

# ACACIA CORUSCA SPECIES DISTRIBUTION MODELLING

PREPARED FOR: BHP WAIO



**Spectrum**  
ECOLOGY & SPATIAL



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Report Details			
Project Description:	Acacia corusca Species Distribution Modelling		
Prepared For:	BHP WAIO		
Project ID:	2066		
Version History	Author	Reviewer	Date of Issue
Version A	Maria Ines Pereda	Chris Parker	30-08-2021
Version B	Maria Ines Pereda	Chris Parker	31-08-2021
Version C	Jared Leigh	Jared Leigh	23-09-2021
Version D	Gabrielle Beca Maria Ines Pereda	Chris Parker	6-10-2021
Version E	Maria Ines Pereda	Chris Parker	22-11-2021
Version F	Chris Parker	Melissa Hay	16-12-2021
Version 1	Chris Parker	Melissa Hay	20-01-2022

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## Executive Summary

*Acacia corusca* was described as a new species in 2019 and is listed as Priority One under the Conservation Codes for Western Australia Flora by the Department of Biodiversity Conservation and Attractions (Smith & Jones, 2018). It occurs in the southeast Pilbara bioregion of Western Australia and has been recorded on BHP Western Australian Iron Ore (BHP WAIO) tenements. In 2015, Onshore Environmental Consultants (Onshore Environmental) conducted species distribution mapping using the Atlas of Living Australia online 'Prediction' tool to identify potentially suitable *Acacia corusca* habitat. Follow up on-ground surveys were conducted based on the mapping results; however, no new specimens were recorded in identified target areas. Many areas were also not accessible by vehicle. BHP WAIO has requested that Spectrum Ecology and Spatial (Spectrum) perform a desktop assessment to clarify the potential distribution of *Acacia corusca* over areas not previously surveyed within the Study Area.

Spectrum Ecology performed Species Distribution Modelling (SDM) based on existing *Acacia corusca* locations provided by BHP WAIO and sourced from the Herbarium of Western Australia. Due to the clustered nature of records, they were filtered during the analysis to avoid spatial dependencies where possible that would bias the model's results. Twenty-five environmental variables were chosen according to the species abiotic and biotic interactions with its environment. These included landscape and soil attributes, vegetation indices, and GIS generated predictors from categorical variables of geological attributes. Modelling was implemented using maximum entropy algorithms within the MAXENT software with parameters selected for best results as per peer-reviewed literature.

The results of this analysis suggested that *Acacia corusca* occurs in close proximity to the Boolgeeda Iron Formation (<12 km). Environmental variables which represent drainage, eroded and exposed materials, slopes and ridges (MrVBF and Slope Relief Classification) were also important in representing the species' preference to drainage, eroded materials, slopes, and ridges. These results support the hypothesis suggested by Onshore Environmental that *Acacia corusca* is highly specific to Banded Iron Formations (BIF) of the Hamersley Range. For this reason, the species presents a small and limited distribution to the junction of these geological attributes. The current analysis assessed the probability of occurrence of *Acacia corusca* at previously identified target sites and proposes eight new target areas, including 50 target sites in areas of potentially suitable habitat on BHP tenure and where no current tenure exists. An additional 24 target sites have been identified on tenure held by other operators. These sites should be targeted once other options are exhausted, as access is depended on external parties.

# 1. PROJECT INFORMATION

## 1.1. Project Background

*Acacia corusca* was described as a new species in 2019 and is listed as Priority One under the Conservation Codes for Western Australia Flora by the Department of Biodiversity Conservation and Attractions (Smith & Jones, 2018). It occurs in the southeast Pilbara bioregion of Western Australia (Map 1.1) and has been recorded on BHP Western Australian Iron Ore (BHP WAIO tenements. In 2015, Onshore Environmental conducted species distribution mapping using the Atlas of Living Australia's online 'Prediction' tool (Atlas of Living Australia, 2015) to identify potentially suitable *Acacia corusca* habitat. An on-ground survey was also conducted based on the modelling results; however, access issues at the time prevented many areas from being surveyed.

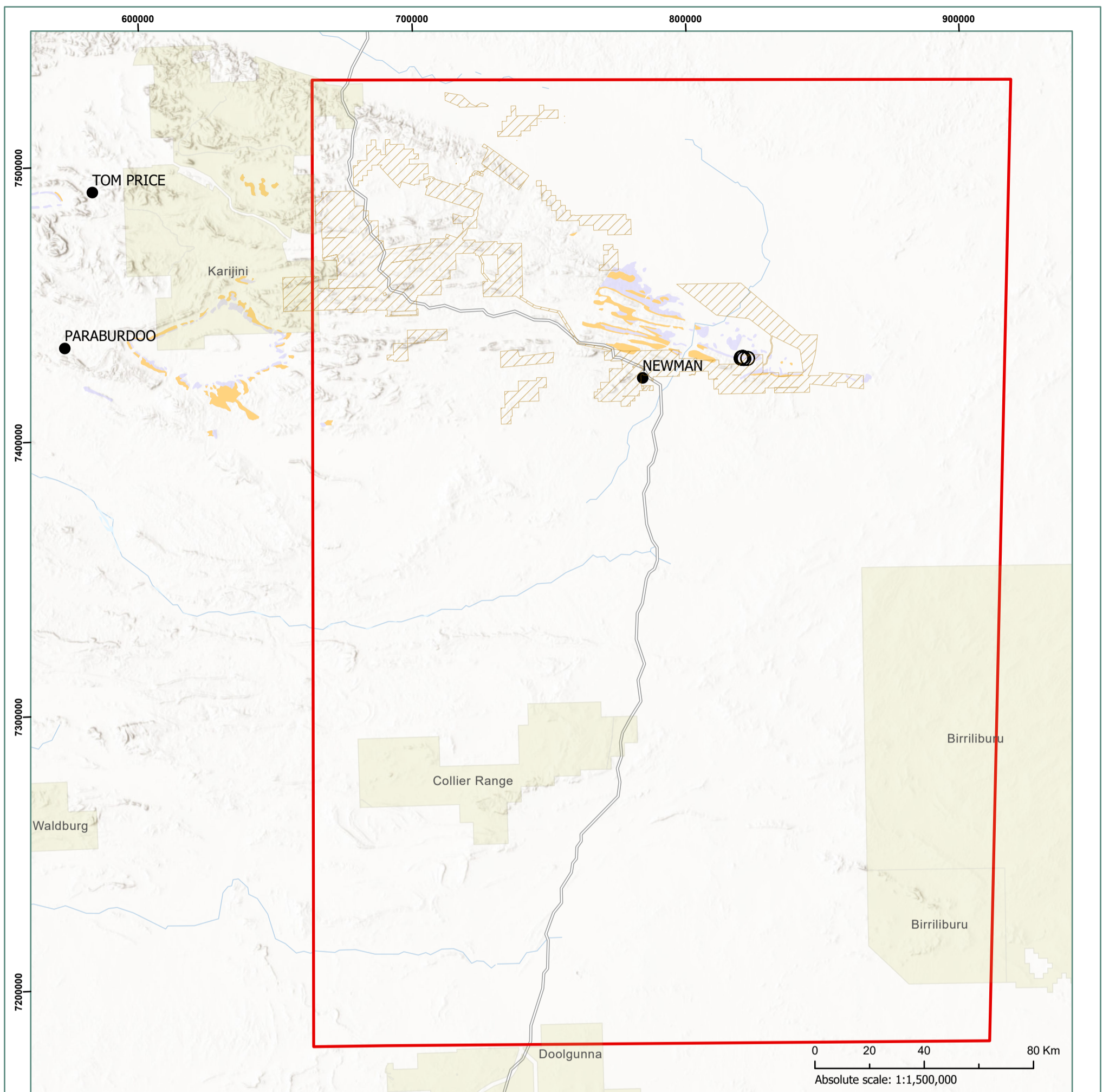
## 1.2. Scope of Work

BHP WAIO has requested a desktop assessment to clarify the potential distribution of *Acacia corusca* within the Pilbara region, with particular attention to existing target areas that were inaccessible during previous surveys. The extent of this desktop assessment totals 88,000 km<sup>2</sup> in the eastern Pilbara (the Study Area, Map 1.1) and encompasses previous target areas, as well as potential regional habitat. Within the Study Area, the purpose of this study was to:

- Complete a comprehensive desktop review of previous records of *Acacia corusca*, as well as preferred habitat descriptions and likely occurrence of this habitat in the Eastern Pilbara.
- Identify the likely of occurrence for *Acacia corusca* in the Study Area from previous records and Species Distribution Modelling (SDM) techniques.
- Review of previous survey target areas and effort, and areas that have not been adequately surveyed.

