Australian Melliferous Flora Database

Guide to database development and metadata overview

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CRCHBP
FOR HONEY BEE PRODUCTS

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Foreword

This report describes the production of an Australian melliferous flora spatial database describing the geographic distribution of over 500 plant species important to the Australian beekeeping industry. The database provides information for Australian apiarists on the location, seasonality and utility of native flora and crop species for commercial honey production and apiary services. The database adheres to national taxonomic standards to aid in the correct identification of species across time and space.

The database was developed as an output of the Cooperative Research Centre for Honey Bee Products (CRCHBP) to resolve the industry challenge of resource availability limiting the increased production of Australian Honey bee products. The spatiotemporal mapping of native flora and crop species provides an important resource for new apiarists entering the industry or established apiarists interested in expanding their business. Through linking and standardising the disparate information available on the spatial distribution, seasonality and quality of melliferous floral resources across Australia, this project has developed an important resource and management tool for the national beekeeping industry.

We envisage that, when used in conjunction with other datasets, an even broader range of questions may be answered, far beyond what the database was originally intended to achieve. This database is also the foundation of the B-Spatial TM tool developed that links with B-QUAL as a digitised diary for apiary planning and movement. In a changing environment and with government management decisions affecting apiary sites, this tool will provide beekeepers access to current data for their decision-making.

Dr Liz Barbour
CEO

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About the Authors

A/Prof Bryan Boruff

Bryan J Boruff is an Associate Professor in the UWA School of Agriculture and Environment at The University of Western Australia (UWA). Bryan's expertise is in the application of Geographic Information Systems (GIS) and Remote Sensing technologies to the study of environmental hazards. Over the past decade, Bryan's research interests have expanded to encompass a range of environmental management issues including renewable energy and agricultural production, population health, sustainable livelihoods and the development of spatially enabled eResearch tools. He has extensive experience working in developing nations in multidisciplinary settings with academic, private and government stakeholders.

Giles Knight

Giles Knight completed a double major in Environmental and Geographical Sciences at the University of Western Australia and is now enrolled in a PhD at the Centre for Water and Spatial Sciences (CWSS), at the University of Western Australia. He has a keen interest for all things spatial and a great love for the natural environment.

His work for the CRCHBP has been centred on the phenologic and spatial mapping of melliferous flora across the southwest of Western Australia. Throughout the life of the CRCHBP, he has supported researchers and participating apiarists with accurate spatial information and advice for a wide range of industry-relevant applications.

Bri St Jack

Bri St Jack is an Ecologist and Geospatial Data scientist at the University of Western Australia. She has assisted across various facets of this project and others in relation to data sourcing, management, and analysis.

Acknowledgments

The CRCHBP data integration initiative (Project 1) would like to additionally thank the following for their contributions to database development: Manita Ainsworth, Alex Chapman, Vidushi Patel, Ryan Kerr and Emily Barratt.

For consultation, we would like to thank: Rob Manning, Michael Bellman, the Fewster family, the Spurge family, the Leyland family, Tiffane Bates, and countless others that provided information during the construction of the Australian melliferous flora spatial database.

A special thanks to the Bee Industry Council of Western Australia (BICWA) and the Department of Biodiversity, Conservation and Attractions (DBCA) for their CRCHBP Participant support.

Introduction

Honey bees (Apis Mellifera) have a significant role in the commercial production of honey and pollination services in Australia (Benecke, 2007). The Australian honey bee products industry is an important contributor to the Australian economy and biodiversity services (Klein et al., 2007). In many regions of Australia, it promotes commercial agriculture production/harvest as well as the prevalence of ecotourism. Similarly, honey bee products produced from honey bees have grown into a sizeable industry within Australia with several formal training programs and multiple commercial and hobbyist organisations.

Locating appropriate sites for large-scale production in Australia is particularly challenging due to the diverse floral landscape (Crane, 1999) and preference for native vegetation. For this reason, throughout the year, beekeepers have been known to migrate their hives, long distances across multiple apiary sites comprising native ecosystems and agricultural crops (Arundel et al., 2016).

The significance and value of honey bee products in Australia have inspired a range of research initiatives including the compilation of state and local resource guides providing information on regionally available target flora (Sommerville, 2020), as well as the use of machine learning to detect flowering patterns (Dixon et al., 2021) and agent-based modelling to understand hive migration patterns (Patel, 2022).

To support the industry and related research, the Australian Melliferous Flora Database (AMFD) was developed to provide a comprehensive guide to melliferous flora across Australia. The database provides species-specific information for over 400 flora species known to produce relevant nectar or pollen resources in support of honey production and or pollination services. Information for each species includes up-to-date taxonomic and common nomenclatures, spatial distribution, flowering phenology, and known nectar and pollen quality. The following provides a detailed overview of the data assemblage methodology and final spatial database produced for the Cooperative Research Centre for Honey bee Products (CRCHBP).

The outcomes of this research are important for maintaining the longevity and high-quality standards of the Australian HBP industry. Thereby the overarching goals of the project were to provide for the:

- High-quality spatiotemporal phenological information system for individual melliferous flora species
- Linked honey and pollen quality information relevant to apiarists
- Track naming conventions for effective scientific communication

The scope of Project 1 was to develop a spatiotemporal database in support of the honey bee product developments.

CRCHBP Objective

Design and develop a spatiotemporal Geographic Information System database to house and link spatial information gathered across the CRCHBP projects and related sites; and

Develop an enhanced bee-related floristic vegetation mapping database for the SW of WA (expanded to include all of mainland Australia and Tasmania).

Impact

Streamline data sharing to maximise research achievements and provide a decision support tool for the industry.

Output

This project will contribute to the following Outputs as stated in the Funding Agreement:

1.4 Bee hive migration models, incorporating current and future barriers to hive-site accessibility are developed and tested as a decision support tool for beekeepers

2.2 Seasonal flora map with honey bee product quality from biogeographical regions is collated to inform the development of the bee hive site valuation model

3.1 Regional year-round bee hive site establishment models using flora mapping data and valuation are developed

Research Approvals

Approval for this research was provided by the UWA Ethics committee - RA/4/1/9247.

RESEARCH METHOD

Overview

The AMFD consists of discrete seasonal data and qualitative information for over 500 known nectar and pollen-producing species relevant to the Australian beekeeping industry. Melliferous species were initially identified through searches of reputable literary sources, containing information relevant to Australian apiary and agricultural industries as well interviews with commercial beekeepers and industry experts.

The initial step in building the database included the identification of key literature sources that adequately represent known melliferous species relevant to Australian apiary and agricultural pollination industries. This included an exhaustive search of local and regional flora guides to create an initial list of industry-important melliferous flora. This was conducted with a focus on literary sources providing information initially in WA and later across Australia.

