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Land Suitability Assessment in Melbourne's Green Wedge and Peri-Urban Areas

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Land Suitability Assessment in Melbourne's Green Wedge and Peri-Urban Areas

FINAL Report

1. EXECUTIVE SUMMARY

This report presents an analysis of the agricultural potential of Melbourne's Green Wedge and Peri-Urban Areas for soil based agriculture, which is defined as a 100km radius circle from the city's central business district (CBD), as it relates to climate change. This is in response to a request from the Victorian Department of Environment, Land, Water and Planning (DELWP) to prepare evidence to inform work to better identify areas of strategic agricultural land in Melbourne's Green Wedge and Peri-Urban area.

The Victorian Government's metropolitan planning strategy, *Plan Melbourne 2017-2050* sets out the government's long term plan to accommodate Melbourne's projected growth in population between now and 2050 whilst enabling Melbourne to grow more liveable, more sustainable and more prosperous. It outlines the government's policy positions to maintain a permanent urban growth boundary to contain Melbourne's outward growth and commits to "*protect agricultural land and support agricultural production*" (Policy 1.4.1). To deliver on this policy, the Plan Melbourne Five Year Implementation Plan includes Action 17, which states:

Plan Melbourne Action 17 - Support strategic planning for agriculture

Improve planning decision-making to support sustainable agriculture by identifying areas of strategic agricultural land in Melbourne's green wedges and peri-urban areas. This will give consideration to climate change, soils and landscape, access to water, integration with industry and significant government investment in agricultural infrastructure. It will also protect the right to farm in key locations within green wedges and peri-urban areas.

This report supports delivery of Plan Melbourne Action 17 by providing a strategic analysis of biophysical 'Land Suitability' through modelling the versatility of land for key crops under forecast climate changes in 2030, 2050 and 2070. Forecast changes to the climate, including increased temperatures, reduced rainfall, drought, flooding and extreme heat events, are expected to impact agriculture. Understanding the potential impact of climate change on agriculture in the region around Melbourne is a key aspect of the modelling used in this land suitability analysis. The modelling does not take into account adaptation actions, such as breeding and management practices, that may be adopted by farmers to mitigate the impacts of a changing climate. This analysis will be combined with other relevant considerations to assist in identifying areas of strategic significance and support better planning decision-making, this may include consideration of other land use values and industry considerations.

The modelling has been undertaken using soil input data from a complimentary and concurrent land capability study ("Assessment of Agricultural Land Capability in Melbourne's Green Wedge and Peri-Urban Areas") by Agriculture Victoria Research, over a time horizon from the present day to 2070. Looking so far into the future is inherently uncertain but for a sector such as agriculture, which is so highly exposed to climate change impacts, understanding the potential impacts of a changing climate is essential for long-term planning and resilience of green wedge and peri-urban agriculture.

Land Suitability is defined as the fitness of a given area of land for a distinct use (Food and Agricultural Organization of the United Nations, 1977). Differences in the degree of suitability are determined by the relationship, actual or anticipated, between benefits and the required changes associated with the use of the area of land in question. The temporal analysis considers the suitability of land based on soil input data combined with explicit consideration of the 'anticipated' relationships of this land to forecast climate change and water availability from either rainfall or through other potential sources, such as recycled water infrastructure.

An integral component of the biophysical Land Suitability Analysis approach used in this project comprised validation of model outputs with local farmers, which resulted in an iterative process of model optimisation. A first draft of the model output (map) for each section of the study region was generated and analysed by farmers through one-on-one semi-structured interviews. The analysis showed that the suitability of certain commodities will increase over time as the climate changes. Context is important and understanding how land-use will change outside the green wedge and peri-urban boundary is key, particularly from climate-driven changes to regional agricultural production. Temperatures across the state are expected to increase and rainfall is expected to decrease, with the most severe impacts in the north of Victoria. In the event that agricultural production in those regional areas declines in a climate-changed future, then the importance of agricultural land in the less affected parts of the state, including within the Green Wedge and Peri-Urban region, will increase.

The outputs presented in this report are the results of biophysical land suitability modelling of Melbourne's Green-Wedge and Peri-Urban areas, with inputs as described in Section 6. Current land uses (including land sizes), current agricultural productivity levels and current management practices have not been incorporated into these models. The analysis strictly covers the inherent biophysical characteristics that are important for the production of particular agricultural commodities into the future under climate change. As such, there may be inconsistencies between the modelling outputs and existing land use. These models are intended to provide a broad, landscape-level assessment of the potential suitability of agriculture in the context of projected climate change, and therefore represent one possible future scenario. With additional inputs, best practice management practices, agricultural innovations or different climate outcomes, a multiplicity of potential agricultural land-suitability outcomes are possible. This report presents the most probable scenario given current data and projections.

The analysis included twelve commodities as agreed on by the steering committee to represent a broad array of agricultural production in the study area.

The commodities included:

- Vegetables: a generic Brassica, Lettuce and Tomato variety (all run with irrigated models),
- Fruits: a generic early season Pome Fruit, generic early and late season Stone Fruit varieties (all run with irrigated models);
- Cropping, a winter red wheat and canola variety (all run with non-irrigated models),
- Pastures, a Perennial Ryegrass and generic Lucerne variety (all run with non-irrigated models).

The models were run with and without irrigation, as per the usual practice for each commodity. For those commodities that can be either irrigated or rainfed (cropping and pasture), non-irrigated models were used because the outputs would represent the likely situation in a greater proportion of the study area.

According to the analysis the areas projected to have the most suitable conditions (e.g. soil, water, landscape, climate) and greatest versatility into the future to accommodate productive agriculture for the identified commodities are:

1) Parts of the Dandenong ranges, extending down to the Bunyip food belt and up through the Yarra Valley to Healesville and Warburton;
2) The Gippsland region around Warragul and Drouin, extending up to Neerim North and south to Poowong;
3) Parts of the Mornington Peninsula, particularly around Rosebud and Red Hill;
4) Whittlesea and the region extending east through Kinglake and through to Toolangi;
5) Parts of the Central Highlands region, including Daylesford and surrounds, through to Tylden/Woodend and Kyneton in the north;
6) Gisborne and areas north bounded by Kilmore and Tooborac;
7) Parts of the region extending from Seymour/Tallarook through to Yarck;
8) Werribee South.

Some differences between the outputs of the 'suitability' and the complimentary 'capability' analyses are to be expected. Suitability uses a modelling approach that takes into account climate (and climate change), soil and topography to projects far into the future (to 2070). By comparison, the capability assessment uses an observational approach to describe and assess land with soil information and data as the primary input. Further information on how to interpret the suitability outputs provided in this report, including why they may differ from the capability outputs, can be found in Section 7.2.

It is also important to note that the land suitability mapping is undertaken at a broad regional scale and the outputs are intended for decision-making at the regional level, not at a farm or property level. Model caveats are addressed more fully in Section 7.3 of this report. Combining information from the land capability mapping (Agriculture Victoria 2018) and the land suitability mapping from this report, together with site-specific analysis, may allow decision-making at a more local level. This report is intended primarily to provide a foundation to understand the potential future context of strategic agricultural land in Melbourne's Green Wedge and Peri-Urban Areas, in a changing climate.

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5. INTRODUCTION

5.1. Background and Project Scope

This report presents an analysis of the agricultural potential of Melbourne's Green Wedge and Peri-Urban Areas, which is defined as a 100km radius circle from the city's central business district (CBD), as it relates to climate change. This is in response to a request from the Victorian Department of Environment, Land, Water and Planning (DELWP) for information to underpin better, evidence-based planning decisions over the short to medium term in relation to land-use in the Green Wedge and Peri-Urban area where urban-expansion is rapidly transforming the landscape.

Plan Melbourne 2017-2050 commits to "*protect agricultural land and support agricultural production*" (Policy 1.4.1). To deliver on this policy, the Plan Melbourne Five Year Implementation Plan includes Action 17, which states:

Plan Melbourne Action 17 - Support strategic planning for agriculture
Improve planning decision-making to support sustainable agriculture by identifying areas of strategic agricultural land in Melbourne's green wedges and peri-urban areas. This will give consideration to climate change, soils and landscape, access to water, integration with industry and significant government investment in agricultural infrastructure. It will also protect the right to farm in key locations within green wedges and peri-urban areas.

This report supports delivery of Plan Melbourne Action 17 by providing a strategic analysis of biophysical 'Land Suitability' through modelling the versatility of land for key crops under forecast climate changes in 2030, 2050 and 2070. This analysis will be combined with other relevant considerations to assist in identifying areas of strategic significance and support better planning decision-making.

As per the accepted project proposal provided by Deakin to DELWP, the analysis was carried out using a biophysical 'Land Suitability' with a temporal approach over a time horizon from the present day to 2070. Soil input data was obtained from a complimentary and concurrent land capability study ("Assessment of Agricultural Land Capability in Melbourne's Green Wedge and Peri-Urban Areas") by Agriculture Victoria Research.

Suitability and *capability* are two words that are often used interchangeably with respect to landscape ecology and associated analyses. However, the two terms are distinct and refer to different methodological approaches. In general, *Land Capability* is a specific classification scheme devised by soil scientists that refers to groupings of soil into units, classes and sub-classes according to their potential uses and the management options required to ensure their continued use (e.g. Brady, 1974).

Land Suitability, on the other hand, is defined as the fitness of a given area of land for a distinct use (Food and Agricultural Organization of the United Nations, 1977). Differences in the degree of suitability are determined by the relationship, actual or anticipated, between benefits and the required changes associated with the use of the area of land in question. The explicit consideration of the 'anticipated' relationships between land use and benefits is important because it provides the means to incorporate a temporal component to the analysis – in the context of the problem being addressed here, that includes temporal issues like climate change. Following Steiner (2008), we therefore consider that *Land Suitability Analysis* is the process of determining the fitness, or appropriateness, of a given area of land for a specified use. *Capability* is then a largely static assessment based on soils, while *Suitability* is a more holistic assessment that can include spatial (soil, landscape, land cover, etc) as well as temporal (climate, water availability, etc) factors.