This report has been prepared with the following in consideration:

- EPA (2018) Statement of Environmental Principles, Factors and Objectives.
- EPA (2016) Environmental Factor Guideline: Flora and Vegetation.
- EPA (2016) Technical Guidance – Flora and Vegetation Surveys for Environmental Impact Assessment.
- Latest version of BHP WAIO's Biological Survey Spatial Data Requirements (SPR-IEN-EMS-015).
- Latest version of BHP WAIO's Vegetation and Flora Survey Procedure (0124627).
- Existing flora and vegetation survey data available for the Study Area.



**Legend**

- BHP *Acacia corusca* Records
- ▭ Study Area
- Woongarra Rhyolite
- Boolgeeda Iron Formation
- ▨ BHP tenements

***Acacia corusca* Records and Study Area**

Drawn: M.I. Pereda  
Date: 2021-12-16



**MAP 1.1**

Spatial Reference  
Name: GDA 1994 MGA Zone 51  
Datum: GDA 1994  
Projection: Transverse Mercator

## 2. METHODS

### 2.1. Significant Flora Definitions

Significant flora can include (Environmental Protection Authority, 2016):

- Being identified as Threatened: Critically Endangered, Endangered, or Vulnerable (state listed Biodiversity conservation - BC Act and/or nationally listed Environment Protection and Biodiversity Conservation - EPBC Act);
- Locally endemic or associated with a restricted habitat type (e.g. surface water or groundwater dependent ecosystems);
- New species or anomalous features that indicate a potential new species;
- Representative of the range of a species (particularly, at the extremes of range, recently discovered range extensions, or isolated outliers of the main range);
- Unusual species, including restricted subspecies, varieties or naturally occurring hybrids; or
- Relictual status, being representative of taxonomic groups that no longer occur widely in the broader landscape.

### 2.2. Desktop Assessment

#### 2.2.1. Biological Database Searches

Database searches of relevant and available biological data sources that may yield records of *Acacia corusca* within the Study Area are presented in Table 2.1 and Map 1.1.

Table 2.1: Database Searches

Data Source	Custodian	Details	Records Returned
DBCA Threatened & Priority Flora Databases (TPFL / WA Herbarium)	DBCA	Within the Study Area envelope Reference: 48-0721FL	12 (although not unique to records held by BHP WAIO)
BHP WAIO Species Database	BHP WAIO	Within the Study Area envelope	95

### 2.3. Species Distribution Modelling

Species distribute in space and time according to their; dispersal capabilities, ecophysiology needs, and the interaction with other species (Guisan et al., 2017). SDMs look to predict the locations of a species, associating known records (presences) to a set of environmental predictor variables that might help to describe any abiotic and biotic interactions. The relationship between known presences and environmental predictors are statistically compared using a wide arrange of mathematical techniques (Zurell et al., 2020). Some mathematical models require presence and known absence locations, whereas others require presence and randomly generated background points. Some models may also only require presence data, in order to expand the opportunities to model understudied or rare species. Amongst the presence background mathematical models available, maximum entropy algorithms using MaxEnt is one of the most popular methods amongst the peer-reviewed literature (Elith et al., 2011). Spectrum has also addressed possible SDM limitations and improved the model's predictability by utilising additional environmental variables as model inputs within the advanced MaxEnt (Maximum Entropy), which allows full control over the model's input parameters.

The distribution of *Acacia corusca* was predicted using an occurrence based (presence-background) SDM approach (Bull et al., 2019). The SDM extent covered a rectangular area of 88,000 km<sup>2</sup>, encompassing the

known records and extending over the inaccessible areas of interest identified by Onshore Environmental during the Phase 2 and Phase 3 targeted surveys (Map 1.1, Onshore Environmental Consultants, 2015).

### 2.3.1. Species Data & Environmental Variables

SDM predict species probable locations from known “presences” and randomly generated set of locations to account for sites where the species is not present (“pseudo-absences”). Existing *Acacia corusca* locations provided by BHP WAIO and sourced from the Herbarium of Western Australia were used as occurrence records to train the model. To avoid errors from spatially dependent records, presence data was filtered by sampling method, using locations sampled from: transects, relevés and opportunistic encounters. This process helped built a presence dataset based only on data with accurate locations per specimen. Pseudo-absences were created randomly across the Study Area avoiding overlapping sites with known presences. To account for sampling bias and spatial autocorrelation, sampling intensity across the Study Area was represented as a separate variable. To achieve this, a bias layer was constructed from occurrence points of all species using a two-dimensional Kernel Density estimate in ArcGIS (Fourcade et al., 2014; Phillips & Dudík, 2008).

Twenty-five environmental predictor variables, that represent the habitat preferences of *Acacia corusca*, were obtained to predict the potential occurrence within the Study Area (Table 2.2). These variables were selected in accordance with the species ecophysiological requirements related to abiotic landscape and soil characteristics, especially targeting slopes, ridges and the relationship to the Boolgeeda Iron Formation. CSIRO’s soil and landscape grids were chosen focusing on: slope, ridges and valleys, soil composition, and a Digital Elevation Model (DEM) obtained from the USGS Earth Explorer service (Grundy et al., 2015; O’Brien & Searie, 2021). The Multi-resolution Valley Bottom Flatness (MrVBF) index and Slope Relief Classification were chosen as the variable to represent the species preference to valleys, drainage lines and asses the relationship with slopes of the ridges (Gallant & Dowling, 2003). Mean temperature and rainfall bioclimatic variables were retrieved from WorldClim database to represent the species preference to areas with increased soil moisture and water availability.

Two vegetation indices were calculated from May 2021 Landsat 8 level 2 satellite imagery (<https://earthexplorer.usgs.gov/>). The Modified Soil-Adjusted Vegetation Index 2 (MSAVI) and the Normalised Difference Wetness Index (NDWI) represent the greenness and moisture in vegetation (Gao, 1996; Qi et al., 1994; Xue & Su, 2017). A set of categorical variables were used to represent the Study Area’s environment; soil landscape systems (Department of Primary Industries and Regional Development, 2021), vegetation units of Western Australia (Western Australian Government, 2020) and identified soil types (Northcote et al., 1968). To focus on the importance of the Hamersley Ranges Banded Iron Formations, the Euclidean distance to the Boolgeeda BIF was calculated for the Study Area’s extent. All environmental datasets were set at the same resolution provided by CSIRO’s soil and landscape grids at 92 m pixels (Table 2.2). To avoid multicollinearity and select only the most representative variables, two correlation tests were undertaken. In the first test, environmental variables were assessed against each other for all the Study Area. In the second test, correlation amongst predictor variables were assessed only for locations with known records of *Acacia corusca* (Appendix A). Variables with correlation higher than 0.7 in both instances were excluded when performing the SDM (Dormann et al., 2013).

Table 2.2: Environmental Predictor Variables

Environmental Variable	Description	Source	Type	
Landscape Attributes	Slope (%)	Slope measures the inclination of the land surface from the horizontal.	CSIRO	Numeric
	Slope Relief Classification	Soil relief landform pattern classification based on Speight (2009).		Numeric
	Depth of Regolith	Metres of <i>in situ</i> and transported material overlying unweathered bedrock.		Numeric
	Topographic Wetness Index	TWI estimates the relative wetness within moist catchments, but is more commonly used as a measure of position on the slope with larger values indicating a lower slope position.		Numeric
	MrVBF	MrVBF is a topographic index designed to identify areas of deposited material at a range of scales based on the observations that valley bottoms are low and flat relative to their surroundings and that large valley bottoms are flatter than smaller ones. This dataset was classified into five categories based on the Jenks Natural breaks classification.		Categorical
	SRAD Net Radiation July	Mean monthly solar radiation was modelled across Australia using topography from the 1 second resolution SRTM-derived DEM-S and climatic and land surface data.		Numeric
	Digital Elevation Model	Height above sea level.	USGS	Numeric
Soil Attributes	Soil Bulk Density	Bulk density of the whole soil (including coarse fragments) in mass per unit volume.		Numeric
	Soil Clay (%)	Percentage of clay content of the soil at a depth of 0-5 cm.		Numeric
	Soil Organic Carbon	Mass fraction of carbon by weight in the < 2 mm soil material as determined by dry combustion at 900 Celsius.		Numeric
	Soil pH (CaCl <sub>2</sub> )	pH of 1:5 soil/0.01M calcium chloride extract at a depth of 0-5 cm.		Numeric
	Silt	2-20 um mass fraction of the < 2 mm soil material determined using the pipette method.		Numeric
	Soil Sand (%)	Percentage of sand content of the soil at a depth of 0-5 cm.		Numeric
	Soil Depth	Depth of soil (A & B horizons) to 2 m.		Numeric
	Soil Total Phosphorus	Percentage of phosphorus content of the soil at a depth of 0-5 cm.		Numeric
	Soil Total Nitrogen	Mass fraction of total nitrogen in the soil by weight.		Numeric
	Effective Cation Exchange Capacity	Cations extracted using barium chloride (BaCl <sub>2</sub> ) plus exchangeable H + Al.		Numeric
Geology & GIS	Atlas of Australian Soils	Digitalised soil landscapes from Northcote et al. (1960-1968).	Bureau of Rural Sciences	Categorical
	Pre-European Vegetation	Pre-European Vegetation of Western Australia (DPIRD-006) (ID:7).	DPIRD	Categorical
	Land systems	Soil Landscape systems.	DPIRD	Categorical
	Distance to Boolgeeda Iron Formation and Woongarra Rhyolite	Combined Euclidean Distance from the Boolgeeda Iron Formation and Woongarra Rhyolite (Surface Geology from Geoscience Australia) calculated in ArcMap.	Calculated by Spectrum	Numeric
Vegetation Indices	MSAVI	Modified Soil Vegetation Index from Landsat 8 Imagery.	Landsat 8	Numeric
	NDWI	Normalized Wetness Index from Landsat 8 Imagery.	Landsat 8	Numeric
Bioclimatic	Bioclim1	Annual Mean Temperature.	Hijmans 2005	Numeric
	Bioclim12	Annual Precipitation.	Hijmans 2005	Numeric