The initial species list was validated through consultation with commercial apiarists and experts in the industry removing erroneous flora entries. This process included discussions of the types of information to be collected for each species to develop the best set of important attributes to be compiled for each species from available literary sources.

Using known sources, a database of relevant melliferous species was developed with each entry populated with agreed attribute information. Apiarist relevant information sourced from known literature included current taxonomic nomenclature, occurrences or habitat information, quality of honey and pollen production, and flowering period (by month). Once a comprehensive database was developed, the database was spatialised by transposing Atlas of Living Australia (ALA) records into generalised presence about the Interim Biogeographic Regionalisation for Australia (IBRA) Subregion dataset.

The overall process of collating species information is summarised in *Figure 1*. The database is bound by species entries for all of Australia (Appendix B) each with a unique serial number and ApnID (where possible – some crop species do not have an ApnID number). Database composition, layout and availability are detailed below.

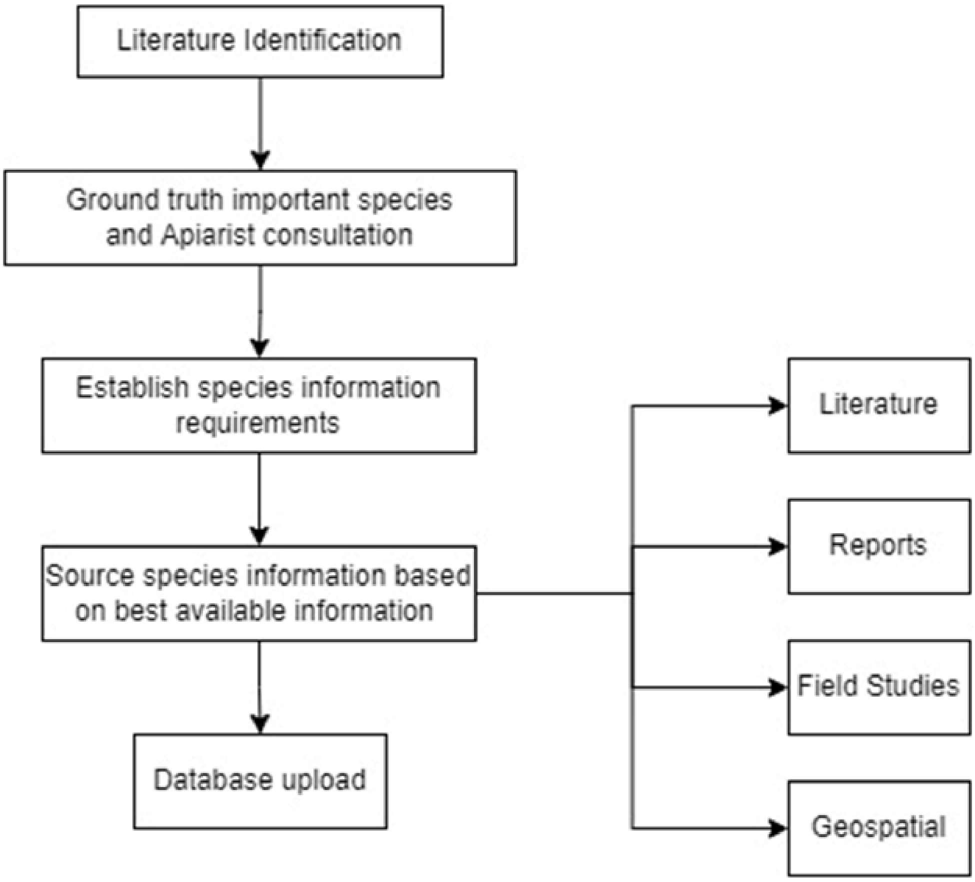

Figure 1: Overview of development of the AMFD.

Species inclusion and attribution

Melliferous flora species included in the AMFD were compiled and attributed from a range of sources including the following:

- Atlas of Living Australia Spatial Portal - website at http://www.ala.org.au.
- Birtchnell, M.J. & Gibson, M. (2008*) Flowering ecology of honey-producing flora in south-east Australia*. Rural Industries Research and Development Corporation, Barton, ACT. No. 08/098.
- Coleman, R S. (1962) Bee farming: honey flora of Western Australia, *Journal of the Department of Agriculture, Western Australia, Series 4.* Vol. 3(8), Article 21.
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Compilation of species consisted of creating an individual record for each species listed in the resources above. Once identified, each species was then attributed with information identified in *Table 1.* To conform with national taxonomic standards, each record was assigned a corresponding Australian Plant Name Index (APNI). Current taxonomy was verified using the Max 3.0 WA species database, the Atlas of Living Australia (ALA), and the Australia Plant Index (API).

Attribute information for each species includes species, botanical, common and previous naming conventions if changed. This also included the family, genus and plant type.

Where available, each species was provided with an overall rating in terms of utility to the industry (1 poor – 5 excellent, *Appendix A*). This data was compiled from existing sources where available and when ratings were provided by multiple sources, the most conservative value was used. Similarly, ratings were provided for nectar and pollen quality using the following scale: Excellent, Good, Useful, and Poor.

Flower colour and period in months were compiled from existing sources for each species. Again, where discrepancies occurred, the most conservative flowering range was recorded recognising that flower times will vary locally and between states.

The location of each species was recorded by transposing Atlas of Living Australia (ALA) records into generalised presence in relation to the Interim Biogeographic Regionalisation for Australia (IBRA) Subregion dataset. Or, in relation to agricultural crops, the Australian Bureau of Statistics Agricultural Census and information from the Australian Collaborative Land Use Mapping Program (ACLUMP) to identify the IBRA Subregions a particular crop species is known to be cultivated. As such, for each species, the IBRA Region, IBRA Subregion and Local Government Area (LGA) in which each crop species is grown (based on data availability) was recorded. A more detailed description of this approach is provided in the next subsection.

Finally, the source from which each species was identified and from which the attribute information was derived is provided. This includes the original publication source, honey and pollen rating source, and flowering information.

Table 1: Variables and variable definitions for species found within the AMFD.

No	Variables	Definitions
1	No	Serial number
2	APNIID	ID of the Australian Plant Name Index (APNI) for the botanical community that deals with plant names and their usage in the scientific literature. When collecting any species data, please use the APNI as the project aims to use this unique APNI_ID for joining spatial data.
3	SpeciesName	A species or scientific name is used to refer to a real-life organism. The name is permanently and uniquely assigned to a representative specimen. Species names are determined by taxonomists using rules specified by international nomenclatural codes.
4	BotanicalName	A botanical name is a formal scientific name conforming to the International Code of Nomenclature for plants.
5	CommonName	A common name or a vernacular name of a taxon or organism. The name was commonly given to the plant.
6	PreviousName	Previous census name for species.
7	Family	The plant's family name. Family is one of the eight major hierarchical taxonomic ranks. Family is classified between order and genus.