Other approaches related to Suitability and Capability assessments include, soil class classification systems like that of the Natural Resources Conservation Service from the US Federal Government, the Agricultural Land Evaluation and Site Assessment system (and various modifications from Arizona State University and others), Important Farmland Classification scheme (USDA), Land Suitability Assessment (McHarg and University of Pennsylvania approach), Dutch Suitability Analysis system (including 'actual land suitability', 'soil suitability' and 'potential land suitability' as defined by University of Amsterdam).

Given the number of methods in use around the world, a brief summary of their evolution over time has been provided in Appendix I. This is intended as a basis for planners to better contextualise the genesis of land suitability information and therefore better understand how it can be interpreted and used for planning purposes.

5.1.1. Project Stages

The project was delivered in four stages. Agriculture Victoria Research generated outputs (soil data) in stages that formed inputs to the biophysical Land Suitability Assessment by Deakin. This data was post-processed into a raster based GIS format that could be inserted into the models (discussed in Section 6**)**.

- **Stage 1** – South East
- **Stage 2** – North East
- **Stage 3** – North West
- **Stage 4** – South West

6. PHYSICAL ENVIRONMENT

6.1. Soil

Soil type (Isbell and CSIRO, 2002) is one of the most important factors that influences land utilisation. It provides the physical, chemical and biological-activity basis required for plant growth. All soil data and information was sourced directly from research undertaken by Agriculture Victoria Research, presented in the report *Assessment of Land Capability in Melbourne's Green Wedge and Peri-Urban Areas* in order for the two studies to be fully comparable. These soil datasets were converted from the original feature class datasets with accompanying database to a raster grid formation at a typical resolution of $30m^2$. Some of the data with Land Units within the Greater Melbourne land survey (although outside the Urban Growth Boundary) did not have all fields and attributes associated. This may be due to the restriction of land units within surveys that encompass urban and public land. In these areas the classification was translated into a classification of 'unsuitable' due to having insufficient input data for the suitability models, however for the general purposes of this study the coverage of the data is adequate for general observation of landscape scale trends.

Soils attributes, as used in land-use suitability modelling, can be categorised into two broad groups; physical attributes and chemical attributes. Physical attributes relate to the actual physical properties of the soil and include measures such as texture or soil horizon depth. Measurements are usually done in the field. Chemical attributes relate to the chemical composition of the soil and can include soil nutrient composition or soil pH.

6.2. Landscape

A Victoria wide Digital Elevation Model (DEM) provided the basis for landscape analysis. This existing in raster grid format with a grid cell resolution of $100m^2$. This data set represents the ground surface topography or terrain of Victoria. The dataset allowed the calculation of critical geographic features such as slope, altitude and aspect. The DEM was been sourced from NASA's Shuttle Radar Topography Mission (SRTM) landscape dataset (NASA and USGS, 2014), which is supplied at 1 arc second (equivalent to a 30 metre resolution). This is hosted in conjunction with the United States Geological Survey (USGS).

6.3. Climate

6.3.1. Observed Climate

Past and current climate data was obtained through the SILO Project (Jeffrey et al., 2001), which is hosted by The Science Delivery Division of the Queensland Department of Science, Information Technology, Innovation and the Arts (DSITIA), and the *WorldClim* Global Climate Data online database. SILO is based on Bureau of Meteorology (BoM) climate data and includes multiple datasets of variables such as temperature and rainfall. The data is Victoria-wide and is presented at a resolution of 5 km2 (grid). The *WorldClim* database is an online spatial dataset with a spatial resolution of 1 km^2. The layers are generated using interpolation of available monthly readings from weather stations on a 20 arc-second resolution grid (comparable to 1 km^2 resolution spatially). The dataset also includes variables of rainfall, temperature and additional bioclimatic variables for the years 1950 – 2000. This is commonly used in climate studies as the 'climate normal', which is used as a reference period for comparative purposes between current, historical and future climates. Generally, the climate normal period is calculated over thirty years, which is long enough to include year to year variations but not that long to allow it to be influenced by long term climate trends. The World Meteorological Organisation (WMO) uses the period of 1961 to 1990, which is also used in Australian meteorological references. For use in this project a climate normal period was used as a baseline comparison against future climate projections and simulated suitability analyses. The climate normal, hereafter, will be referred to as the 'historical' or 'baseline' climate.

6.3.2. Future Climate

Future climate projections were developed through the use of the CSIRO ACCESS 1.0 Global Climate Change Model (GCM). This was run through the emissions scenarios or *Representative Concentration Pathways* (RCP), 8.5 for the years 2030, 2050 and 2070. RCP8.5 is a scenario in which global temperatures reach on average, temperatures that are 4^0C warmer than pre-industrial averages by 2100. The Interim Emission Reduction Targets for Victoria Issues paper notes that 'over recent decades, global greenhouse gas emissions have been growing at a rate similar to RCP8.5 (IEPIT, 2017). The RCP8.5 scenario assumes a rising greenhouse gas concentration over time, representative of a scenario leading to high greenhouse gas concentration levels by 2100. It is the highest representative concentration pathway as described by the Intergovernmental Panel on Climate Change. The RCP8.5 scenario was chosen as it is reflective of the global situation currently, as also confirmed by the most recent Intergovernmental Panel on Climate Change (IPCC) summary report on the impacts of global warming of 1.5^0C above pre-industrial levels and related global greenhouse gas emission pathways (IPCC, 2018)..

In this study, the atmospheric content of the GCM model for RCP8.5 has been used to generate monthly based data inserted into the models to measure against comparative historical averages for the same monthly timeframes.

To model the possibility of an alternate future scenario with more water availability, either from precipitation or the provision of alternative water sources, a second water scenario was undertaken in which 20% was added to the precipitation models (2030, 2050 and 2070) (see Section 7.11 for more details).

Figure 6.1 shows the mean temperature for Melbourne's Green Wedge and Peri-Urban Areas (averaged annually over the 12 months). The left panel depicts the SILO baseline historical mean average from 1960 to 1990. The panels to the right show the RCP 8.5 projection annual mean, averaged monthly for 2030, 2050 and 2070. Figure 6.2 shows the average total annual precipitation for Melbourne's Green Wedge and Peri-Urban Areas. The left panel depicts the SILO baseline historical average total from 1960 to 1990. The panels to the right show the RCP 8.5 projection precipitation, averaged annually for 2030, 2050 and 2070.

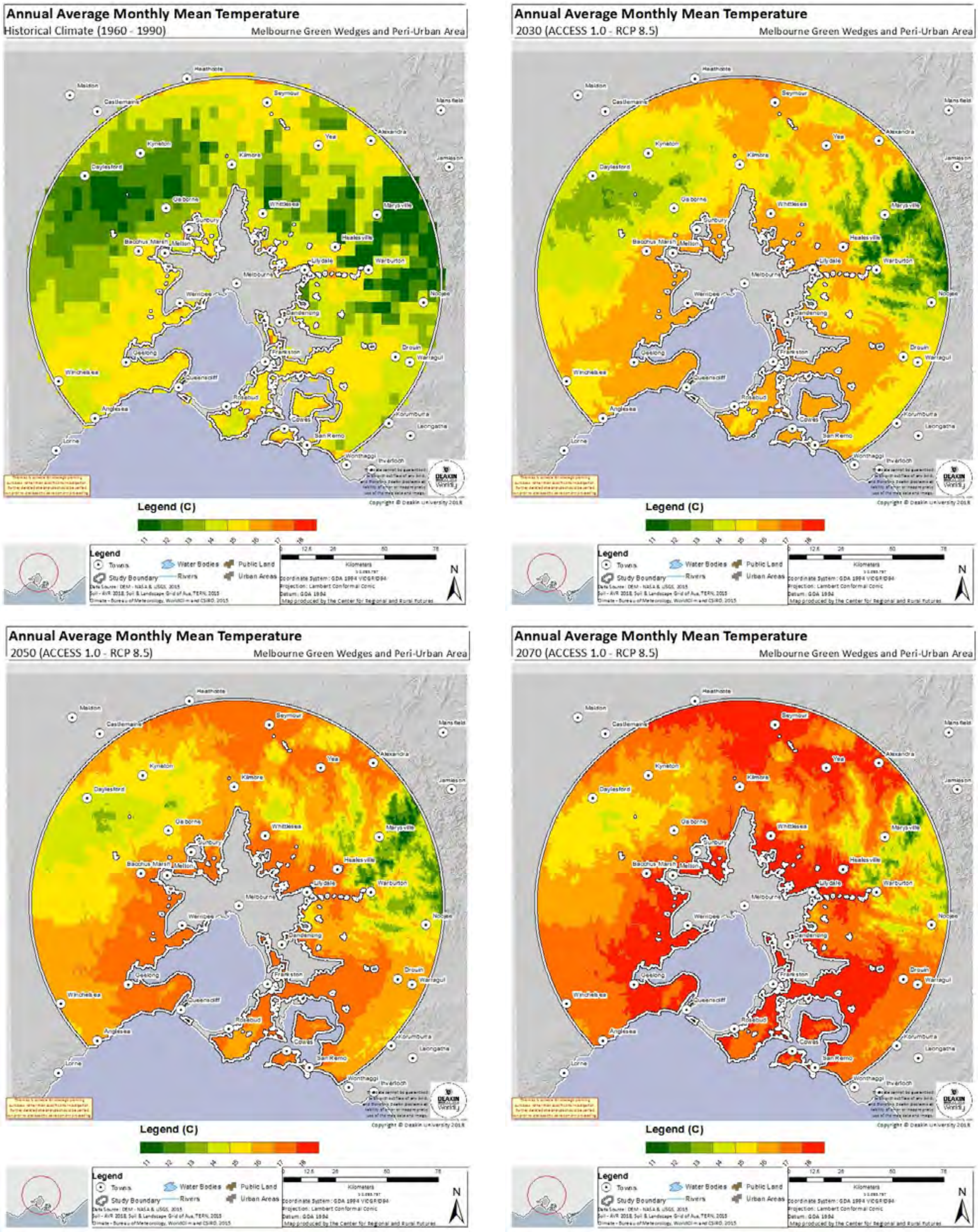


Figure 6.1 Average Annual Monthly Mean Temperature (L-R Historical, 2030, 2050, 2070)