### 2.3.2. Maximum Entropy Model Parametrization & Validation

The SDM was generated using the software package MaxEnt v.3.4.1 (Phillips et al., 2006). MaxEnt models species distributions to predict the probability of species occurrence based on a set of environmental variables in conjunction with known occurrence records and pseudo-absences (Phillips et al., 2004). Model settings and input parameters were optimised over 26 unique models. Key settings include 10,000 background points, 100 iterations and a threshold rule to maximum test sensitivity plus specificity, presences randomly partitioned into testing (75%) and training (25%) datasets to validate the model independently, and increased regularisation multiplier was from a value from one to three to further reduce model overfitting.

The predictive performance of models was tested by the area under the receiver operating curve (AUC) to the independent testing dataset (Hao et al., 2019; Zurell et al., 2020). AUC is considered as the probability that a presence location has a higher occurrence value than an absence location. Models with AUC values above 0.75 were considered of high performance. Environmental predictor variables were selected or extracted from the models according to the percent contribution and the permutation importance until the best performing model was found.

### 2.3.3. Model Outputs

Model outputs were expressed as two maps showing the probability of occurrence within the Study Area, BHP WAIO tenements, and Targeted Sites. The first map represents the probability of occurrence in 10 ranks of likelihood from 0 to 1. The second map shows the probability of occurrence in three ranks as; "Low" (0.1-0.66), "Medium" (0.66-0.80) and "High" (0.80-1). These ranks were defined using a data driven approach where the threshold of each represents the 95% (medium) and 50% (high) occurrence of known presence records over the predicted model output values.

A review of the existing presence locations was included with further improvements on survey effort locations, if relevant; with particular attention drawn to inaccessible areas as highlighted by Onshore Environmental Consultants (2015).

## 3. RESULTS AND DISCUSSION

### 3.1. Desktop Assessment

#### 3.1.1. Previously Conducted Biological Assessments

*Acacia corusca* was first recorded during a detailed flora and vegetation survey at Orebody 31 (Onshore Environmental, 2014). After which a three phase targeted survey was conducted by Onshore Environmental, aiming to inform the species' conservation status and management requirements. Survey extents and effort are depicted in Map 3.1 (Onshore Environmental, 2015).

In Phase 1, transects were focussed on previously identified populations at Orebody 31 and surrounding areas. The populations identified at Orebody 31 were found on exposed rock in the intersection between the Boolgeeda BIF and the Woongarra Rhyolite of the Hamersley Ranges. In Phase 2, searches were directed based on the boundary of the Boolgeeda BIF and the Woongarra Rhyolite in the South-east Pilbara where access was permitted. In Phase 3, the results of broad scale species distribution mapping, based on known records and a set of predictor variables (elevation, slope, soil depth, lithology age, temperature, and rainfall), directed further targeted field surveys. Sites inspected were selected according to accessibility (Map 3.1).

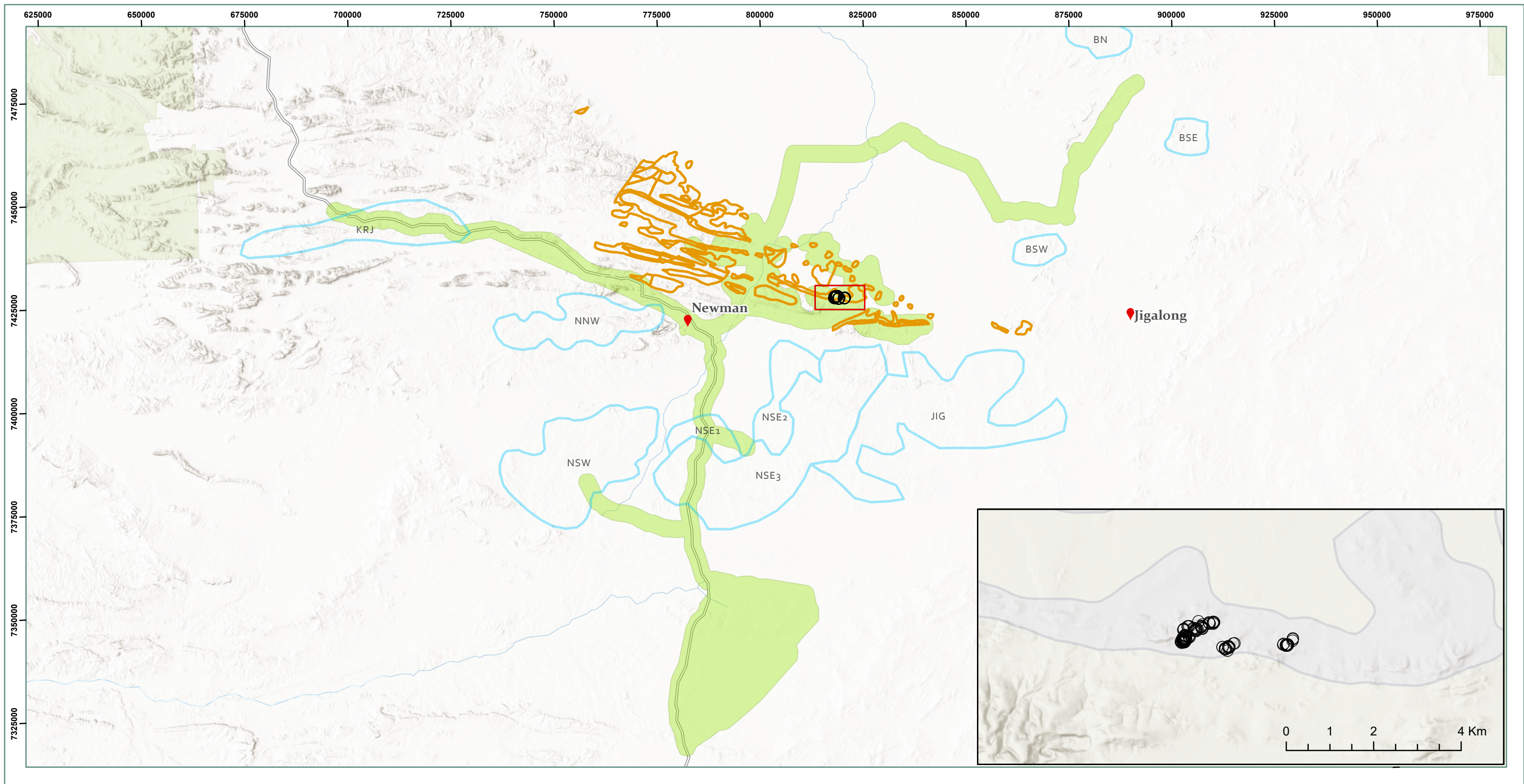
In their findings, Onshore Environmental described the species habitat preferences from the populations found in the targeted surveys, in particular, the geological formations at Orebody 31. Despite targeting preferred habitat types, no new populations were found during the following three phases of targeted survey. In 2019 the species was listed as Priority One under the Conservation Codes for Western Australia Flora and recorded as a new species in the journal of the Western Australia Herbarium (Bull et al., 2019; Smith & Jones, 2018). Previously conducted biological surveys relevant to *Acacia corusca* are listed in Table 3.1.

**Table 3.1: Previously Conducted Assessments**

Source	Survey Type	Author
Orebody 31 Level 2 Flora and Vegetation Assessment	Detailed Vegetation Assessment	Onshore Environmental Consultants (2014)
Targeted Flora Survey <i>Acacia</i> sp. East Fortescue	Targeted Flora Assessment	Onshore Environmental Consultants (2015)

#### 3.1.2. *Acacia Corusca* Habitat Preferences

*Acacia corusca* is a shrub or small tree from the south-east Pilbara bioregion of north-western Australia. It is known to occur in red-brown, sandy-loam soils, crests, ridges, drainage lines and slopes of less than 20 degrees. Identified specimens grew in areas with exposed outcrops and rocky hill slopes typical of the Boolgeeda BIF (Bull et al., 2019). Three known populations of the species exist within an eight hectare extent (Map 1.1) (Bull et al., 2019). The largest population was found where the Boolgeeda BIF meet with the exposed Woongarra Rhyolite. The species is associated with spinifex hummock grassland dominated by *Triodia pungens* and *Triodia vanleeuwenii* and scattered *Eucalyptus leucophloia* subsp. *leucophloia*, and in open shrublands of *Grevillea wickhamii* subsp. *hispidula*, *Senna glutinosa* and *Acacia marramamba* (Bull et al., 2019).