8	Genus	The plant's generic name. The genus is one of the eight major hierarchical taxonomic ranks. Genus comes above species and below a family.
9	PlantType	General types of plant from the kingdom Plantae.
10	SusceptiblePhytophthora	Known susceptibility to Phytophthora. Primarily available for WA species.
10	Rating	Rating corresponding to the commercial value of the species for either nectar or pollen production. Ratings range from 1 (poor) to 5 (excellent).
11	HoneyQuality	Degree of honey quality (Excellent, Good, Useful, Poor) with a description where available.
12	PollenQuality	Degree of pollen quality (Excellent, Good, Useful, Poor) with a description where available.
13	FlowerColour	Colour of flowers.
14	FloweringPeriod	Range of flowering times across Australia. Flowering times may differ locally and between states.
15	JAN-DEC	Discrete flowering times across Australia by month. Flowering times may differ locally and between states (1 = flowering; 0 = not flowering).
16	GrowingConditions	Describes the general growing conditions of the species.
16	IBRARegion	The Region of Interim Biogeographic Regionalisation for Australia.
17	IBRASubRegion	The Sub-region of Interim Biogeographic Regionalisation for Australia.
18	LGALocations	Name of local government area where species are found.
20	Publications	Original sources from which the species was identified for inclusion in the AMFD.
19	Ref1	Source 1 of the URL link to the species name. Only available in some cases.
20	Ref2	Source 2 of the URL link to the species name. Only available in some cases.
21	HoneyRef	The source from where the honey quality rating was found.
22	PollenRef	The source from where the pollen quality rating was found.
23	FloweringRef	The source from where the flowering period range was found.

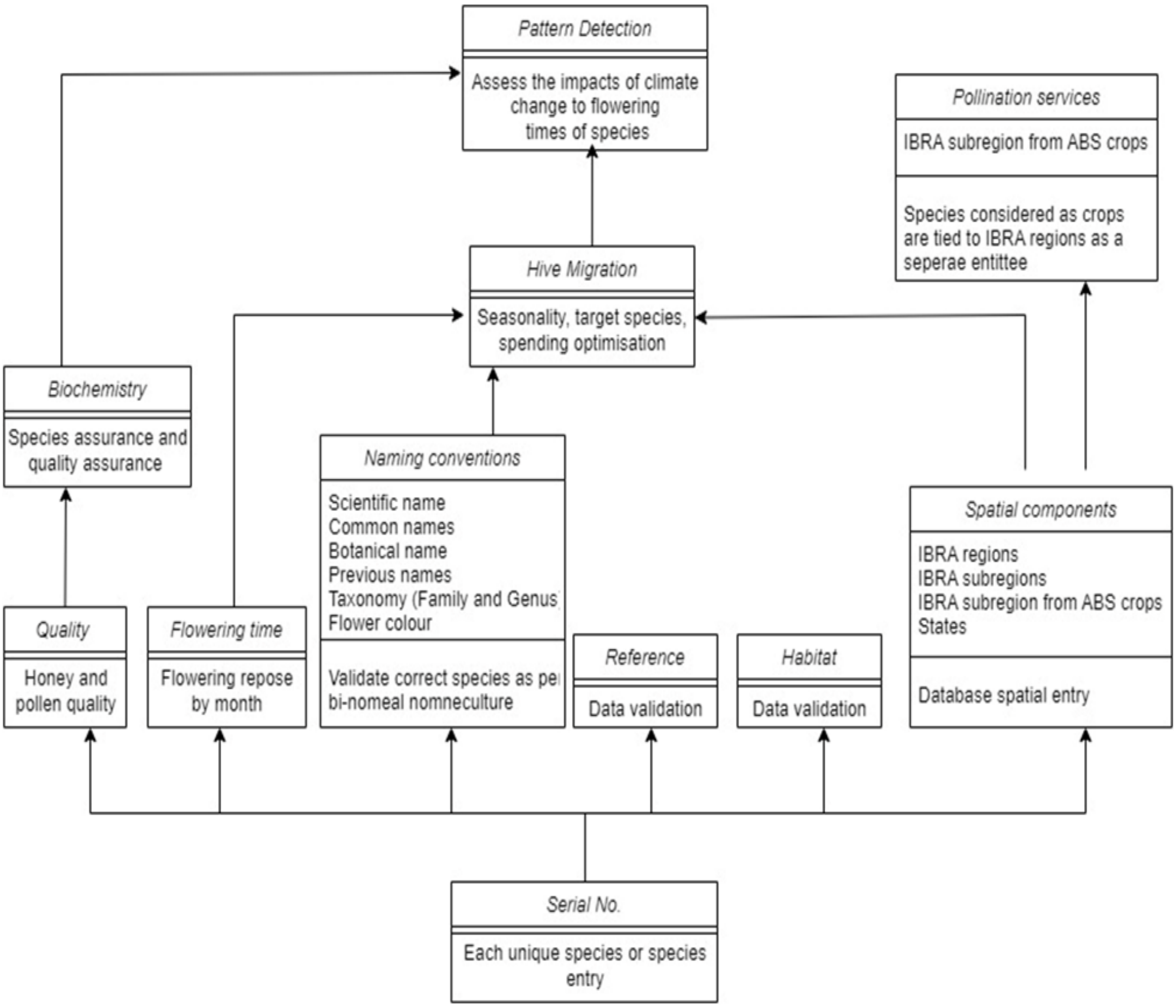

Figure 2 Diagram illustrating key components of the AMFD.

Species spatialisation

Spatialisation of each species was achieved by transposing Atlas of Living Australia (ALA) records into generalised presence in relation to the Interim Biogeographic Regionalisation for Australia (IBRA) Subregion dataset. Species occurrence data for each species found within the AMFD was obtained from Atlas of Living Australia. Where possible, a direct species match was used based on the species name unless the database contained records for subspecies. Each record was spatially filtered by the boundary of the Australian land mass as well as through the use of 'location uncertainties', 'environmental outliers' and 'spatial quality issues'. Presence data were obtained for each species as comma-separated values (.csv) file containing latitudes and longitudes for each collection sample. In the case of agricultural crops, 'Agricultural Commodities' data from the 2015-16 financial year was obtained from the Australian Bureau of Statistics (ABS) at the SA-2 level. For each crop species the associated commodity code for a 'number of trees of bearing age' where possible or the 'total plantation area' in hectares for crop production were extracted and if the condition 'greater than 0' was satisfied, the related SA2 boundaries were selected. As the ABS models this information, the relative standard errors were used as a filter of the records with a low probablility of occurrence. Only crops with a probability occurrence of 'greater than 50%' were selected for spatialisation. The IBRA Subregion in which each species can be found was attributed to the corresponding species record in the AMFD based on spatial congruence of ALA collection samples and the IBRA Subregion in which they were found (Figure 3).