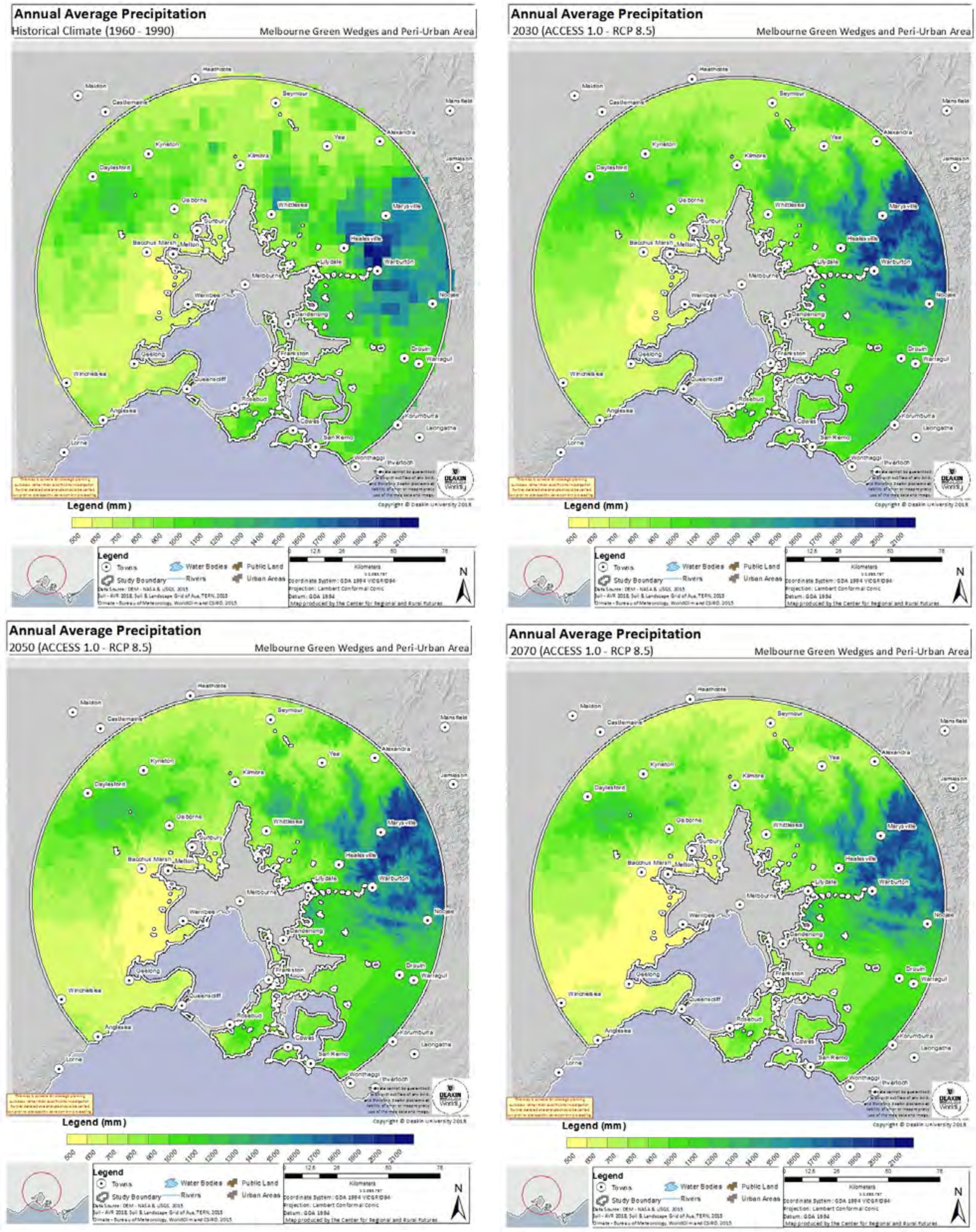


Figure 6.2 Average Annual Precipitation (L-R Historical, 2030, 2050, 2070)

6.4. Land Use

Figure 6.3 depicts land use in the Green Wedge and Peri-Urban areas of Melbourne as classified by the Australian Land Use Manual (2017) grouped into sub-classes of the six primary classifications:

1. **Conservation and Natural Environments**: Land is used primarily for conservation purposes, based on the maintenance of essentially natural ecosystems already present.
2. **Production from Relatively Natural Environments**: Land is used mainly for primary production based on limited change to the native vegetation.
3. **Production from Dryland Agriculture and Plantations**: Land is used mainly for primary production, based on dryland farming systems.
4. **Production from Irrigated Agriculture and Plantations**: Land is used mainly for primary production, based on irrigated farming.
5. **Intensive uses**: Land is subject to substantial modification, generally in association with closer residential settlement, commercial or industrial uses.
6. **Water**: Although primarily land cover types, water features are regarded as essential to the classification.

Land use in the Green Wedge and Peri-Urban areas of Melbourne is largely production from dryland agriculture and plantations with large areas of urban usages on the fringe of metropolitan Melbourne and parks and conservations areas to the east and north-west.

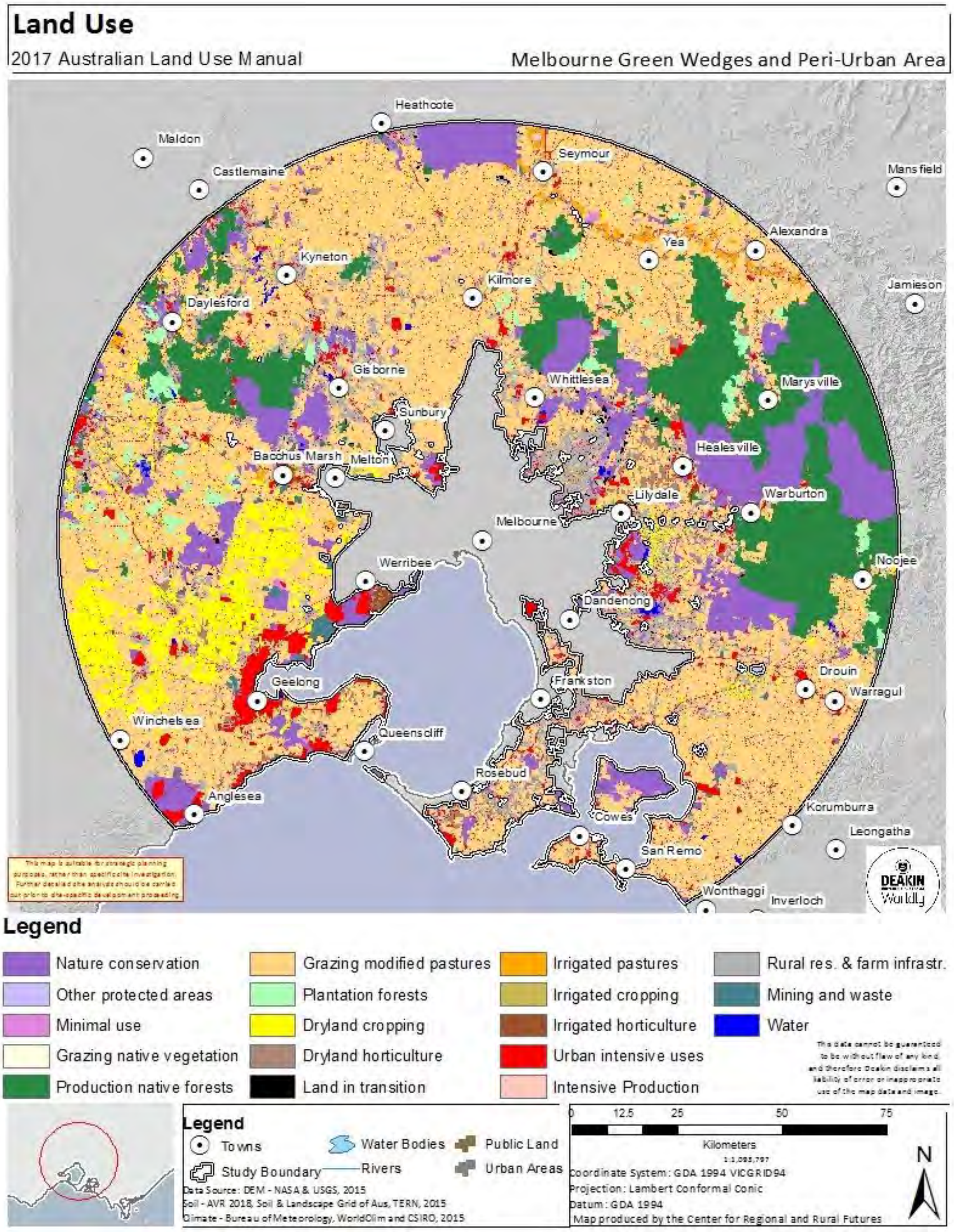


Figure 6.3 Land Use in the Green Wedge and Peri-Urban Area of Melbourne

7. LAND SUITABILITY ANALYSIS

7.1. Method

In order to understand how projected climatic changes impact on agricultural production, we have followed the approach as discussed in this Chapter. In short, we use a Multi Criteria Analysis (MCA) applied with an Analytical Hierarchy Process (AHP) in a Geographic Information Systems (GIS), to spatially represent the biophysically suitability of land for a particular commodity. The approach has been published (Sposito et al 2013) and applied extensively across Victoria (Faggian et al 2016) and in other parts of the world. An important point to note is that the underpinning AHP and land suitability models allow for experts' participation in the decision making process. Compared to empirical models, an expert systems model such as this one explicitly incorporates the 'subjective' knowledge of experts who have understanding of the system of concern. This is an essential step in regional and local suitability analysis because often regional empirical data is lacking in detail or resolution and therefore expert based knowledge can fill the gaps. The key to using expert knowledge as a data input is to ensure that a consensus position is achieved from all contributors on the weighting of each criteria (see also Section 8.2).