**Legend**

- Survey Effort Buffer
- Phase 3 target areas - elevation, slope, soil depth
- Phase 2 target areas - Geology
- Conservation Estate
- BHP Tenements
- BHP Acacia corusca Records

**Onshore Targeted Survey Sites**  
*Acacia corusca* Distribution Modelling

DATE: 2021-12-16  
DRAWN: M.I. PEREDA



MAP 3.1

0 12.5 25 50 Km

Spatial reference  
Name: GDA 1994 MGA Zone 51  
Datum: GDA 1994  
Projection: Transverse Mercator  
Absolute scale 1:850,000



## 3.2. Species Distribution Modelling Results

### 3.2.1. Correlation Test Amongst Environmental Predictors

The correlation test amongst environmental predictor variables for the Study Area revealed that they are not independent. Slope, Topographic Wetness Index, and the July Net Radiation showed correlation above 0.7. Furthermore, the correlation test between environmental variables in the locations of previous records found dependencies amongst some variables. These variables were then removed, and the correlation test process was iterated until all variables resulted in a correlation lower than 0.7. The final selected variables to feed the model are shown in in Appendix A.

### 3.2.2. Maximum Entropy Model Performance

Twenty-six models were tested in the selection process, choosing a best model that presented a very high performance with an AUC of 0.98. This means that the model was highly efficient measuring presences and pseudo-absences. However, the omission rate (the proportion of test presences incorrectly predicted) is lower than expected randomly. This means that the model is very good at distinguishing absences from presences, but as the chance of finding an individual increases, the model is less accurate as would be expected by chance (Figure 3.1). This suggests that although the model's performance was very high, overfitting, although reduced, was present due to the spatial closeness between the records. These findings were somewhat expected, since modelling species with known records in close vicinity is often challenging, especially when extrapolating to larger extents (Fois et al., 2018).

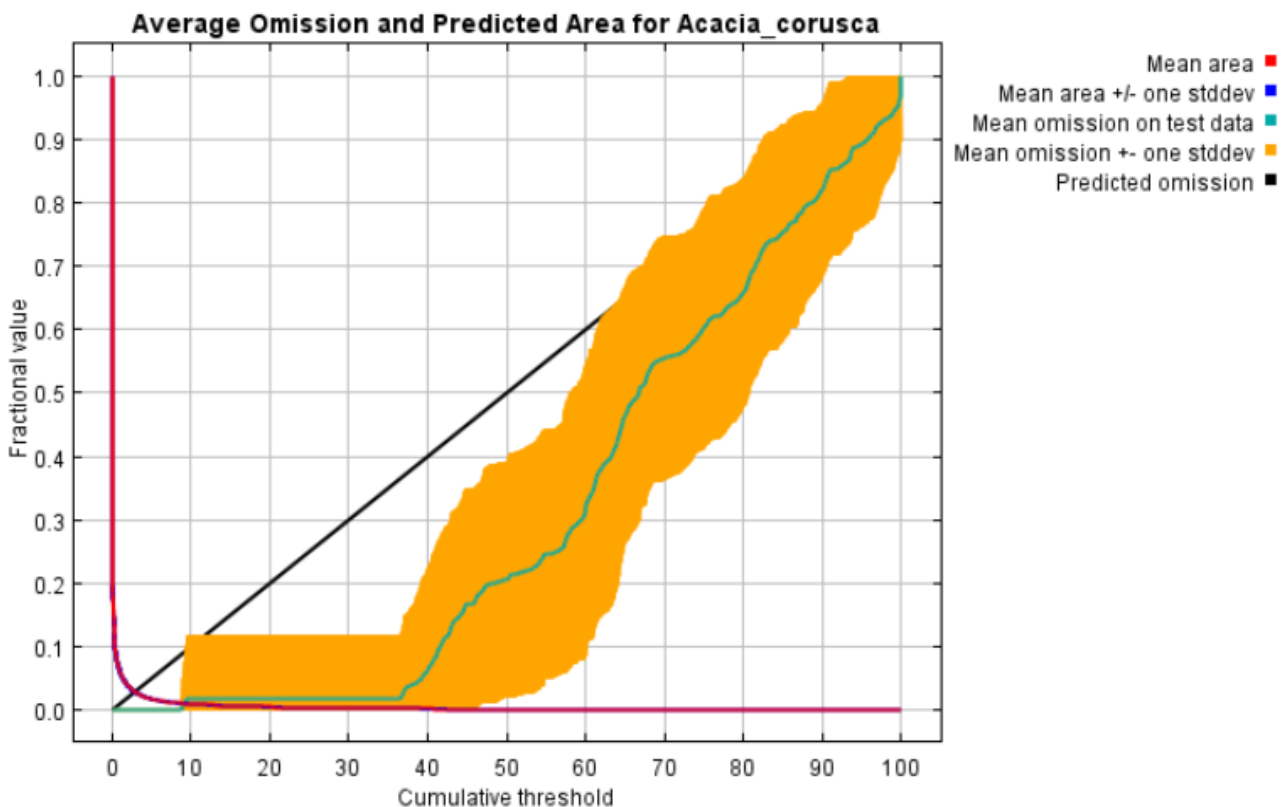


Figure 3.1: Average Omission and Predicted Area for *Acacia corusca*

### 3.2.3. Environmental Variable Importance & Contribution

Amongst the 17 unique predictor variables tested (Appendix A; Table 0.1), nine were the most influential when explaining the distribution of *Acacia corusca*. Land Systems (Newman System) and the distance to the Boolgeeda BIF and Woongarra Rhyolite were the most influential predictors, with 27.9 and 24.8 percent contribution. Of these two variables, distance to Boolgeeda BIF and the Woongarra Rhyolite was the most important variable (87.2%), with the probability of *Acacia corusca* occurrence decreasing to zero ~12 km away from this formation (Table 3.2 and Appendix B). This result reinforces the theory that the species is habitat-specific to the junction between the Boolgeeda BIF and the Woongarra Rhyolite as proposed by Onshore Environmental Consultants (Onshore Environmental, 2015). MrVBF and Slope Relief Classification variables were chosen to represent the species preference to drainage, eroded and exposed materials, slopes and ridges; explaining 17.8% and 5.3% of the data's variance, respectively (Table 3.2).

Of the soil attribute predictor variables tested, Soil Sand Percentage and Soil Organic Carbon were selected by the model explaining 4.3% and 2.3% of the data's variance, respectively (Table 3.2, Appendix B). West Australian Soils (Soils Atlas) explains 14.4% of the variance, with records located in the Fa13 unit; described as ranges of banded jaspilite, chert along shales, dolomites, and iron ore formations with areas of ferruginous duricrust (Northcote et al., 1968).

Out of the vegetation indices tested, MSAVI helped to explain 0.8% of the variance. MSAVI aids in the prediction of the species distribution in value ranges equivalent to ground and dry vegetation (Appendix B). These values may be representative of sparse vegetation on exposed, loose, and heterogeneous deposits from the weathered Boolgeeda BIF and exposed Woongarra Rhyolite (Onshore Environmental Consultants, 2015).

**Table 3.2: Variable Importance of the Best Performing Model**

Variable	Percent Contribution	Permutation Importance
Land Systems (DPIRD)	27.9	0.4
Distance to Boolgeeda Iron Formation and Woongarra Rhyolite	24.8	87.2
MrVBF Classified	17.8	3.8
Soil Atlas	14.4	0.4
Slope Relief Classification	5.3	0.1
Soil Sand (%)	4.3	6.8
Digital Elevation Model	2.4	0.9
Soil Organic Carbon	2.3	0
MSAVI	0.8	0.5

### 3.3. Representation of Predicted Areas within the Study Area

An assessment of the extent of probability of occurrence within the Study Area was performed, with the total predicted extent occupying 91,437.2 ha (1%) of the Study Area. Within the modelled extent, 92%

(83,372 ha) was classified as having a Low probability of occurrence of the species. Areas of Medium and High probability represented 4,608 ha (5%) and 3,097 ha (3%) of the modelled extent, respectively (Map 3.2).

Much of the total modelled extent of *Acacia corusca* (97%) is present within existing mining and exploration tenements (Table 3.3). Of the total classified model extent, areas categorised as having a Medium or High probability of occurrence within BHP tenements, were found at proportions of 26% and 29%, respectively (Table 3.3).