Specifically, the location based '.csv' files were converted to a point feature class and then IBRA Subregions were extracted as ESRI shapefiles using the 'Select by Location' tool. IBRA Subregion information (unique ID) for which each species collection samples were found, was then attributed to each associated species. Similarly, SA2s for which a crop species was known to occur, were examined for spatial congruence with IBRA Subregions. Where congruence occurred, each species in the database was attributed with the corresponding IBRA Subregion information; i.e. unique ID (Figure 4).

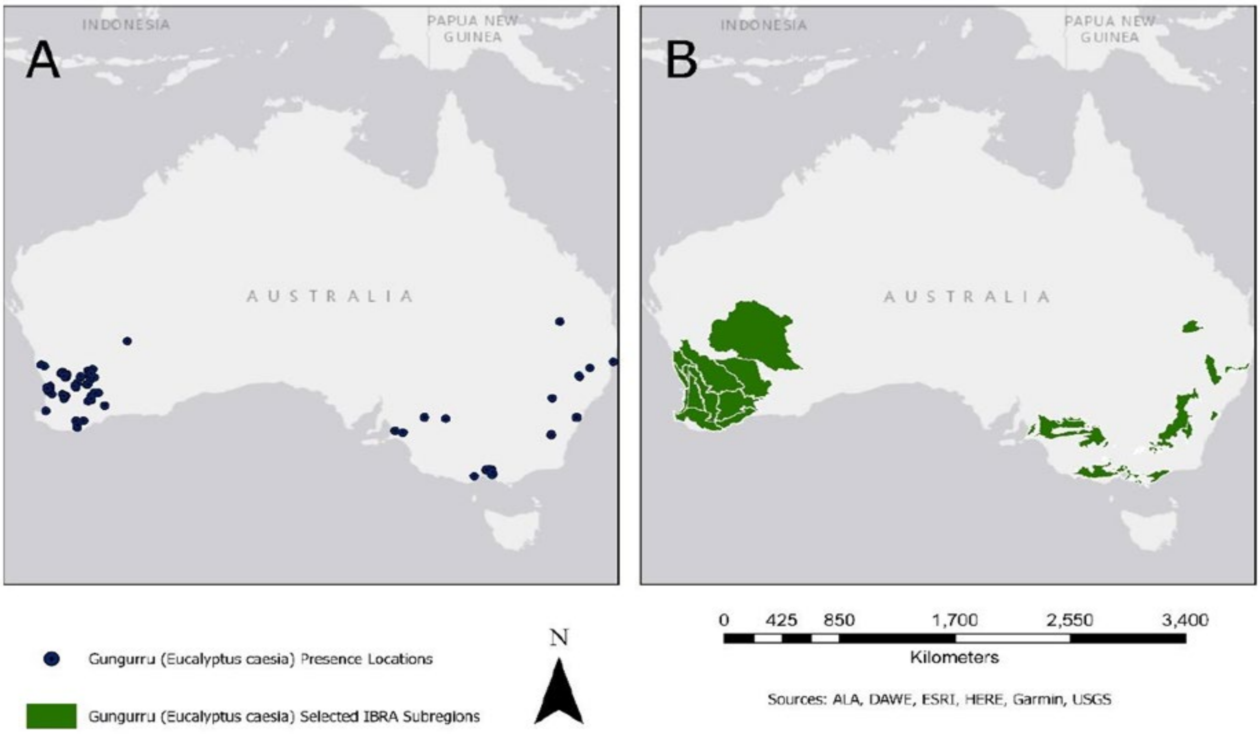

Figure 3 Point location dataset for Gungurru (Eucalyptus caesia) obtain from ALA (A) before subsequently using an overlay to obtain the relevant IBRA subregions across Australia (B).

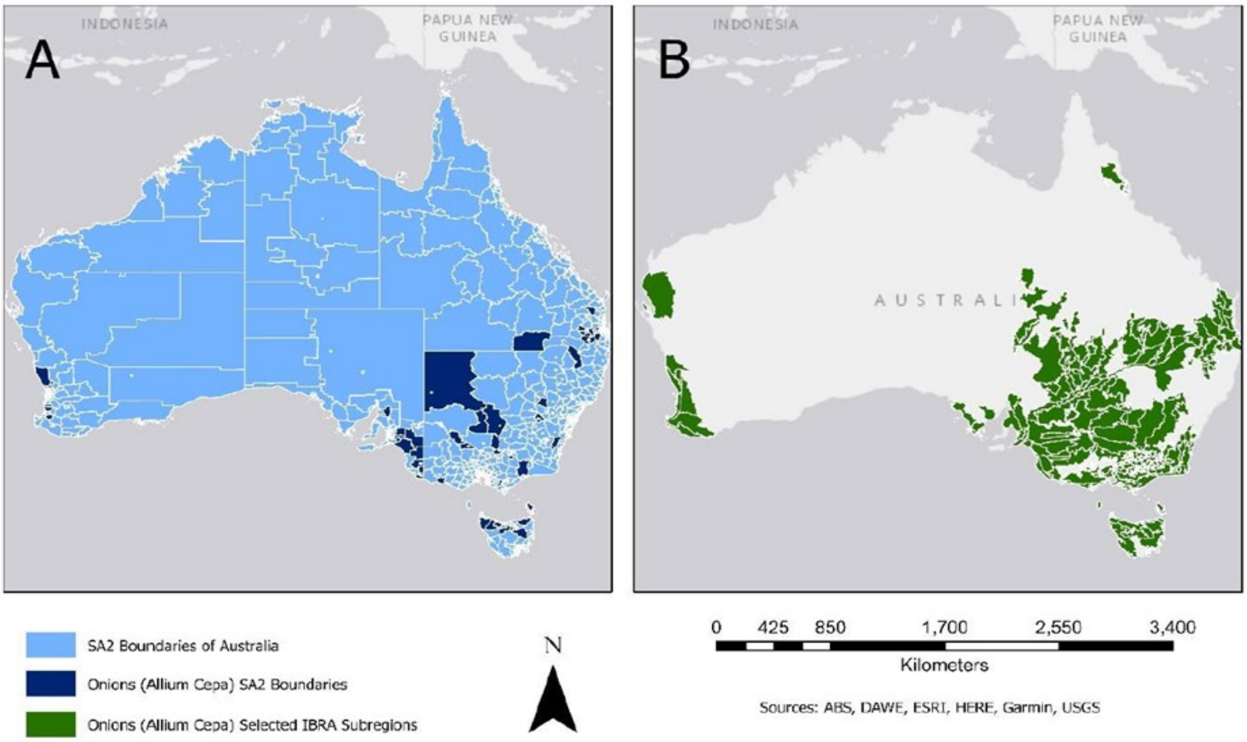

Figure 4 SA2 boundaries for Onions (Allium Cepa) identified in (A) before subsequently using an overlay to obtain the relevant IBRA subregions across Australia (B). Note some SA2 boundaries where Onions are known to be grown cannot be seen on the map as they are too small at this scale presented.