It should be noted that the models look specifically at biophysical suitability and deliberately do not consider human-influenced parameters such as farmer management practices. This is to enable a more objective comparison of one geographical area versus another, where only the *intrinsic* biophysical features of the study region inform the model outputs. This eliminates spurious results that reflect bad practices or are the result of farming systems establishing and developing over time in areas not particularly suited to such a commodity (which has occurred in some areas because of settlement patterns or soldier resettlement policies). The analysis also does not account for farm improvement practices where less favourable conditions are improved by good land management practices.Irrigated crops are assumed to have some portion of their water requirements met as a parameterised setting within the model. That is, we assume that some water is supplied by irrigation, regardless of its availability, and then suitability is defined as plant water requirements move up or down around that water threshold. In this situation, we can assess whether geographical areas have the potential to support irrigated crops if water infrastructure was introduced in the future, or if irrigation water supply levels changed.

Figure 7.1 depicts the methodology used in this study, illustrating the key inputs in the model (discussed in Sections 6.1 to 6.3) and the key commodity grouping analysed: Crops, Fruits and Vegetable Horticulture and Pastures. The outputs of the model are then used to create various scenarios of agricultural versatility for use in identification of strategic prioritisation and subsequent regional analysis.

7.1.1. Suitability modelling Framework

The United Nations Food and Agricultural Organisation (FAO) have an established framework structure for the assessment of suitability for any type of land use and cover (FAO, 1976). This structure is hierarchical in design and comprises of Orders, Classes, Subclasses and Units. Suitability Orders indicate if a unit of land is Suitable (S) or Not Suitable (NS). Suitability Classes are used to reflect degrees of suitability, with three base classes defined; High, Moderate and

Low Suitability. Furthermore, the Not Suitable order can be divided into two classes; Currently Not Suitable and Permanently Not Suitable. If necessary, in a given analysis, the Classes can be divided into Subclasses, which reflect types of limitation in a Class. Further to this Subclasses can be divided into Units, which are used to show production characteristics or other requirements.

For the purposes of this study, the FAO suitability framework was adopted in modified fashion. The two principle suitability orders, S and NS, were maintained but NS was further defined into Permanently Not Suitable (PNS) and Temporarily Not Suitable (TNS). *Permanently Not Suitable* denotes land with some characteristic that is difficult to manage and makes the production of a given commodity difficult – an example would be temperatures well outside the optimum range for field-grown crops. *Temporarily Not Suitable* denotes land with some characteristic that could be altered by the farmer to make it more suitable for a given crop, if said farmer was willing to invest the time and resources to do so – an example would be raising soil pH by the application of lime. Furthermore, four suitability classes were utilised rather than three; High, Moderate, Low and Very Low.

The outputs of the models are represented as maps with suitability classes represented in colour across the map. Dark green represents areas where the model predicts high yields could be achieved, and as the suitability decreases, so too does yield and this is represented by lighter shades of green and eventually yellows. Areas of public land (such as national and state parks) are excluded, as are built-up urban areas.

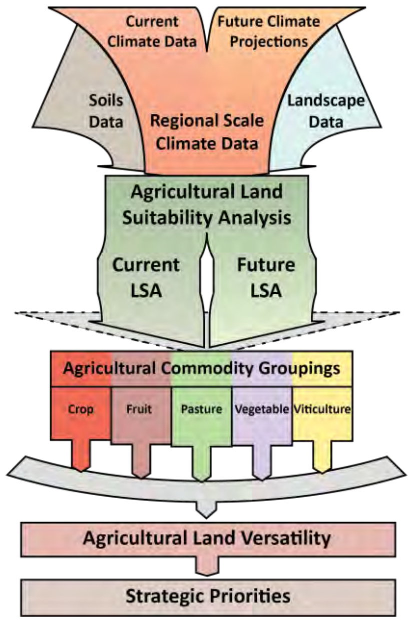


Figure 7.1 Land Suitability Analysis Methodology

7.2. Interpreting the land suitability maps for Melbourne's Green-Wedges and Peri-Urban Areas

The land suitability models deployed in this study ultimately produce a score between 1 and 0, where 1 is land that is assessed as being 100% suitable for a particular commodity and 0 is land that is assessed to be completely unsuitable. The scoring is linear, so 0.8 equates to 80% suitable, 0.5 equates to 50% suitable, and so on. The scores are aggregated into 10 percentage points steps that are represented by a single colour – for example, 0.8 – 0.89 are represented on the maps by a dark shade of green and indicate an area with high suitability, whereas 0.7 – 0.79 are represented by a lighter shade of green and indicate areas that are still suitable but less so than the aforementioned rating range.

It is also important to understand, broadly, how the scores are derived, in order to understand what 'suitability' means and how it might differ from 'capability'. Figure 7.2 shows a simplified version of a typical analytical hierarchy, which underpins the suitability models. In developing the hierarchy, we ask farmers and other commodity experts to decide what biophysical parameters are important to produce a good yield of a particular crop. For example, "what is more important for apple production – climate or soil?" We then ask for the importance of that parameter to be weighted relative to others; "How much more important is climate than soil for the production of apples?" Thus, the top level of the hierarchy is determined and in the example provided here, that is 35% soil and 65% climate, which means that farmers and other experts agree that climate is roughly twice as important a factor as soil. Underneath each factor, we then establish further categories and assign further weightings of importance; Soil A is assigned a score of 1 because it is considered ideal for that commodity, while Soil B is assigned a score of 0.5 because it is not ideal (and a score of 0 would be completely unsuitable). This system is used to construct the full model, which may contain many factors. Some factors will be informed by separate mathematical processes, such as calculations of evapotranspiration to inform the irrigation requirements of a crop, or chill unit calculations to inform the optimal temperature ranges of crops.

The fact that individual factors are weighted is important and the magnitude of the weightings can have a significant influence on the final model output. For example, the simple analytical hierarchy process in Figure 7.3 has climate weighted at 65% relative to soil at 35%. Therefore, if we assess a geographical location with ideal climate (Climate A) and marginal soil (Soil B), the final suitability score will be 0.825 (82.5%), or highly suitable. This is because climate is considered more important and therefore a location with the most suitable climate is more likely to enable the production of the commodity in question at high yields. Similarly, a geographical location with marginal climate (Climate B) and ideal soil (Soil A) will have a final suitability of 0.675 (67.5%), which is relatively low suitability (Figure 7.4) Again, this is because of the heavy weighting towards climate. It is for this reason that 'suitability' and 'capability' assessments can show discrepancies when assessing the same geographical areas. Capability looks only at soil and therefore soil is effectively 'weighted' at 100%, whereas 'suitability' considers climate and potentially other parameters and therefore no single factor can ever be weighted at 100%. This manifests in the outputs as some areas of capability and suitability not aligning on final maps, and particularly in situations where climate is accentuated where the weighting of climate is high.

However, this situation highlights one of the benefits of the suitability approach – it allows the consideration of multiple factors in order to arrive at a decision about the best geographical location for a particular commodity. The process mirrors real-life decision making in that compromises are made between factors that are not strictly limiting. For example, climate is harder to modify than soil, so farmers looking to establish certain farming systems where climate is critical will prioritise locations with ideal climate over locations with ideal soil.

In addition, the methodology deployed here looks only at biophysical factors and does not consider farmer management practices. The intervention of the farmer can have a profound effect on the yield they achieve and therefore on the suitability of a particular geographical location for a particular commodity. For example, soil pH can be modified by the addition of lime and insufficient rainfall can be ameliorated by irrigation. There will also be additional factors that impact on suitability – for example, the soil in some areas identified as suitable may actually contain rock that makes production difficult or expensive. However, it is expected that the combination (overlaying) of the suitability and capability maps will allow such instances to be identified and highlighted in any composite, final map product.

A full explanation of the methodology is provided in Sposito et al 2013.

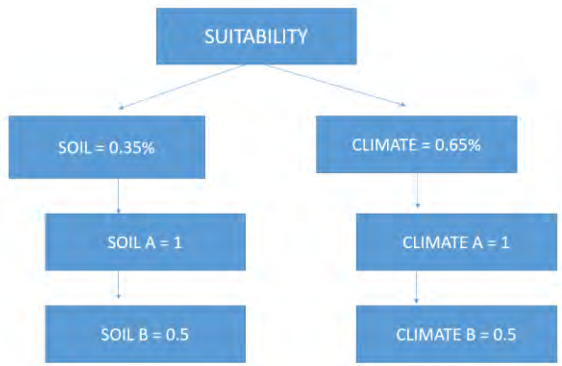


Figure 7.2 Generic Land Suitability Analysis hierarchy

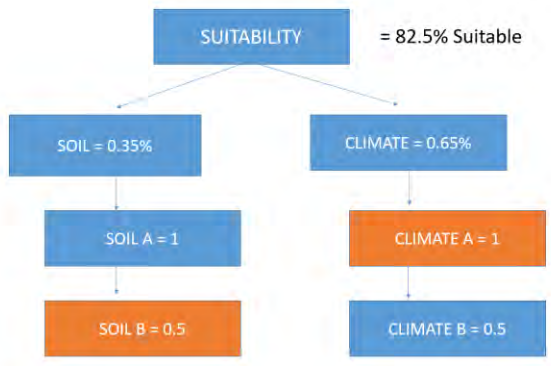


Figure 7.3 Simple land suitability assessment where a location has ideal climate and marginal soil, resulting in a suitability rating of 82.5%.

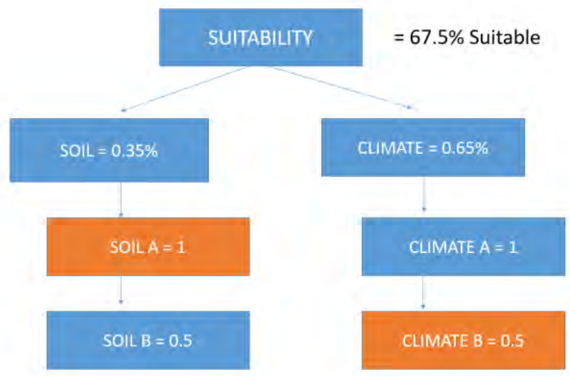


Figure 7.4 Simple land suitability assessment where a location has marginal climate and ideal soil, resulting in a suitability rating of 67.5%.