**Table 3.3: Probability of Occurrence in Study Area & BHP WAIO Tenements**

Site	Low		Medium		High	
	Ha	%	Ha	%	Ha	%
Outside Tenure	2,591.99	3.1	24.10	0.5	1.25	0.1
Other Tenure	67,289.90	80.4	3,381.97	73.5	2,195.15	70.9
BHP WAIO Tenure	13,834.88	16.5	1,197.48	26.0	897.93	29.0

\*Values in table may show slight variance to total area results due to gaps and overlaps in tenement dataset.

### 3.4. Evaluation of Predictability within Target Sites

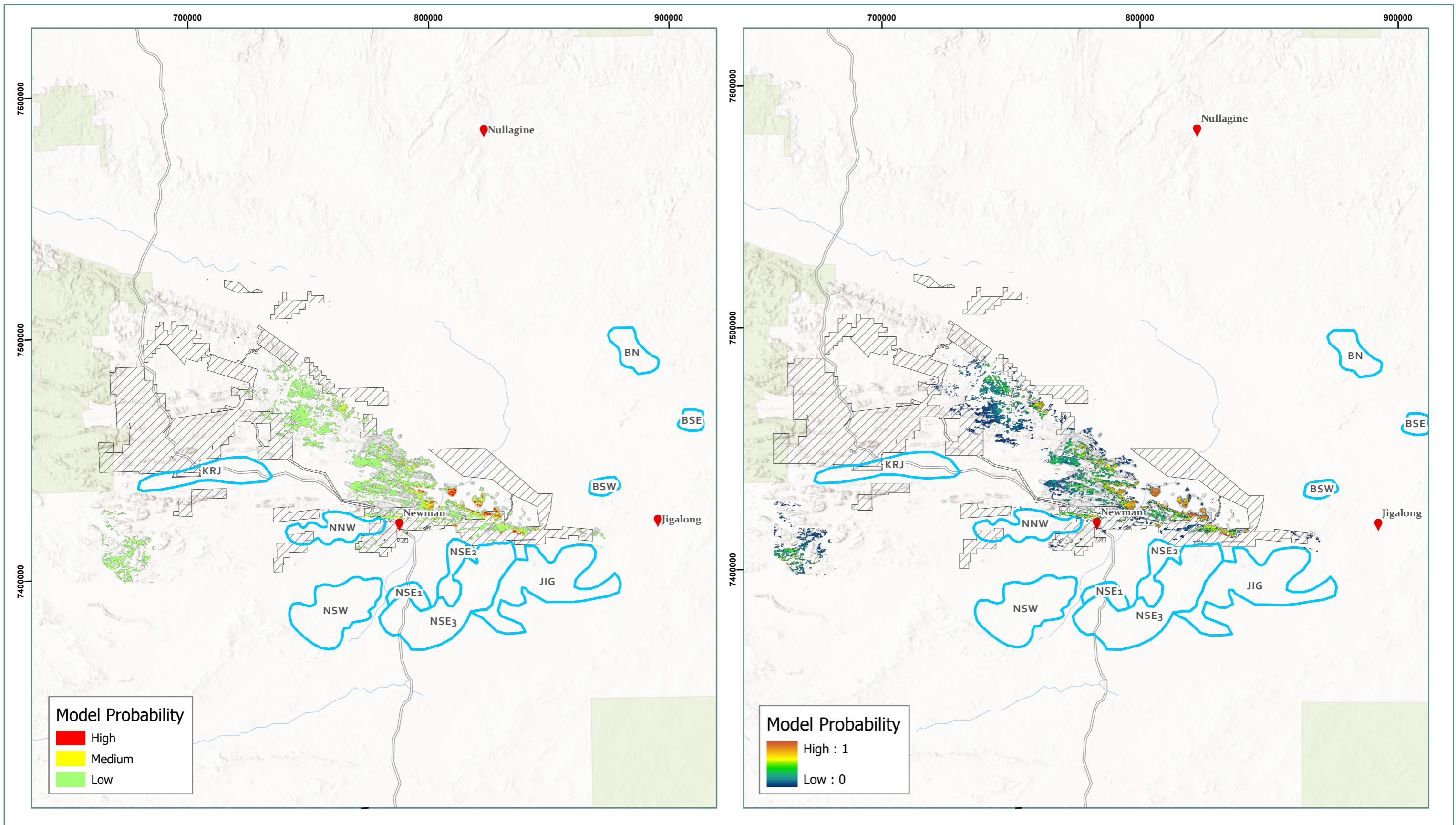
#### 3.4.1. Previously Mapped Target Extents 2015

The probability of occurrence was evaluated for each of the target sites identified in Phase 2 and Phase 3 by Onshore Environmental (Onshore Environmental, 2015). Phase 2 sites were selected following the Boolgeeda Iron Formation and the Woongarra Rhyolite; however, not all the targeted sites could be accessed in 2015 (Map 3.2). Within the inaccessible Phase 2 target areas, results of the current model identified 7% (1,154.1 ha) as Medium likelihood and 4% (755.6 ha) as High likelihood of presence of *Acacia corusca* (Table 3.4). Phase 3 sites proposed in 2015 had recorded Low probability of occurrence (<1%) according to the model proposed in this report (Table 3.4). The JIG and NEW target sites recorded a probability of occurrence of the species, with 11.70 ha and 46.1 ha of low probability areas, respectively. However, these extents represent less than 1% of the total area (Map 3.2). The remaining 10 Phase 3 target sites did not record any probability of occurrence.


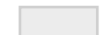


The model proposed by Onshore Environmental (Phase 3 targeted survey) used elevation, slope, soil depth, temperature, and rainfall as environmental predictor variables, without considering Land Systems or geological formation; and as a result, the Phase 3 target areas covered broad locations throughout the Study Area. However, the Land System and geological variables have proven to be important in predicting the distribution of *Acacia corusca* (Table 3.2). The omission of these variables from the Phase 3 modelling is the likely explanation for the observed low probability of occurrence within the Phase 3 target areas (Table 3.4). Conversely, the results of the current model are more congruent with the Phase 2 target areas which were derived from the extents of the Boolgeeda BIF and Woongarra Rhyolite formations.

**Table 3.4: Probability of Occurrence for Each Target & Proposed Site**

Survey	Target Sites	Low		Medium		High	
		Ha	%	Ha	%	Ha	%
Phase 2 2015	Inaccessible	15,415.0	89	1,154.1	7	755.6	4
Phase 3 2015	JIG	11.7	100	0	0	0	0
	NNW	46.1	100	0	0	0	0



**Legend**

-  Phase 3 target areas - SDM
-  Phase 2 target areas - Geology
-  BHP Tenements
-  Conservation Estate

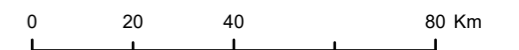
**Species Distribution Model Results**

*Acacia corusca* Distribution Modelling

Drawn: M.I. Pereda  
Date: 2021-12-16



**MAP 3.2**



Spatial Reference  
Name: GDA 1994 MGA Zone 51  
Datum: GDA 1994  
Projection: Transverse Mercator  
Absolute Scale 1:1,500,000