Application

Overview

The AMFD developed for this project has been applied to a number of case studies. This section highlights three applications of the AMFD as case studies to showcase the potential uses of the database in a diverse range of applications.

Case study 1: Hive migration scenario planning

Within Australia apiarists commonly access native flora for honey production. These sites, which may be found on both private and public land, together comprise an apiarist's portfolio of hive sites. Accessing the sites in a meaningful manner enhances production and maintains hive health and requires an apiarist to migrating hives from nectar flow to nectar flow. Hive migration scenarios can be constructed using the information contained in the AMFD. Using species information relating to the spatial location, flowering time, and honey and pollen quality of specific melliferous species, an apiarist can begin to plan their migratory pattern for the upcoming year.

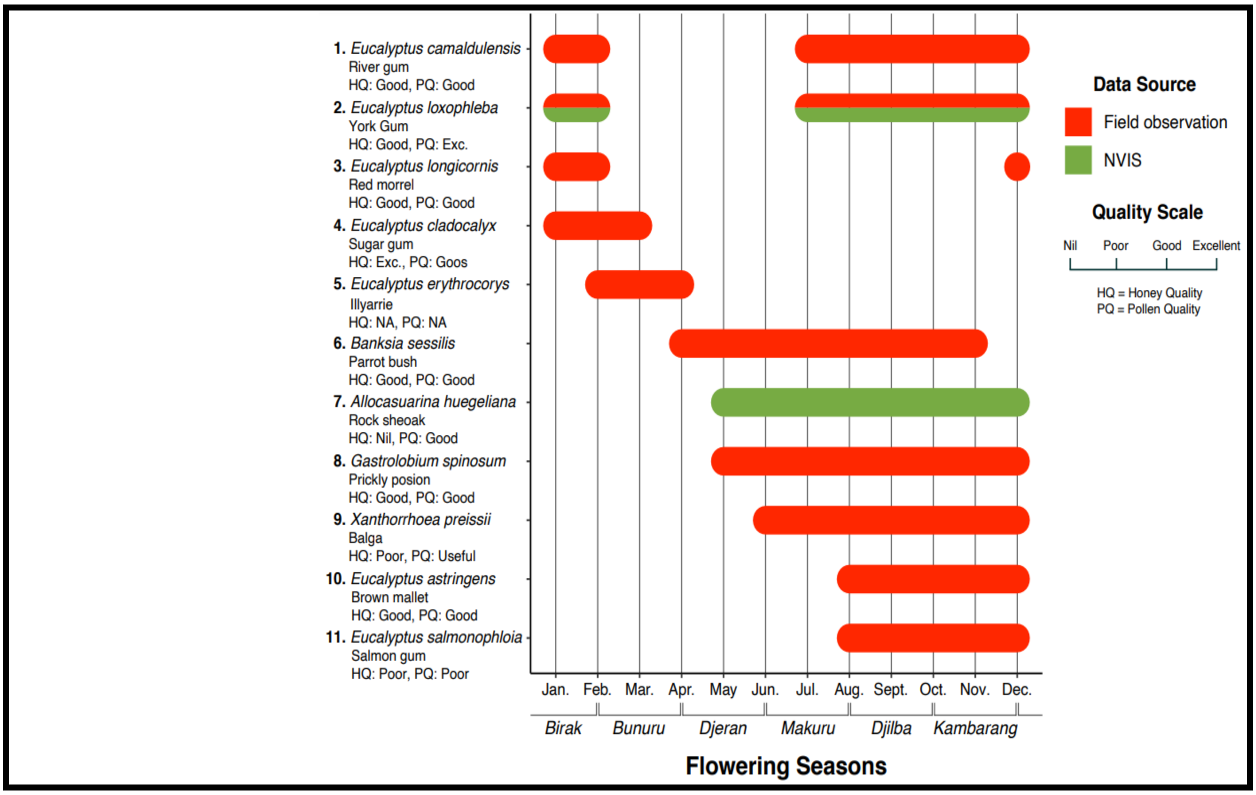

Figure 5 Melliferous species flowering chart for a member farm, example.

In this application, an Indigenous agricultural group was considering establishing a honey production business utilising native vegetation found across member properties in the southwest of WA. Vegetation on each property was mapped and field verified. Next, each farm's melliferous flora was compared with flower phenology of species across all of the company properties (Figure 5 provides an example of species flowering times of native flora found on a member property).

By understanding the presence, flowering times, and quality of melliferous flora across all the company properties, a plan was devised for migrating hives across member properties throughout the year (Figure 6). The migration plan considers honey production from the most lucrative species whilst maximizing bee health through access to a diversity of pollen resources.