7.3. Model Validation

An integral component of the biophysical Land Suitability Analysis approach used in this project comprises validation of model outputs with local farmers and the iterative process of model optimisation that results. A first draft of the model output (map) for each section of the study region was generated and analysed by farmers through one-on-one semi-structured interviews. The selection of farmers was based initially on existing contacts within the study region, including with farmers that had previously assisted with model validation in earlier projects. Additional farmers were suggested by their peers or by local government staff that engage with farmers (e.g. agribusiness officers).

This phase of the research proved somewhat difficult. In general, a large proportion of farmers and local government staff were reluctant to assist with the validation of the models. This was an unusual occurrence and one that we as a research group had not previously encountered across fifteen years of developing land suitability models in Regional Victoria.

The predominant reasons given by farmers for their reluctance were:

a) lack of sufficient detailed information about how the model outputs would be used by DELWP;
b) concern that the models would lead to restrictions on how they could use their land in the future (including the ability to subdivide and sell);
c) some confusion around if/how this project related to the concurrent 'Foodprint Melbourne' research being led by the University of Melbourne (and exacerbated by the fact that Foodprint were running farmer workshops at the same time as this project was seeking farmer input).

The primary reason given by local council staff for their reluctance to assist was uncertainty about how the model outputs would affect them.

As such, this situation necessitated interviews with many more farmers than initially anticipated. Ultimately, more than 60 farmers were interviewed across the study region but only 33 farmers provided objective feedback on the model outputs. This input, along with widespread feedback provided across the state during previous projects undertaken in Gippsland, Goulburn Broken, Hepburn and the South West on the same commodities, ensures the robustness of the model runs. Of the 33 that provided feedback, the bulk wished to remain anonymous. Therefore, no names or other identifying information have been included in this report. Some of the Green Wedge and Peri-Urban Areas from which feedback was secured includes Bannockburn, Bacchus Marsh, Daylesford, Kyneton, Broadford, Whittlesea, Werribee South, Hazeldene, Murrindindi, Toolangi, Silvan, Yarra Junction, Neerim East, Tynong North, Lang Lang, Koo Wee Rup and Red Hill, amongst others.

Farmers were provided with some background information on the project and then taken through the likely impacts of climate change across Victoria, using temperature and rainfall maps, as a means to introduce the modelling. The modelling methodology was also outlined, including previous examples showing the pre- and post-validation steps and the impact on the resultant maps. Farmers were then asked simply to examine the maps and comment on the accuracy of those geographical areas with which they were most familiar. In many cases, farmers had experience of more than one location and multiple commodities across the study region. If farmers wished, we would then delve into the model to interrogate the various parameters, weightings and rankings.

The farmers interviewed generally fell into two camps and provided different feedback:

1) The first group were those that could be considered entrepreneurial and focussed on the multiple components of the food production value-chain. They tended to have smaller farms. They were interested to receive any new information that they could act on immediately but were also keen for information that enabled strategic planning for their agribusinesses. This group recognised the difficulties of being farmers in the Green Wedge and Peri-Urban area but were more focused on the opportunities for agriculture arising from proximity to markets and population centres. They also accepted that climate change was a significant threat and were already engaged in various forms of adaptation.
2) The second group were those that could be considered generally pessimistic about agriculture in the Green Wedge and Peri-Urban Areas (and possibly about agriculture in general). They had larger farms and saw urbanisation as an unstoppable tide that would one day sweep them aside. As such, they were wary of any changed regulatory environment that inhibited their ability to capitalise on urbanisation and increasing land values. They were also less concerned with climate change and more comfortable discussing climate *variability*. They were interested in information that could help with existing problems but being pessimistic about the future meant they were not particularly interested in strategic information. This group talked about the large cost of re-establishment if they were to be pushed out of their current locations by urban expansion, about the difficulties of achieving good gross margins in agriculture and of the various well-known sources of conflict between farmers and urban residents.

The bulk of the feedback on the maps themselves was either positive or had little impact on the model output, because farmers considered that on balance, they were accurate. On this point it should be noted that all the models implemented here have already been subjected to substantial validation in recent large-scale suitability projects in the Goulburn-Broken Region, the Central Highlands Region and the southwest Victoria region. The initial (prior) model validation was carried out in workshops that contained farmers as well as other subject matter experts (agronomists, plant breeders, soil experts, etc) to achieve a consensus view on all model parameters. Since that time, in order to limit the influence of dominant personalities in group situations, validation has been carried out via one-on-one interviews. This is a more time-consuming and labour-intensive process but provides a greater depth and breadth of feedback from farmers.

7.4. Model Caveats

Despite the extensive validation at a local level with farmers, it should always be remembered that LSA modelling, as implemented here, is intended to inform regional-level decision-making rather than farm-level decision-making. As such, farmers and others who participated in the model validation were alerted to certain limitations in the resultant information that are presented here as a set of caveats for those reading this report:

1. The methodology has been formulated for application at regional and local levels. In particular, LSA maps are developed and presented at a regional level with a spatial resolution of 5 square km, which is the resolution of the downscaled climate change projections. *Therefore, LSA maps should not be used to infer (current and future) conditions at a site level (e.g. at farm level).*

2. LSA maps depicting future conditions substantially depend on the input climate change projection data, which are inherently uncertain. A multiplicity of futures is possible depending on major (global) decisions over time and how the climate system will respond to them. *Therefore, future LSA maps depict a likely future and, by no means, the only future.*

3. The modelling approach does not account for some important components of crop production; for instance, the effect that changing climatic conditions may have on bees and pollination, or on crop disease status.

4. Each commodity's biophysical requirements for climate, soil and landscape - were identified by a review of the scientific literature and their value ranges were validated using expert opinion and regional expertise. The final weightings and rankings are consensus values and may differ from the views of, or values provided by, individual experts.

5. The study did not examine different varieties within a particular agricultural commodity. Considerable variation can occur between varieties within a species with respect to their biophysical requirements.

6. It is difficult to account for the contribution that a grower's skill level can make to the suitability of a specific commodity at a particular geographical location. It is hence entirely possible for a particular grower to achieve good yields at a location that has been modelled as having a low biophysical suitability and, conversely for a grower to achieve poor yields at a location that is ranked with a high biophysical suitability. It should also be noted that the models do not take into account other factors that may impact on suitability and yield, such as extreme climate events, pests and diseases, or socio-economic considerations.

7. Future scenarios modelling in this study relies on the assumptions made in the generation of the GCM and RCP8.5. That is, the model assumes a future scenario of water availability according to IPCC RCP8.5 and the provision of relevant infrastructure, including possible irrigation supply for water. Furthermore, the models deal with irrigation in a specific manner: they determine the gap between rainfall and crop water requirements at any given location. As the gap between the two widens, and the need for supplementary irrigation increases, an increasing penalty is applied to suitability at that location.

8. The analysis assumed that for irrigated commodities, irrigation was uniformly available across the study area. Suitability ratings were therefore influenced by the amount of irrigation required by the commodity, as climate changed. However, given that it may not be feasible to provide access to irrigation water to all areas identified as suitable, the reader should be aware that suitability of irrigated crops may be overestimated in some instances.

9. The report has looked at a selection of agricultural commodities across the Green Wedge and Peri-Urban Areas of Melbourne. The reader should therefore be aware that the designation of an area in the region as less suitable or less versatile in future climates only applies to the particular commodities modelled in this report, and that those same areas may become more suitable or versatile for other crops. Additional modelling will be required to examine other agricultural commodities in order to have a more comprehensive understanding of the agricultural potential, now and in the future.

7.5. Land Suitability Analysis per Commodity

The following graphs and maps illustrate the outputs for the twelve commodities modelled as part of this study. The bar graphs indicate the percentage of total land falling within the thirteen suitability classes (0% suitable (Not Suitable) increasing to 100% suitable, (Very Highly Suitable) and Permanently Not Suitable (PNS) and Temporarily Not Suitable (TNS) (see Section 7.2 for more detail). The four bars in the graph depict each scenario modelled: Historical (1960-1990), and projected climate scenarios RCP8.5 for 2030, 2050 and 2070.

The four maps show the spatial distribution of the outputs for the four scenarios modelled for each commodity. Both the graphs and maps use the same colour profile to indicate the suitability classes of the outputs with red indicating low levels of suitability, mustard and yellow indicating moderate levels of suitability and greens indicating high levels of suitability, with dark green indicating the highest level of suitability. The maps are overlayed with public land (indicated by dark brown patches) and water formation such as significant water bodies and main rivers and waterways.

The outputs presented in this report are the results of biophysical land suitability modelling of Melbourne's Green-Wedge and Peri-Urban areas, with inputs as described in Section 6. Current land uses (including land sizes), current agricultural productivity levels and current management practices have not been incorporated into these models. The analysis strictly covers the inherent biophysical characteristics that are important for the production of particular agricultural commodities into the future under climate change. As such, there may be inconsistencies between the modelling outputs and existing land use. These models are intended to provide a broad, landscape-level assessment of the potential suitability of agriculture in the context of projected climate change, and therefore represent one possible future scenario. With additional inputs, best practice management practices, agricultural innovations or different climate outcomes, a multiplicity of potential agricultural land-suitability outcomes are possible. This report presents the most probable scenario given current data and projections.

7.6. Crops – canola and winter red wheat

The biophysical models outputs for canola (Figure 7.5) and winter red wheat (Figure 7.6) show the biophysical suitability of the region to produce a generic canola variety and generic winter feed wheat variety (with a sowing period of May, and harvest period of late November, early December onwards), respectively. Both models were run without an irrigation component, with relevant growing season rainfall accounted for by effective rainfall.