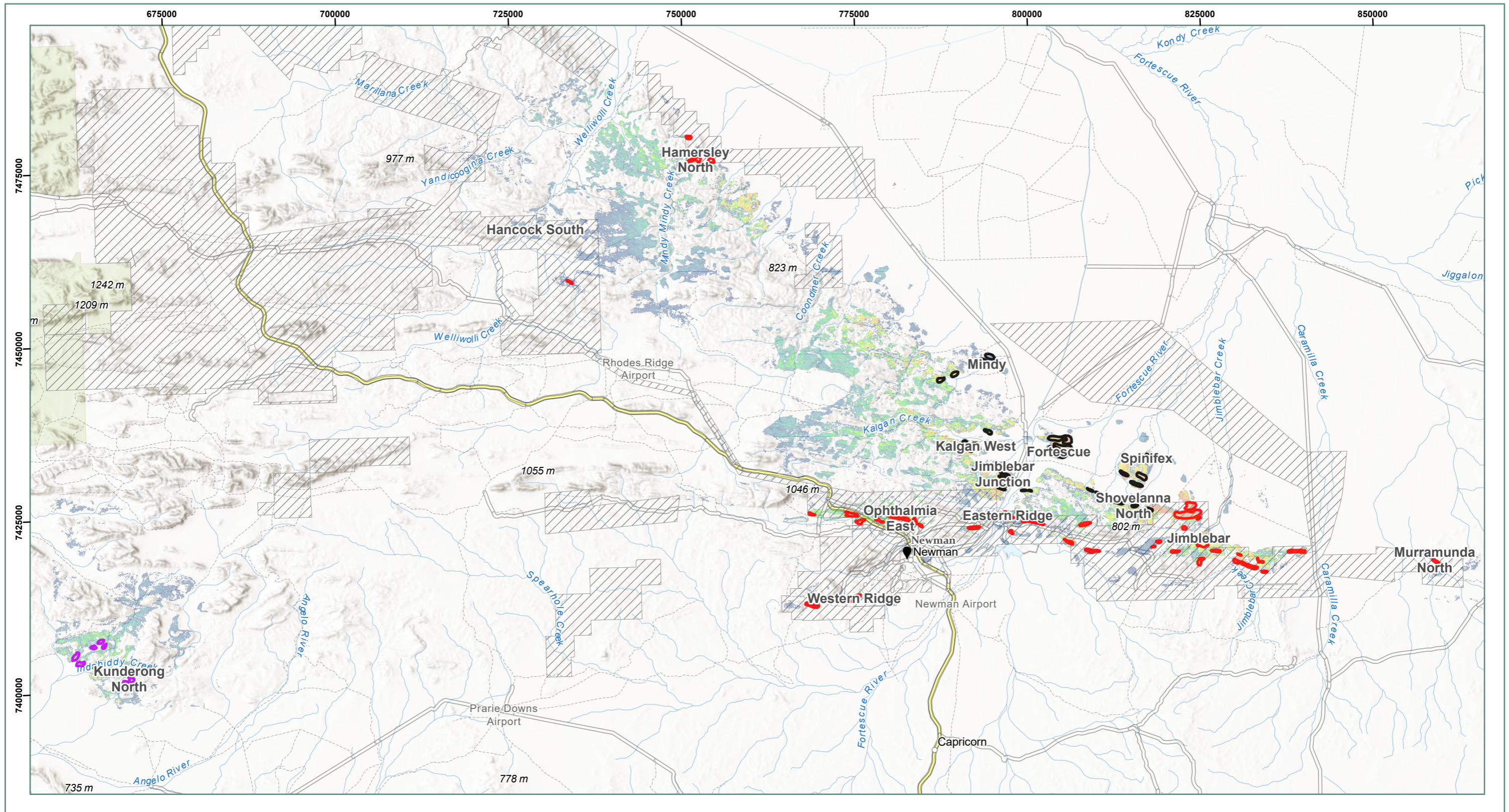
### 3.4.2. Recommended Target Extents

The MaxEnt model proposed in this analysis depicted likely areas of occurrence at locations within BHP WAIO tenure, tenure held by other operators, and where no mining or exploration tenure exists (Map 3.2). Many of these locations have no indication of previous survey effort, with other locations falling within the Onshore Environmental (2015) broad, previous survey effort buffer (Map 3.1). However, it is assumed that not all areas within this extent were able to be visited. These areas were identified as relevant to the species due to the presence of the Woongarra Rhyolite and Boolgeeda Iron Formation, Newman Land System, MrVBF and Slope Relief Classification environmental characteristics.

With the above factors in consideration, eight target areas totalling 50 sites have been identified across Low, Medium, and High probability areas. Forty-four sites are present within BHP WAIO tenements, with the remaining six proposed sites, from the Kunderong North area, falling outside of mining tenure (Table 3.5, Map 3.3 and Appendix C). An additional 24 target sites (Table 3.5, Map 3.3 and Appendix C) have been identified on tenure held by other operators; however, access to these sites is uncertain and may be targeted once other options have been exhausted. Target sites are ranked by model suitability (Appendix C) to enable site prioritisation during field planning; however, a subset of low suitability sites should also be visited in order to increase the absence dataset; or should the species be located, expand the known distribution and preferred environmental characteristics.

**Table 3.5: Probability of Occurrence for Each Target & Proposed Site**

Tenure	Target Area	Area Priority	Number of Sites by Priority			Area (ha)
			High	Medium	Low	
BHP Tenure	Eastern Ridge	High	4	-	4	376.87
	Hamersley North	Low	-	-	3	145.22
	Hancock South	Low	-	-	2	58.66
	Jimblebar	High	10	5	6	1,041.28
	Murramunda North	Low	-	-	1	36.71
	Ophthalmia East	Medium	-	3	4	305.99
	Western Ridge	Low	-	-	1	97.35
<b>BHP Tenure Total:</b>			<b>14</b>	<b>8</b>	<b>21</b>	<b>2,062.08</b>
No Tenure	Kunderong North	Medium	-	2	4	274.79
<b>No Tenure Total:</b>			<b>-</b>	<b>2</b>	<b>4</b>	<b>274.79</b>
Other Tenure	Fortescue	High	1	1	-	624.05
	Jimblebar Junction	High	2	1	2	110.53
	Kalgan West	Medium	2	-	2	190.45
	Mindy	Medium	1	1	2	276.32
	Shovelanna North	High	4	1	1	161.54
	Spinifex	High	2	2	-	245.71
<b>Other Tenure Total:</b>			<b>12</b>	<b>6</b>	<b>7</b>	<b>1,608.59</b>
<b>Grand Total:</b>			<b>74</b>			<b>3,945.46</b>



**Legend**

BHP Tenements  
 Other Tenure

**Modelled Probability**

High : 1  
 Low : 0

**Target Areas**

BHP Tenure  
 No Tenure

**Proposed Target Areas**  
*Acacia corusca* Distribution Modelling

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DATE: 2022-01-20  
 DRAWN: M.I. PEREDA

**MAP 3.3**

0 5 10 20 Km

Spatial Reference  
 Name: GDA 1994 MGA Zone 51  
 Datum: GDA 1994  
 Projection: Transverse Mercator  
 Absolute scale: 1:550,000

## 4. CONCLUSIONS

*Acacia corusca* is a recently named taxon with only three populations recorded and separated by approximately one kilometre. These populations occur where the Boolgeeda BIF and the Woongarra Rhyolite meet. Therefore, the probability of encountering this species greater than ~12 km from their junction is low. Ironstone outcrops, such as the BIF of the south-west and north-west of Western Australia, are known to provide unique environments that favour endemism's and geographically restricted species (Gibson et al., 2012; Yates et al., 2011). The Hamersley Range presents high flora biodiversity with 1,385 taxa identified, of which 66 are BIF specialists (Gibson et al., 2015). BIF endemism of the genus *Acacia* (e.g. *Acacia woodmaniorum*) has been reported in Western Australia only growing in cracks and crevices of iron outcrops, where a microclimate is formed by the accumulation of moisture and runoff (Hopper et al., 1996; Millar et al., 2013).

The model output was categorised into areas of High, Medium and Low probability of occurrence, of which 92% represented areas of Low probability. The extent of Low probability area suggests that *Acacia corusca* may present a restricted distribution within the Study Area. The species showed higher probability of occurrence in areas close to the Boolgeeda BIF, where it meets with the Woongarra Rhyolite, as hypothesised by previous reports (Onshore Environmental, 2015). This study also indicated that eroded materials (MrVBF), coupled with the position in the landscape (Slope Relief Classification), are also important environmental predictors for the presence of the species.

The probability of the species' occurrence was evaluated within previously identified target areas, with 4% of the areas recording a High probability. Eight new target areas, totalling 50 locations with the potential to harbour *Acacia corusca* were identified during the current analysis. These locations were placed both in areas within BHO WAIO tenure, and regionally outside tenure (six sites); avoiding locations of previously known survey effort, where possible. An additional 24 locations were identified on tenure held by other operators; however, access to these sites may be limited. Surveys at these locations would have the highest likelihood of locating additional *Acacia corusca* populations, expanding the known absence dataset, and informing environmental preferences.

The model presented in this study represents a robust approach, with finely tuned parameters and inputs designed to address spatial autocorrelation limitations. Spatial correlation of dependent records was addressed by, informed model parameter optimisation, selection of presence record locations and the inclusion of a bias layer; accounting for the sampling effort as a result of land access constraints in previous surveys. However, some residual overfitting was evident in the results, an outcome that is often expected when modelling spatially constrained species (Fois et al., 2018). In the future, additional records located by targeted surveys informed by distribution models, such as that proposed in this report, will further reduce bias and obtain results with less specificity to sites within known locations. Although this study minimised autocorrelation limitations and maximum entropy models have been proven to be robust when working with scarce data and poorly known species, exploration of other modelling algorithms may also help to further address spatially correlated data (Fois et al., 2018; Zurell et al., 2020).

The SDM generated in this study from records found in 2015 supports the hypothesis of the importance of the Boolgeeda BIF and the moisture held by heterogeneous superficial deposits predicting a restricted distribution pattern in the Pilbara.