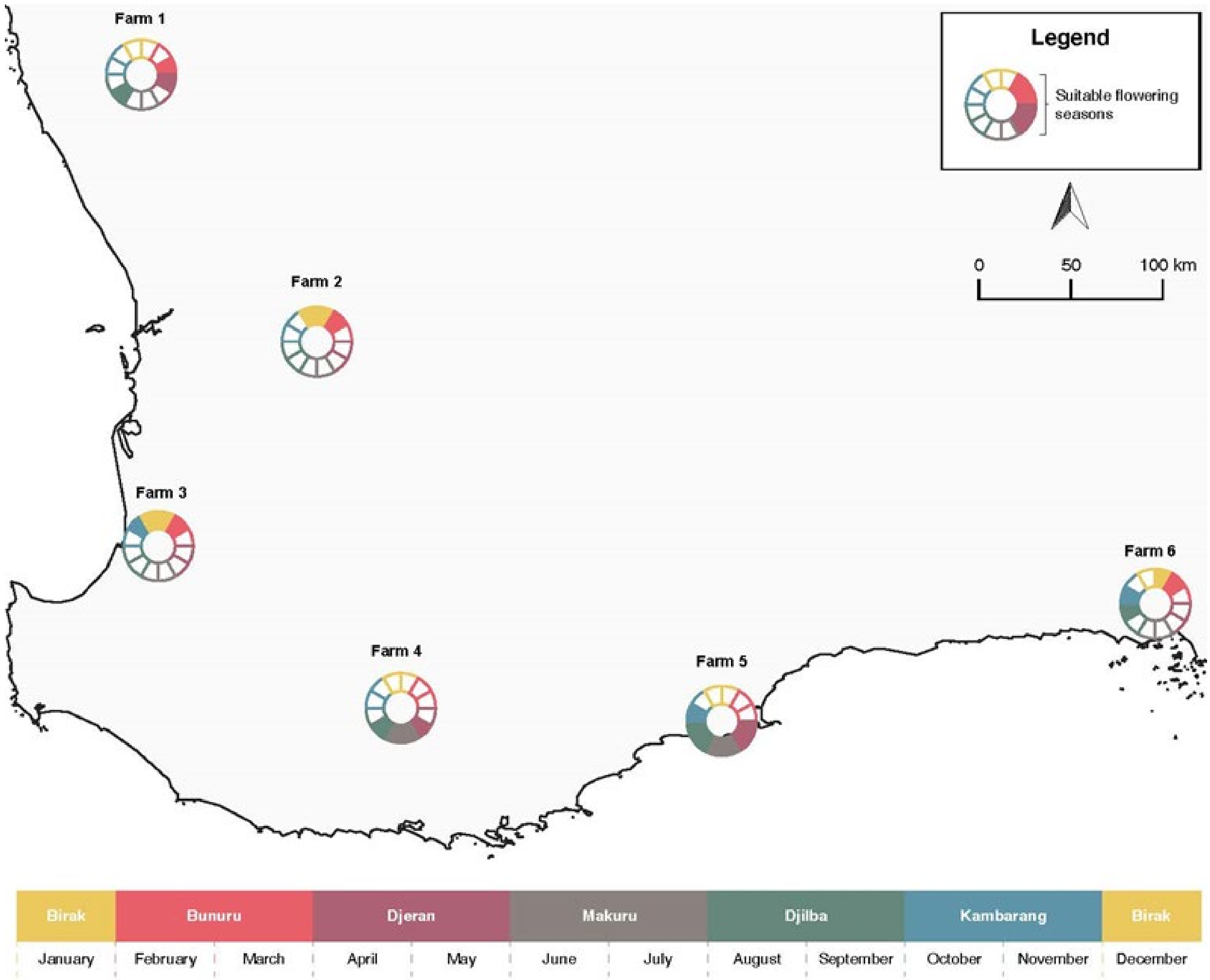

Figure 6 Hive Migration example targeting high value melliferous flora on member farms across the southwest of Western Australia

Case study 2: B-Agent – modelling pressures on migratory beekeeping

Migratory beekeeping depends on access to quality forage sites in order to maintain bee colony health and produce honey profitably. Decisions around beehive migration are mainly driven by availability and diversity of bee forage. While Australia is rich in floral diversity, land management practices, climate change, and irregular flowering events affect the availability of flowering bee forage at a given time. The goal of the model is to understand how pressures on floral resources may impact the forage landscape and thus the migratory beekeeping industry. This requires (i) identification of the key species targeted by beekeepers, (ii) an assessment of how the spatial patterns of flowering forage availability may change when pressures impact key forage species, and (iii) an assessment of how changing flowering forage availability may contribute to a change in beehive migration patterns.

Identification of key bee forage species provided the foundation for the *B-Agent* model, and Agent Based Model (ABM) that has been developed to mimic how apiarists move throughout the landscape to access floral resources. In this example, target bee forage species were first identified through consultation with WA commercial beekeepers (30 species identified). The AMFD was then used to confirm species scientific names and general geography as beekeepers often use common names when describing local vegetation. The spatial distribution of each species was then modelled using a Species Distribution Model (Maxent) for two scenarios: i. current species distribution, and ii. distribution under a future climate (2050). Flowering times were extracted from the AMFD for each species in order to understand the spatial distribution of flowering resources now and in relation to climate induced changes to the environment. The ABM was then used to model how an apiarist migrates their hives around the southwest of WA to take advantage of flowering floral resources. The model then allowed for an assessment of these same migratory patterns into the future to understand how climate change will impact the distances travelled when migrating hives to access flora in the future. Results indicate that by the year 2050, extra travel distance could increase business costs and the working hours of beekeepers significantly.