The Canola model output relative to historical climate indicates that a significant portion of the region is suitable for canola production now and will remain so out to 2070 (although some of the western parts of the region are classified as unsuitable largely because of limitations in the input soil data).

The Winer Red Wheat model output relative to historical climate indicates a relatively poor suitability (50% suitable) across much of the region, particularly in the east, improving slightly to the west. Into the future projections the outlook improves, with approximately 20% of the region showing high suitability by 2050, mostly concentrated in the north and south west. Again, large regions in the west that have been classified as unsuitable are due to limitations in the input soil data.

Canola, both currently and into the future, shows a higher suitability across the region than Winter Red Wheat. However, wheat is the largest grain crop in Australia (grown on over 12 million hectares across Australia) (ABS, 2015), so is likely to continue being an important commodity in Victoria in the future. This is particularly the case in some areas where increased winter and spring temperatures result in longer growing seasons and higher yields, in which case winter red wheat can provides a viable alternative to existing pasture types.

The percentage area of the region that falls within each suitability rating (for example, 80% suitable) at each time point is also displayed in Figure 7.5 and Figure 7.6 which gives a good indication of degree of change over time.

7.6.1.1. Canola

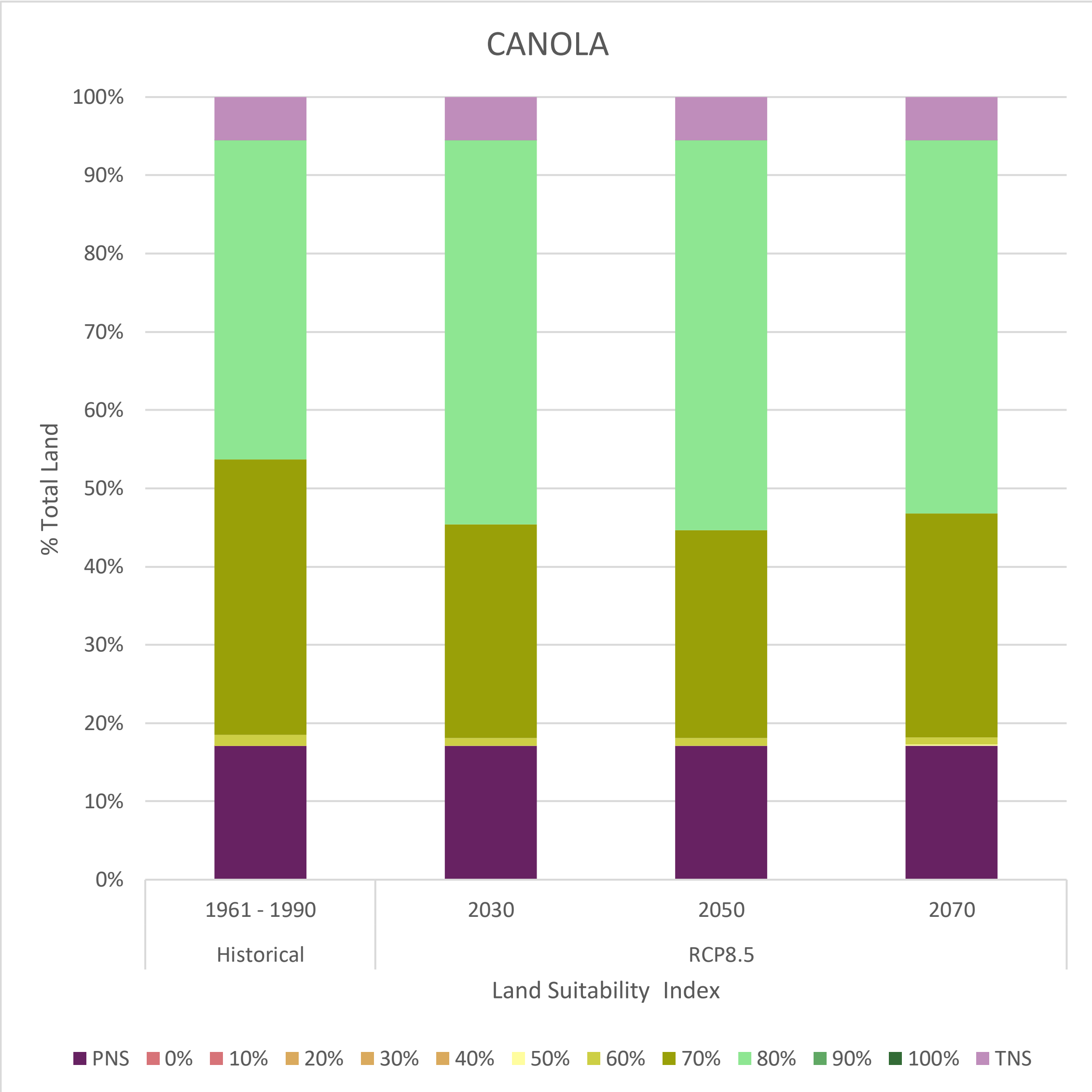
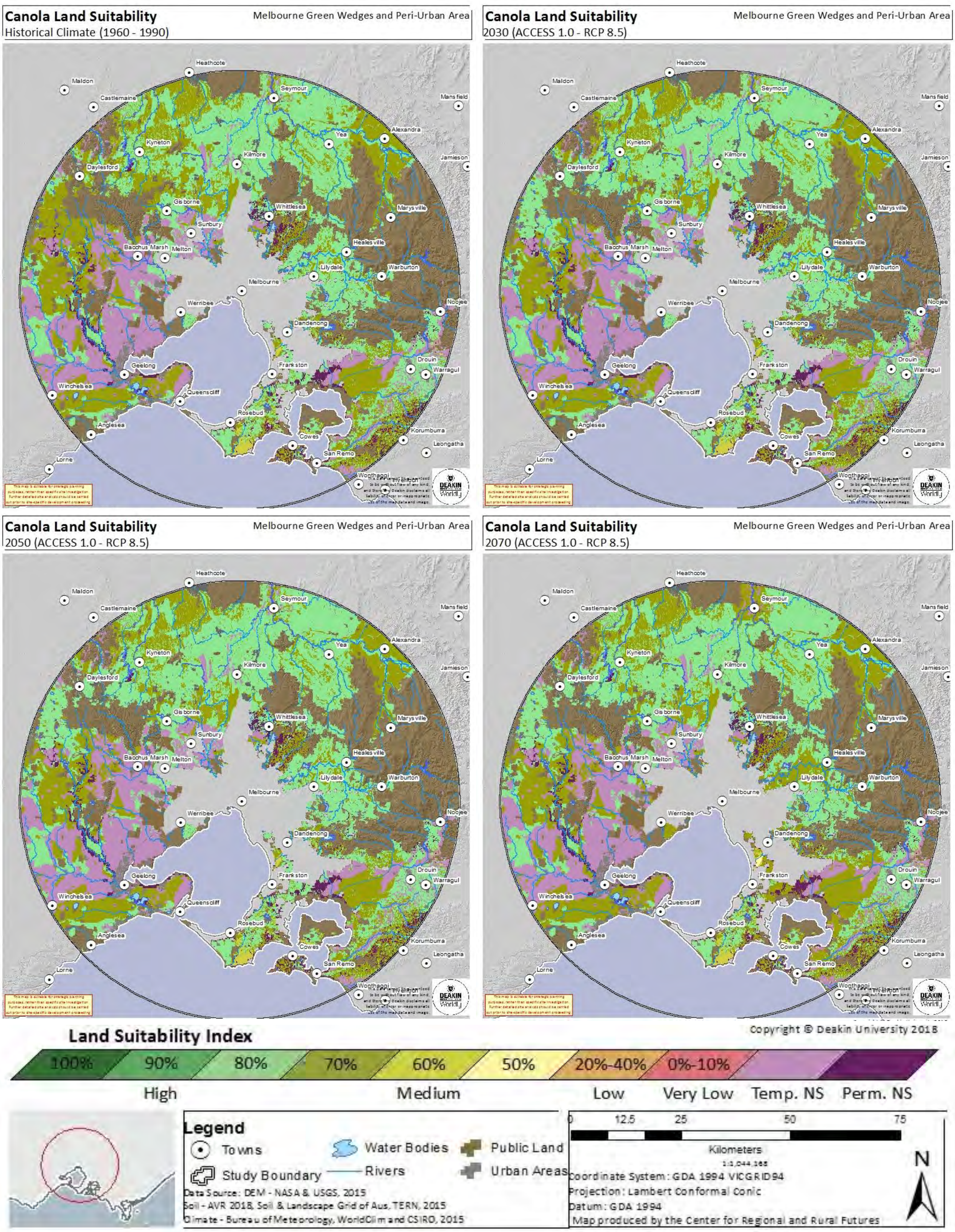


Figure 7.5 Canola Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 20: Mapping Outputs


Canola Land Suitability
Historical Climate (1960 - 1990)
Melbourne Green Wedges and Peri-Urban Area
Canola Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Canola Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Canola Land Suitability
2070 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Heathcote
Maldon
Castlemaine
Seymour
Mansfield
Alexandra
Yea
Kyneton
Kilmore
Jamieson
Daylesford
Gisborne
Whittlesea
Marysville
Sunbury
Bacchus Marsh
Melton
Healesville
Lilydale
Warburton
Melbourne
Werribee
Noojee
Dandenong
Drouin
Warragul
Geelong
Frankston
Winchelsea
Queenscliff
Rosebud
Anglesea
Korumburra
Cowes
Leongatha
Lorne
San Remo
Wonthaggi
DEAKIN
Copyright © Deakin University 2018
Land Suitability Index
100%
90%
80%
70%
60%
50%
20%-40%
0%-10%
High
Medium
Low
Very Low
Temp. NS
Perm. NS
Legend
Towns
Water Bodies
Public Land
Study Boundary
Rivers
Urban Areas
Data Source: DEM - NASA & USGS, 2015
Soil - AVR 2018, Soil & Landscape Grid of Aus, TERN, 2015
Climate - Bureau of Meteorology, WorldClim and CSIRO, 2015
0
12.5
25
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75
Kilometers
1:1,044,168
Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Map produced by the Center for Regional and Rural Futures
N