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## Appendix A: Correlation Test



Table 0.1 Selected Variables after Correlation Test

Environmental Variable		Description	Source	Type
Landscape Attributes	Depth of Regolith	Metres of <i>in situ</i> and transported material overlying unweathered bedrock	CSIRO	Numeric
	MrVBF	MrVBF is a topographic index designed to identify areas of deposited material at a range of scales based on the observations that valley bottoms are low and flat relative to their surroundings and that large valley bottoms are flatter than smaller ones. This dataset was classified into five categories based on the Jenks Natural breaks classification.		Numeric
	Slope Relief Classification	Soil relief landform pattern classification based on Speight (2009).		Categorical
Soil Attributes	Soil Bulk Density	Bulk density of the whole soil (including coarse fragments) in mass per unit volume		Numeric
	Soil Organic Carbon	Mass fraction of carbon by weight in the < 2 mm soil material as determined by dry combustion at 900 Celsius		Numeric
	Soil Sand (%)	Percentage of sand content of the soil at a depth of 0-5 cm		Numeric
	Soil Depth	Depth of soil (A & B horizons) to 2m	Numeric	
	Soil Total Phosphorus	Percentage of phosphorus content of the soil at a depth of 0-5 cm	Numeric	
	Effective Cation Exchange Capacity	Cations extracted using barium chloride (BaCl <sub>2</sub> ) plus exchangeable H + Al	Numeric	
Geology & GIS	Atlas of Australian Soils	Digitalised soil landscapes from Northcote et al. (1960-1968)	Bureau of Rural Sciences	Categorical
	Pre-European Vegetation	Pre-European Vegetation of Western Australia (DPIRD-006) (ID:7)	DPIRD	Categorical
	Land Systems	Soil Landscape systems	DPIRD	Categorical
	Distance to Boolgeeda Iron Formation and Woongarra Rhyolite	Combined Euclidean Distance from the Boolgeeda Iron Formation and Woongarra Rhyolite (Surface Geology from Geoscience Australia) calculated in ArcMap	Calculated by Spectrum	Numeric
Vegetation Indices	MSAVI	Modified Soil Vegetation Index from Landsat 8 Imagery	Landsat 8	Numeric
	NDWI	Normalized Wetness Index from Landsat 8 Imagery	Landsat 8	Numeric
Bioclimatic	Bioclim1	Annual Mean Temperature	Hijmans 2005	Numeric
	Bioclim12	Annual Precipitation	Hijmans 2005	Numeric

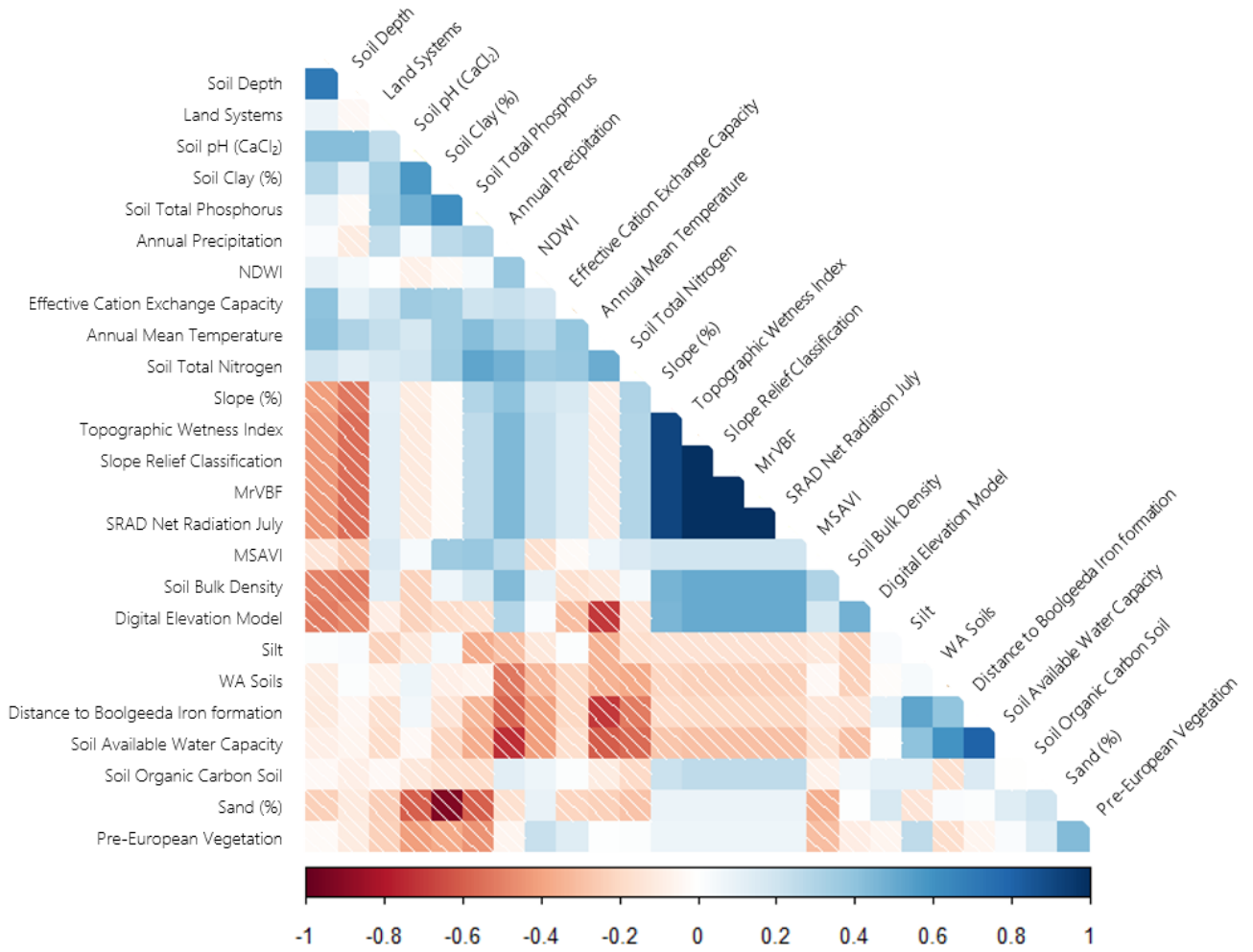


Figure 0.1: Correlation Test of Environmental Predictors.

## Appendix B: MaxEnt Additional Results



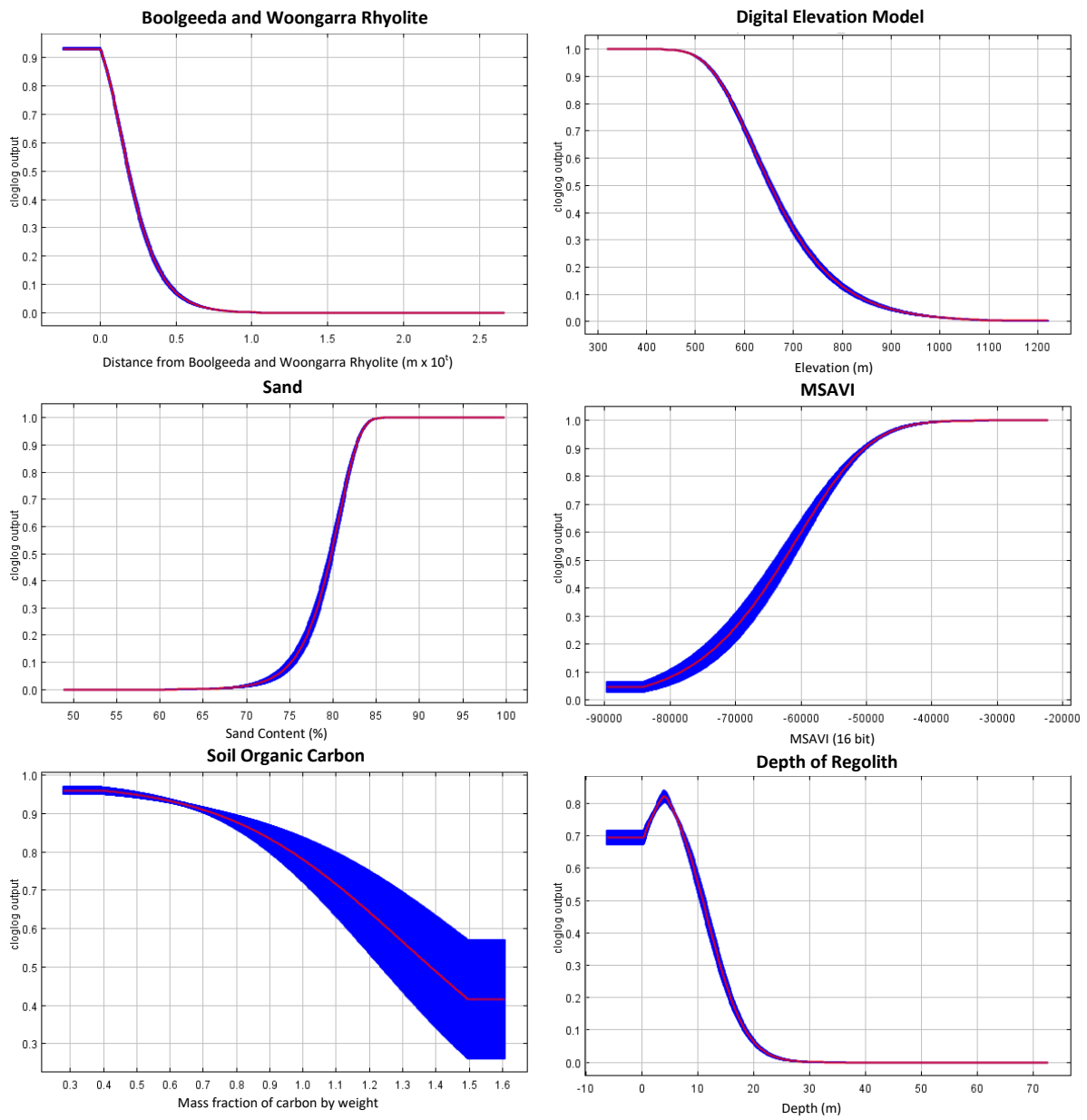


Figure 0.2: Response curves of numerical variables. The horizontal (x) axis corresponds to the units intrinsic of each variable.