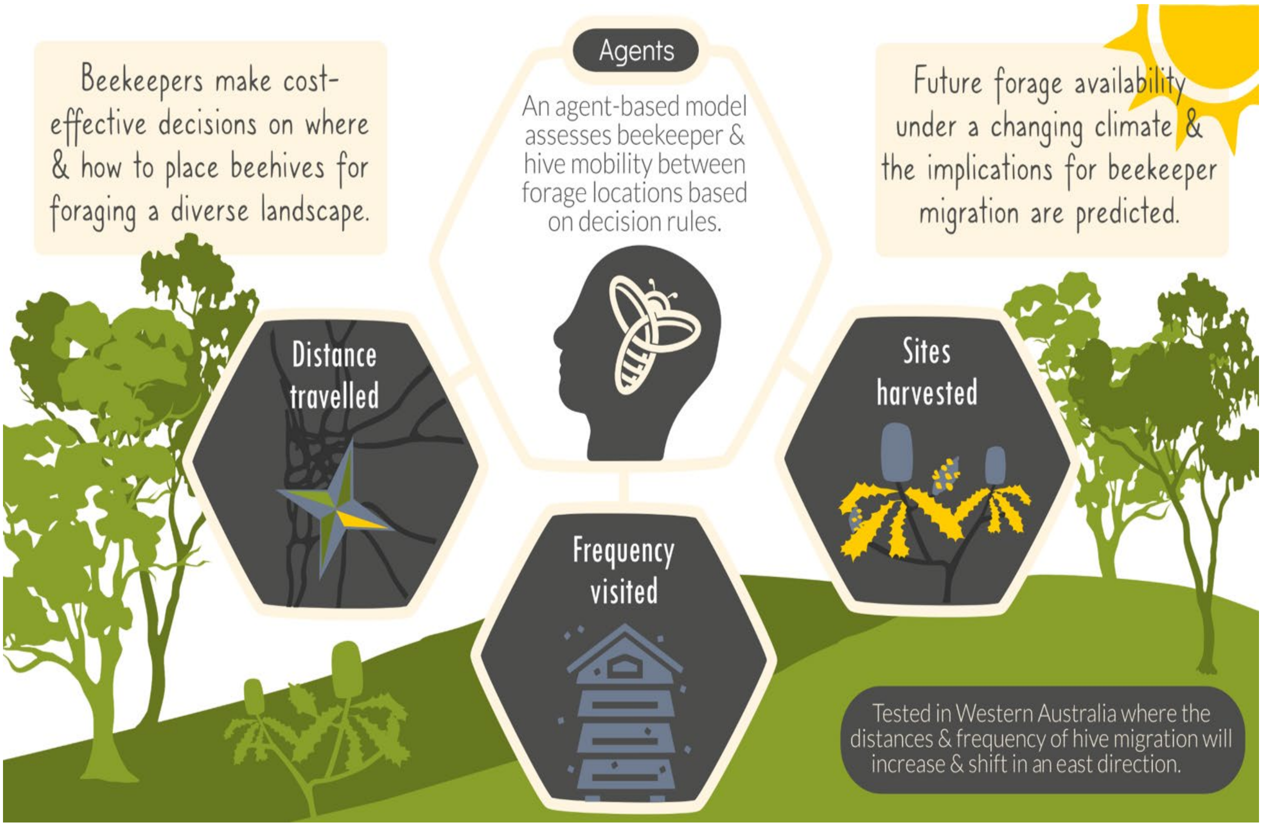

Figure 7 Info graphic describing the B-Agent model.

Case study 3: B-Spatial – Future-proofing bee hive site selection

Honey bee health and honey production depend on access to quality and abundant flora - the pollen and nectar produced by flowers when attracting pollinators. Australia's mild weather, large tracts of wild forest, woodlands and spring wildflower bloom are key to a successful beekeeping industry. However, Australian flowering events are often short lived (often only two to three weeks long) and are not a regular annual event, especially for flowering trees.

Understanding when and where flowering is likely to occur is vital for Australian beekeepers when selecting hive locations. Finding suitable sites is becoming more difficult as the landscape and flowering events adjust to shifts in the climate, land-use change and the impact of altered fire regimes.

Geographic Information Systems (GIS) can facilitate the use of landscape information, in space and time, to better understand the resources available to beekeepers across Australia. Combined with information on flowering season, pollen and nectar quality, rainfall data, and burn scar information to track flora recovery, GIS information can help beekeepers select their hive site destinations across the terrain.

Using information from the AMFD, the CRC for Honey Bee Products developed B-Spatial^{TM}, a decision support tool platform collating multiple sources of GIS data to help commercial beekeepers decide which of their many apiary sites to inspect for suitable pollen and nectar production to meet the food needs of their hives (Figure 8). Planning before they go into the field, B-Spatial^{TM} provides a GIS format for beekeepers to inspect a site, query information on resource availability and flowering times and integrate information from their own apiary sites. B-Spatial^{TM} presents data in visual easy-to-use maps and interactive tables.

Figure 8 Infographic describing the B-Agent model. B-Spatial^{TM} allows users to map, store, validate and access AMFD information, providing a digital diary of bee food resources.

E-diary functions within the platform, combined with the ability to link to the B-QUAL database, allows beekeepers to digitally track the history of their hive locations and harvest output – information that has not previously been collated. Bespoke to each beekeeper, this information supports planning to meet the demands of their hives and, when the times are tough, find new hive locations. As such, B-Spatial^{TM} provides an interactive and visually appealing platform for accessing the AMFD.

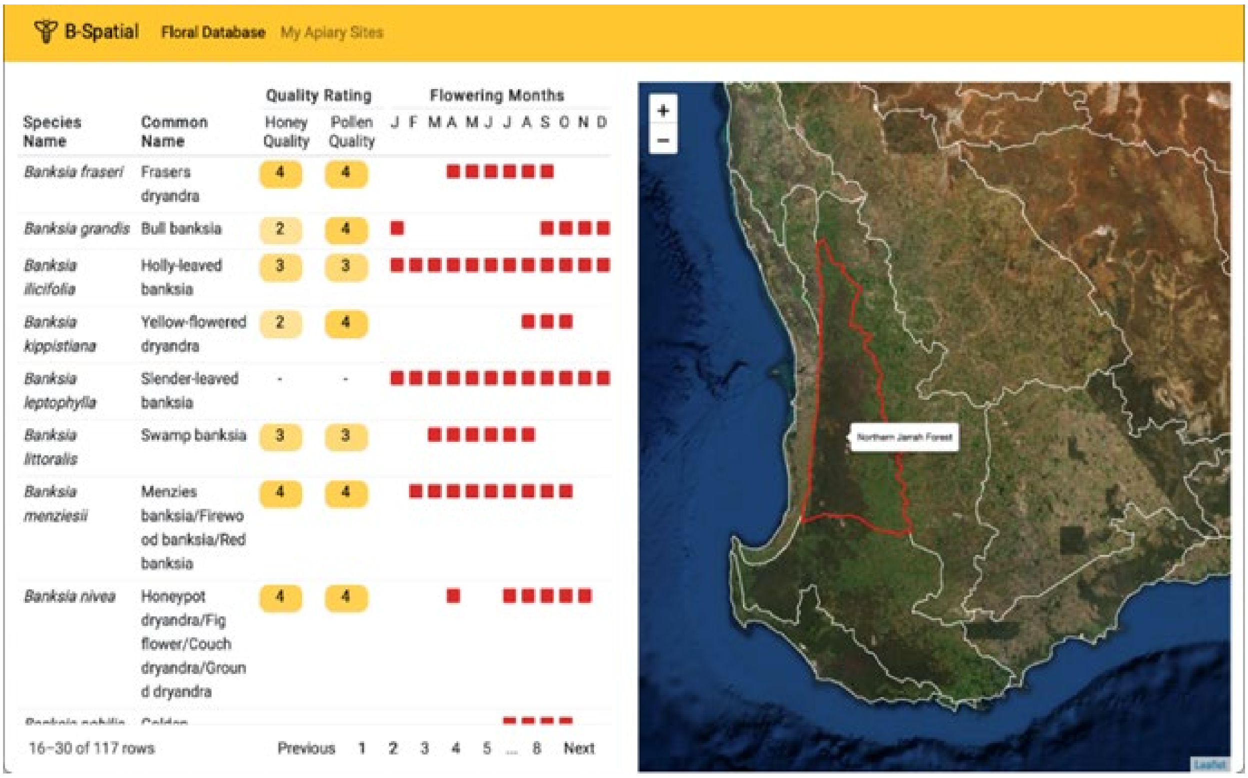

Figure 9 B-Spatial™ dashboard includes a map and an interactive table with species information

Conclusions

This report described the generation of the Australian Melliferous Flora Database – AMFD. The development of the database was motivated by the requirements of commercial and hobby beekeepers providing a valuable spatial planning too to support annual migration planning, identification of new sites and support traceability efforts tracking honey bee products from paddock to plate. Through a collaboration with a range of local, state and national organisation, the AMFD provides a one-stop-shop for understanding melliferous flora resource availability across the nation.