7.6.1.2. Winter Red Wheat

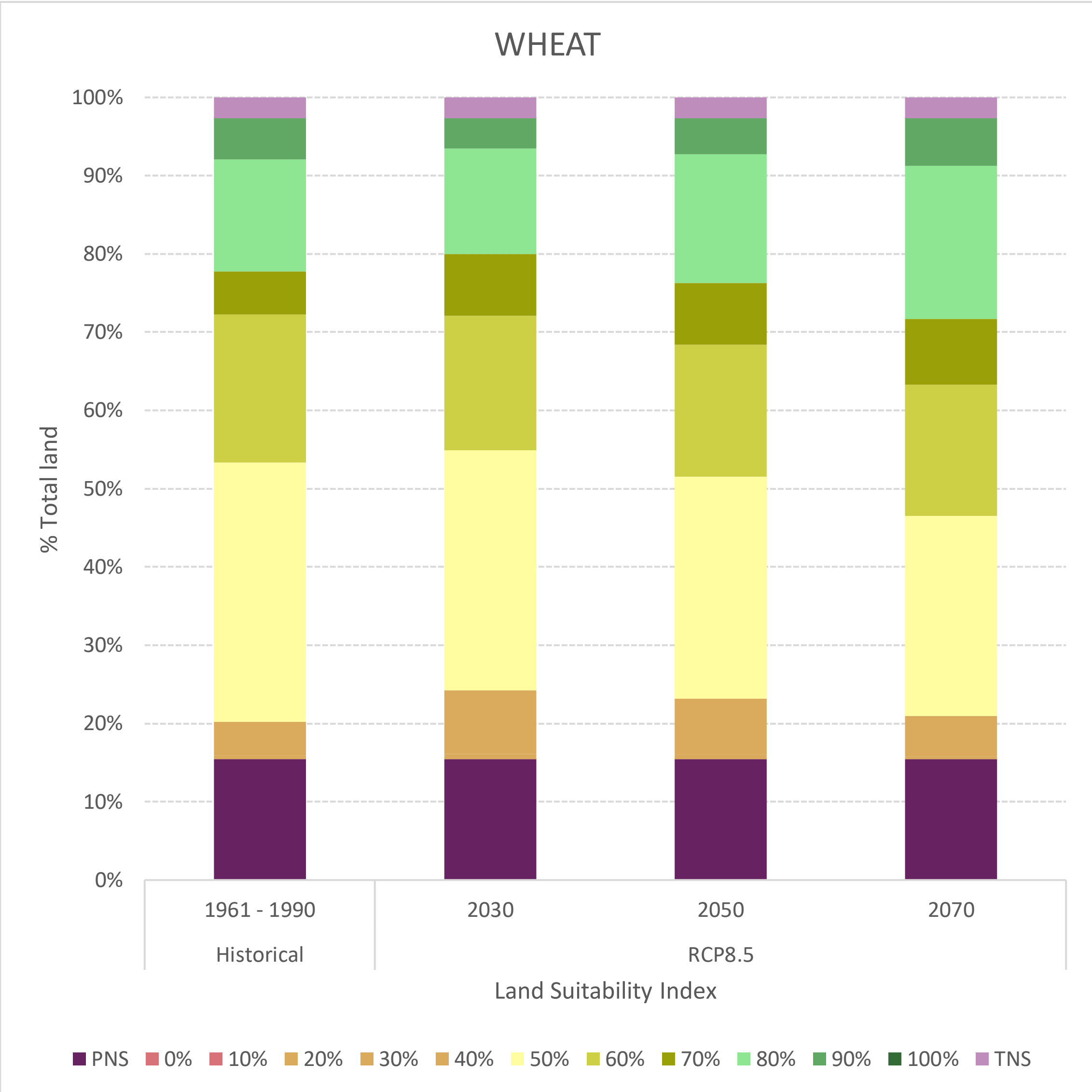
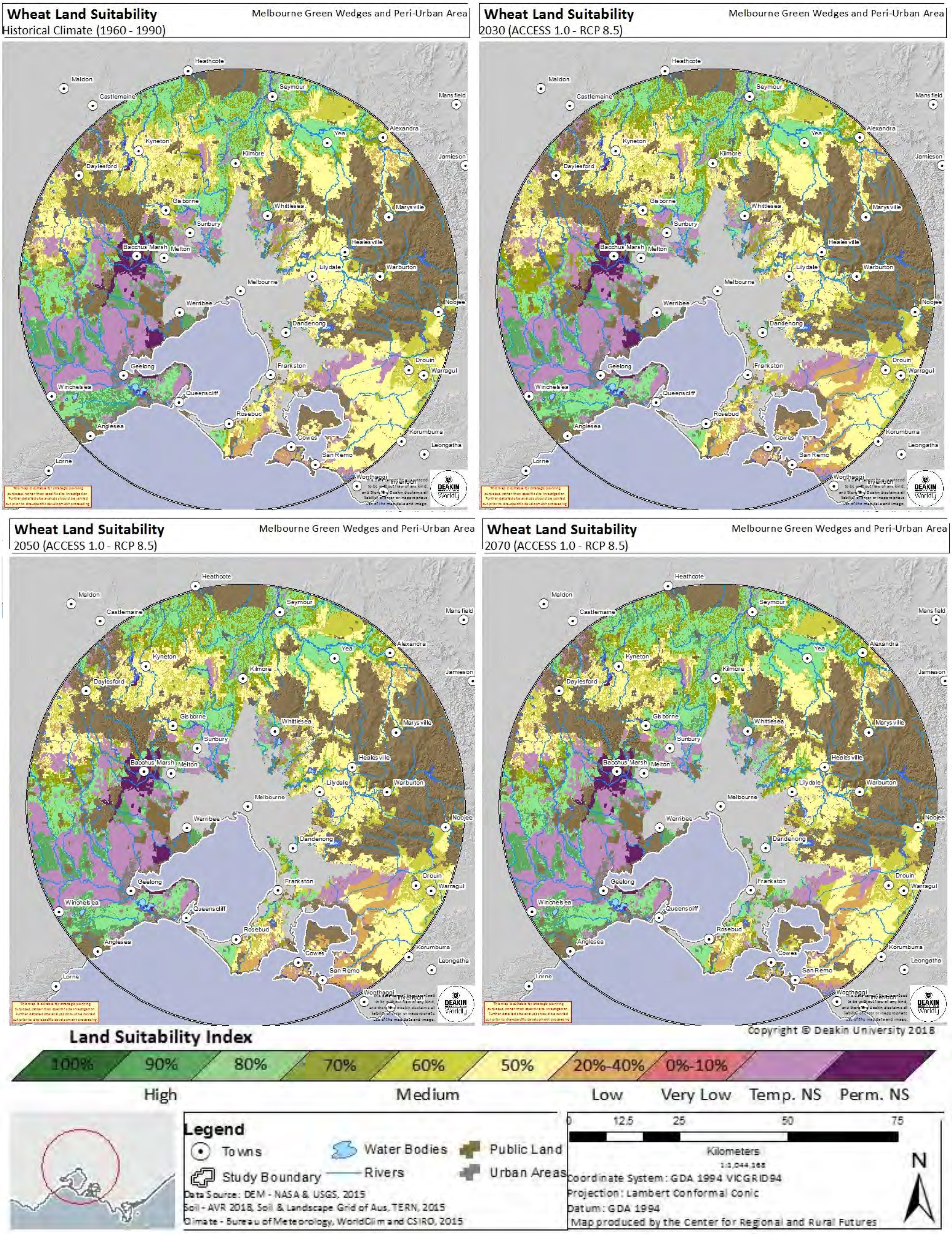


Figure 7.6 Winter Red Wheat Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 22: Mapping Outputs


Wheat Land Suitability
Historical Climate (1960 - 1990)
Melbourne Green Wedges and Peri-Urban Area
Wheat Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Wheat Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Wheat Land Suitability
2070 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Heathcote
Maldon
Castlemaine
Seymour
Mansfield
Alexandra
Yea
Kyneton
Kilmore
Jamieson
Daylesford
Gisborne
Whittlesea
Marysville
Sunbury
Healesville
Bacchus Marsh
Melton
Lilydale
Warburton
Melbourne
Werribee
Noojee
Dandenong
Geelong
Frankston
Drouin
Warragul
Winchelsea
Queenscliff
Rosebud
Anglesea
Korumburra
Cowes
Leongatha
Lorne
San Remo
Wonthaggi
Copyright © Deakin University 2018
Land Suitability Index
100%
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Towns
Water Bodies
Public Land
Study Boundary
Rivers
Urban Areas
Data Source: DEM - NASA & USGS, 2015
Soil - AVR 2018, Soil & Landscape Grid of Aus, TERN, 2015
Climate - Bureau of Meteorology, WorldClim and CSIRO, 2015
0
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Kilometers
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Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Map produced by the Center for Regional and Rural Futures
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7.7. Fruit – grapes, pome and stone fruit

Grapes, Pome Fruit and Stone Fruits were selected to represent fruit horticultural systems in Melbourne's Green Wedge and Peri-Urban areas. To represent the diversity in varieties grown around the state, both a generic 'Cool' and generic 'Warm' climate grape variety were selected, in addition to a generic 'Early' and 'Late' season stone fruit (to capture a range of varieties, including cherries (early) and peach (late)). This provides the full spectrum of possibilities with respect to suitability but at the expense of variety-specific information. The biophysical models depicted in Figure 7.7 to Figure 7.11 show the suitability of the region to produce these commodities. All models were run with an irrigation component, calculated within each relevant growing season, and coming into effect only if effective rainfall thresholds were not met.