## Appendix C: Proposed Target Areas



Tenure	Target Area	Site ID	Area (ha)	Priority	Rank	Model Prediction			Latitude (WGS84)	Longitude (WGS84)
						Min	Max	Mean		
BHP Tenure	Ophthalmia East	EO01	95.36	Medium	33	0.06	0.77	0.63	-23.3025978	119.7241987
		EO02	49.17	Low	49	0.05	0.74	0.42	-23.306007	119.668109
		EO03	21.46	Medium	35	0.44	0.73	0.6	-23.305132	119.6952165
		EO04	15.41	Low	45	0.06	0.75	0.44	-23.3129796	119.7537057
		EO05	30.47	Medium	44	0.05	0.74	0.45	-23.3071221	119.7454535
		EO06	75.74	Low	42	0.05	0.69	0.49	-23.2964075	119.6557664
		EO07	18.38	Low	38	0.18	0.74	0.51	-23.2946925	119.5994657
	Eastern Ridge	ER01	62.34	Low	67	0.05	0.24	0.11	-23.3506976	119.9945892
		ER02	37.25	High	16	0.71	0.92	0.81	-23.3385861	119.9628893
		ER03	17.98	High	51	0.05	0.84	0.38	-23.3238785	119.8811359
		ER04	49.11	High	53	0.05	0.87	0.36	-23.3017976	119.8772586
		ER05	14.74	Low	57	0.06	0.61	0.34	-23.3003098	119.8188233
		ER06	47.65	Low	45	0.06	0.79	0.44	-23.3172386	119.8287808
		ER07	97.44	High	58	0.05	0.95	0.32	-23.3109985	119.9118441
		ER08	50.36	Low	50	0.05	0.57	0.4	-23.3155986	119.9856265
	Hamersley North	HN01	45.1	Low	52	0.05	0.56	0.37	-22.830321	119.4699649
		HN02	71.22	Low	59	0.05	0.69	0.31	-22.8285235	119.4478068
		HN03	28.9	Low	60	0.06	0.65	0.22	-22.7993153	119.439136
	Hancock South	HS01	42.7	Low	70	0.05	0.17	0.09	-22.9160786	119.2177505
		HS02	15.96	Low	73	0.05	0.11	0.07	-22.9839773	119.2665592
	Jimblebar	JB01	35.2	High	2	0.58	0.96	0.86	-23.3683461	120.198877
		JB02	23.61	High	1	0.11	0.96	0.87	-23.3711746	120.2085273
		JB03	57.96	High	40	0.06	0.98	0.5	-23.3759114	120.2206528
		JB04	16.75	Low	70	0.07	0.12	0.09	-23.3826178	120.2383483
		JB05	4.55	High	2	0.73	0.93	0.86	-23.3696835	120.2358449

Tenure	Target Area	Site ID	Area (ha)	Priority	Rank	Model Prediction			Latitude (WGS84)	Longitude (WGS84)		
						Min	Max	Mean				
		JB06	10.41	Medium	29	0.55	0.85	0.68	-23.36753	120.229901		
		JB07	128.04	High	33	0.07	0.94	0.63	-23.2949212	120.1354055		
		JB08	319.34	High	27	0.05	0.96	0.71	-23.3058166	120.1315999		
		JB09	9.01	High	16	0.66	0.92	0.81	-23.3110642	120.146685		
		JB10	22.45	High	22	0.59	0.89	0.78	-23.3233849	120.1262003		
		JB11	1.23	Low	65	0.13	0.13	0.13	-23.335787	120.1202218		
		JB12	15.18	Low	61	0.12	0.6	0.21	-23.3383059	120.126182		
		JB13	51.78	High	23	0.39	0.96	0.77	-23.3672524	120.1475463		
		JB14	16.13	Low	64	0.1	0.23	0.17	-23.3407476	120.0897321		
		JB15	28.98	Low	66	0.06	0.2	0.12	-23.3350367	120.1124476		
		JB16	6.42	Low	67	0.05	0.18	0.11	-23.3468355	120.0821713		
		JB17	146.19	Medium	37	0.09	0.8	0.52	-23.3432765	120.1510528		
		JB18	78.4	Medium	42	0.06	0.8	0.49	-23.3566482	120.2843476		
		JB19	34.51	Medium	36	0.31	0.79	0.54	-23.3541062	120.1705076		
		JB20	29.21	Medium	55	0.05	0.7	0.35	-23.3538628	120.1121562		
		JB21	5.93	High	25	0.71	0.86	0.75	-23.3597176	120.2035715		
			Murramunda North	MN01	36.71	Low	74	0.05	0.07	0.06	-23.3740937	120.4825373
			Western Ridge	WR01	97.35	Low	62	0.09	0.33	0.2	-23.4059953	119.6568695
		No Tenure	Kunderong North	KN01	64.72	Medium	47	0.07	0.76	0.43	-23.4546541	118.5548037
				KN02	52.98	Medium	38	0.1	0.73	0.51	-23.4643265	118.5608769
				KN03	70.72	Low	62	0.05	0.58	0.2	-23.4873203	118.632433
KN04	26.43			Low	55	0.1	0.58	0.35	-23.4433644	118.580244		
KN05	23.66			Low	47	0.05	0.64	0.43	-23.4424515	118.5952718		
KN06	36.28			Low	53	0.05	0.58	0.36	-23.4361714	118.5907097		
Other Tenure	Fortescue	FR01	395.35	High	6	0.16	0.96	0.85	-23.219934	119.960698		

Tenure	Target Area	Site ID	Area (ha)	Priority	Rank	Model Prediction			Latitude (WGS84)	Longitude (WGS84)
						Min	Max	Mean		
	Jimblebar Junction	FR02	228.71	Medium	13	0.10	0.96	0.84	-23.204082	119.955221
		JJ01	5.10	Low	21	0.63	0.85	0.79	-23.270365	119.909194
		JJ02	7.65	High	12	0.77	0.90	0.84	-23.269977	119.90036
		JJ03	23.81	Medium	9	0.67	0.95	0.85	-23.266991	119.869097
		JJ04	11.90	Low	5	0.75	0.95	0.86	-23.262789	119.874563
	Kalgan West	JJ05	62.07	High	4	0.61	0.95	0.86	-23.253129	119.872834
		KW01	45.91	High	19	0.25	0.94	0.81	-23.206794	119.818191
		KW02	68.02	High	10	0.51	0.99	0.85	-23.21096	119.833847
		KW03	34.01	Low	15	0.68	0.92	0.82	-23.21507	119.823442
	Mindy	KW04	42.51	Low	32	0.12	0.93	0.66	-23.192466	119.852106
		MD01	51.01	High	28	0.10	0.88	0.68	-23.117651	119.804886
		MD02	48.46	Medium	30	0.43	0.88	0.67	-23.124868	119.784678
		MD03	71.42	Low	69	0.05	0.15	0.10	-23.095698	119.855191
	Shovelanna North	MD04	105.43	Low	72	0.05	0.16	0.09	-23.104566	119.847551
		SN01	24.66	High	7	0.69	0.95	0.85	-23.293452	120.05671
		SN02	18.70	High	8	0.27	0.96	0.85	-23.282369	120.019419
		SN03	14.45	Medium	14	0.69	0.92	0.83	-23.271448	119.994316
		SN04	34.86	High	31	0.06	0.91	0.66	-23.298514	120.076931
		SN05	44.21	High	26	0.08	0.94	0.74	-23.288228	120.034206
	Spinifex	SN06	24.66	Low	41	0.09	0.98	0.49	-23.276818	120.007258
SX01		89.27	High	20	0.10	0.95	0.79	-23.254807	120.067491	
SX02		40.81	Medium	18	0.17	0.95	0.81	-23.250883	120.042378	
SX03		63.77	High	11	0.64	0.97	0.84	-23.264904	120.059436	
		SX04	51.86	Medium	24	0.07	0.92	0.77	-23.231535	120.074999