Through cataloguing and spatializing over 500 known melliferous flora species found across Australia the project has produced the largest known melliferous floral database available to the nation. We envisage that this product will be used by multiple disciplines, organisations and individuals to support the further development of the beekeeping industry of Australia.

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Appendices

Appendix A: Star rating

The star rating may assist in determining a priority rating by flora species when comparing potential apiary sites.

Table 2 The guiding principles for each species start rating.

STAR	INTERPRETATION
1	Of some value to honey bees for either pollen and/or nectar but regarded as incidental. Unlikely to be of sufficient value to purposely warrant transporting apiaries onto these flowering events. Collectively they may be of increased value where more than one species is in flower.
2	An improvement to one star rating and verging on a valuable source of either pollen and/or nectar, but not regarded of sufficient overall value to purposely transport apiaries onto these flowering events. May have higher nutritionally valuable pollen or maybe it regularly produces a greater volume of pollen seasonally.
3	Of reasonable value as a source of either pollen and/or nectar. The reliability of nectar yields may be variable and/or the pollen may be of low nutritional value or poor quantities may be gathered. Even so, in the event of no higher rating plants, these species should be considered, and their flowering periods investigated. From time-to-time plants in this category are very useful for commercial beekeeping purposes.
4	Plants in this group have an abundance of either pollen and/or nectar that is readily gathered by honey bees. Extractable quantities of honey in commercial volumes are regular and fairly reliable. The pollen may or may not be of high value. Plants in this category will be sought after by commercial beekeeping purposes.
5	In most circumstances plants in this group will be sought out by commercial beekeepers for their value as either a source of pollen and/or nectar. It is possible that some of the species may have little or no value as a source of pollen (e.g., yellow box, ironbark) but they are very reliable when it comes to nectar secretion and the production of marketable of quantities of honey.

This rating system has been adapted from Sommerville (2019).

Appendix B: IBRA7 Spatial Data Information

http://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B1273FBE2-F266-4F3F-895D-C1E45D77CAF5%7D

Representation Type: Vector

Equivalent Scale: 1: 250000

Topic Category: Environment and Conservation

ANZLIC Search Words: ECOLOGY Landscape and BOUNDARIES Biophysical

Spatial Extent:

West Bounding Longitude: 72.577376

East Bounding Longitude: 167.99814

North Bounding Latitude: -9.14129

South Bounding Latitude: -54.776993

West Bounding Longitude: 72.577376

East Bounding Longitude: 167.99814

North Bounding Latitude: -9.14129

South Bounding Latitude: -54.776993

Figure 10 Australia in geographical context

Appendix C: Infographic

Infographic providing an overview of the Australian melliferous flora database

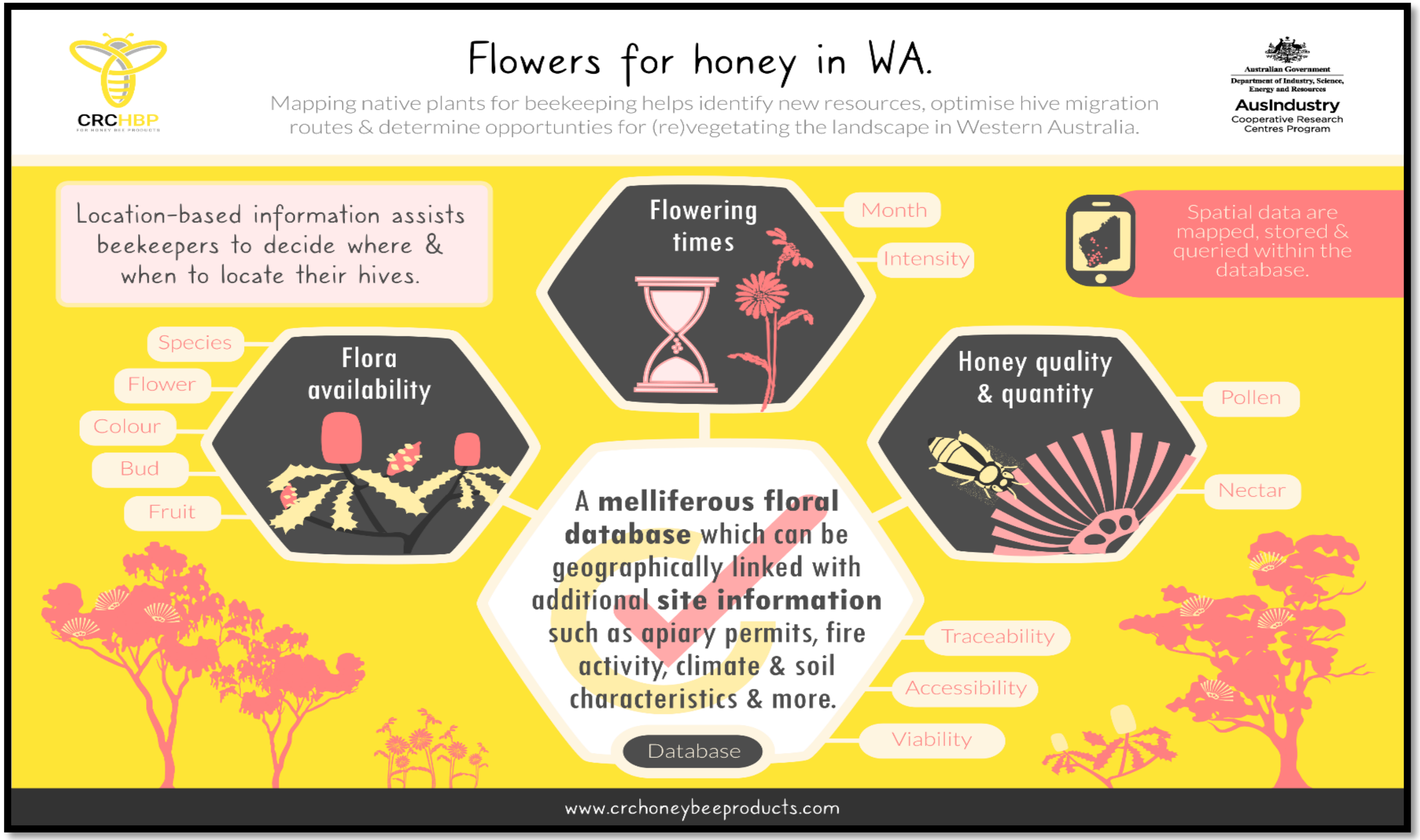

Figure 11 Flowers for honey in Western Australia

Australian Government
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