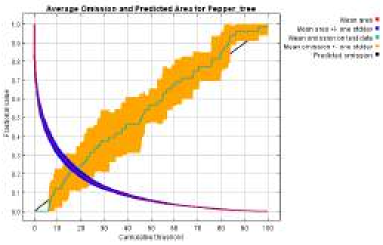
1



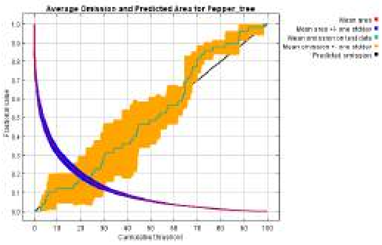
2



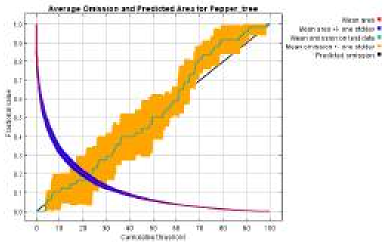
3



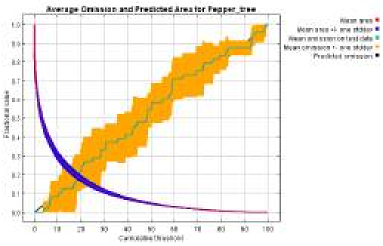
4



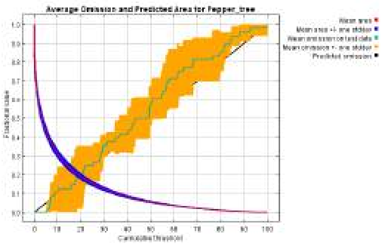
5



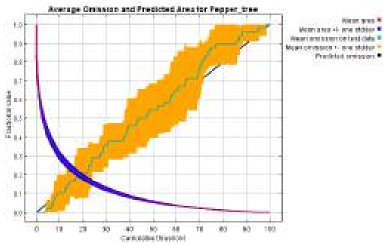
6



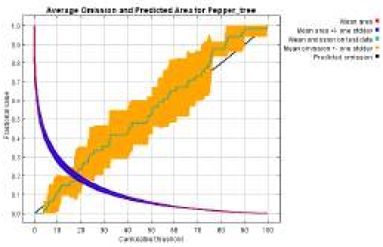
7



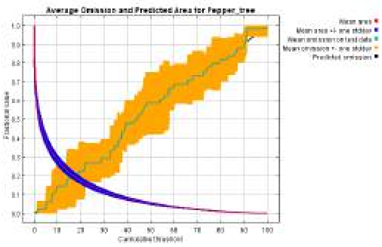
8



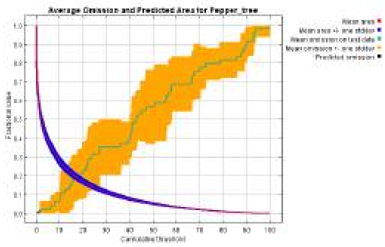
9



10

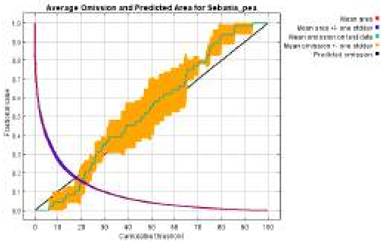


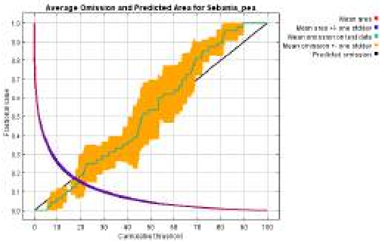
11

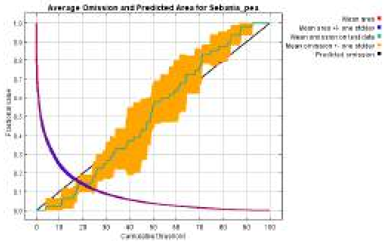


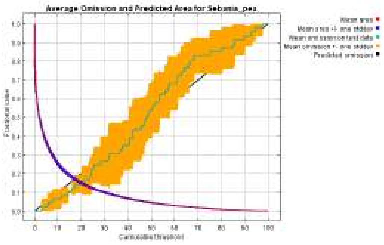
12

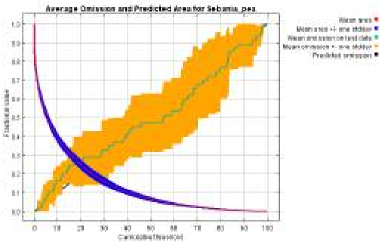
I.9 Sesbania Pea

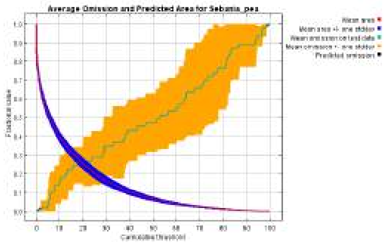

1

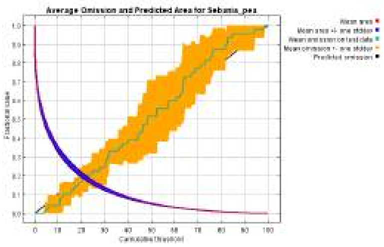

2

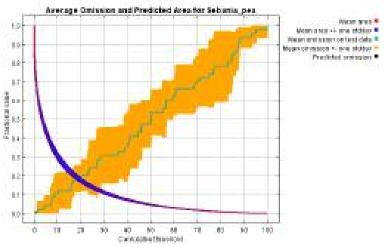

3

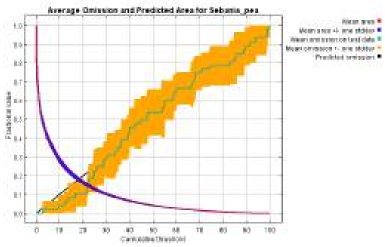

4

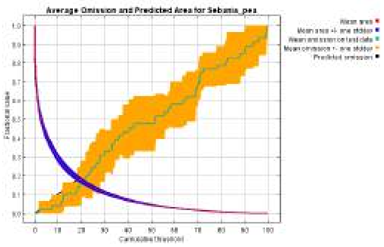

5

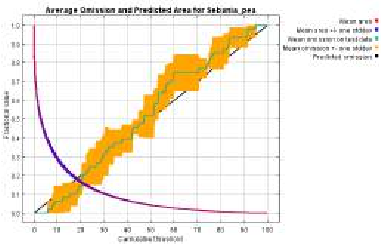

6

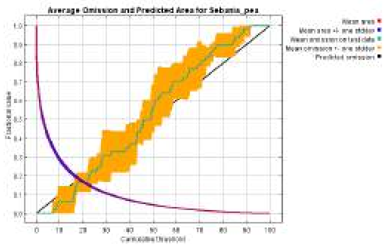

7


8


9


10


11


12