The Cool Climate Grape model output relative to historical climate indicates that suitability in the study region will decline out to 2070. Currently the region is largely suitable for cool climate grape production, with approximately 50% of the land area suitable (80% suitable or higher). Moving to 2050 and 2070, the proportional area reduces substantially as suitability shifts from high to moderate, with only small patches of high suitability in the north-west and east. This is contrasted however, with a less marked decline in the suitability of Warm Climate Grapes. Which, after an initial decline, remains relatively stable at about 20% of the area suitable (80% or higher) out to 2070, with key areas in the south-east edge of the Green Wedge and Peri-Urban area maintaining their suitability (80% suitable).

Pome Fruit suitability declines markedly, shifting from predominantly suitable in the present climate (over 80% of the land area being suitable at 80% or higher) to less than 10% of the area being suitable in 2030, and remaining at this rate in the other future projection scenarios 2050 and 2070. This is due to a variety of inter-related factors but primarily declining chill accumulation.

By contrast, Early Season Stone Fruit improves over time, shifting from about 50% of the land area being suitable historically, to nearly 80% of the land area in 2050. The three projected future scenarios remain relatively stable, with highly suitable land areas ranging from 25-30% of the total area. Similarly, Late Season Stone Fruit shows improvements into the projected future scenarios. Suitable areas increase form 40% historically, to 70% in 2050. Most of the highly suitable areas (90% suitable and higher) are centred in the south east of the region both historically and into the future.

The percentage area of the region that falls within each suitability rating (for example, 80%) at each time point is also displayed in Figure 7.7 to Figure 7.11 which gives a good indication of degree of change over time.

7.7.1.1. Grapes

Cool Climate Grapes

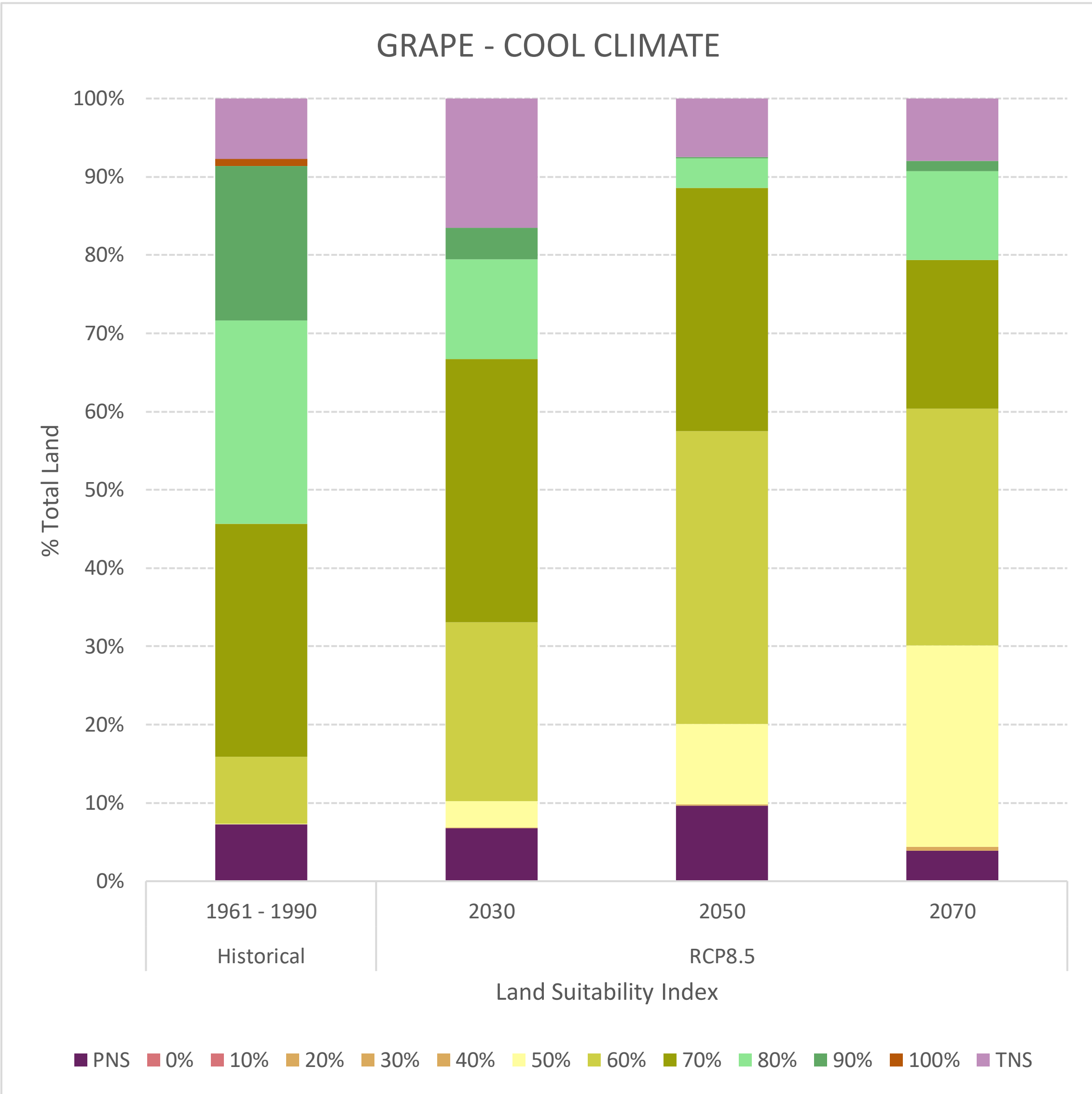
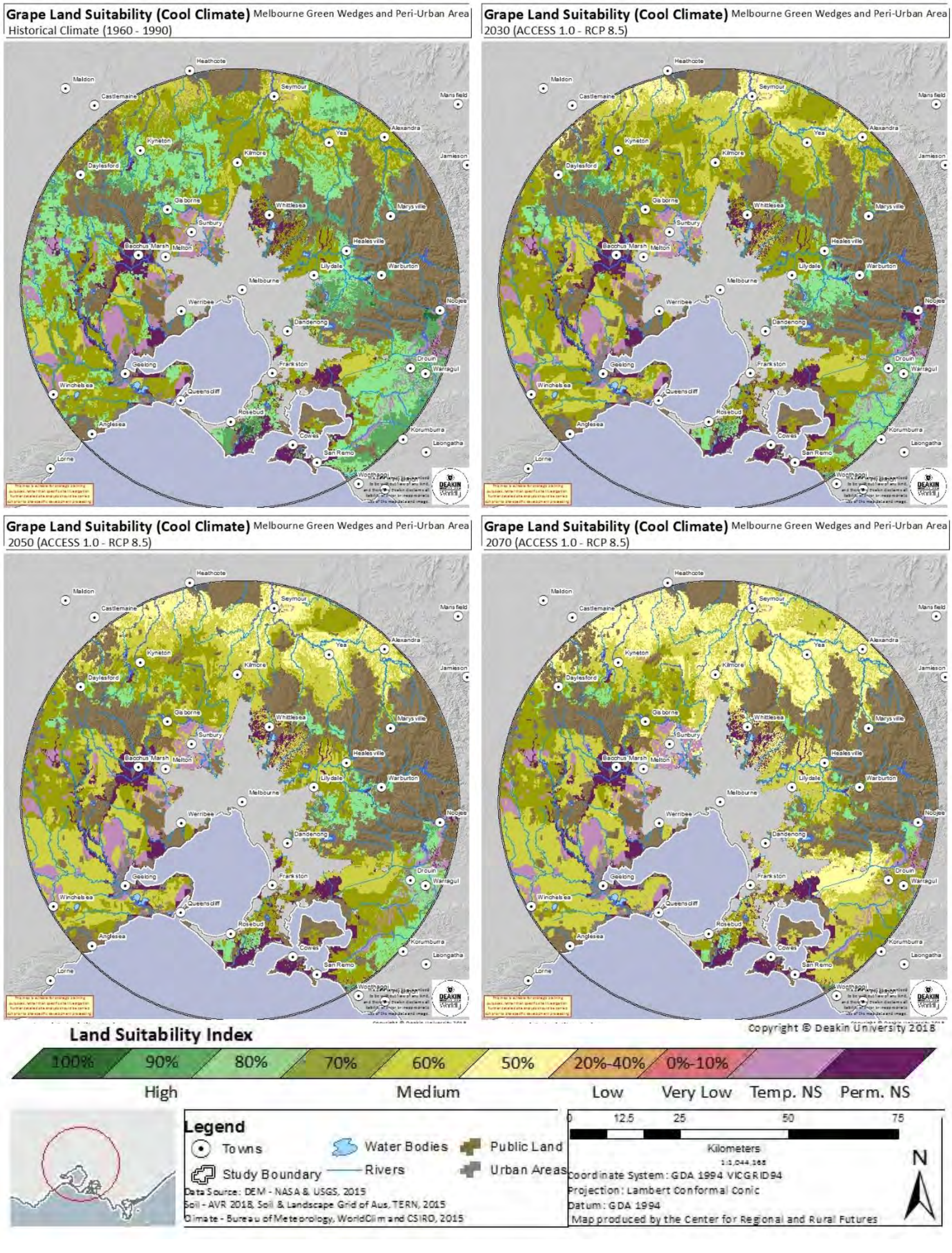


Figure 7.7 Cool Climate Grape Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 25: Mapping Outputs


Grape Land Suitability (Cool Climate) Melbourne Green Wedges and Peri-Urban Area
Historical Climate (1960 - 1990)
Grape Land Suitability (Cool Climate) Melbourne Green Wedges and Peri-Urban Area
2030 (ACCESS 1.0 - RCP 8.5)
Grape Land Suitability (Cool Climate) Melbourne Green Wedges and Peri-Urban Area
2050 (ACCESS 1.0 - RCP 8.5)
Grape Land Suitability (Cool Climate) Melbourne Green Wedges and Peri-Urban Area
2070 (ACCESS 1.0 - RCP 8.5)
Heathcote
Maldon
Castlemaine
Seymour
Mansfield
Alexandra
Kyneton
Yea
Kilmore
Jamieson
Daylesford
Gisborne
Whittlesea
Marysville
Sunbury
Healesville
Bacchus Marsh
Melton
Lilydale
Warburton
Melbourne
Werribee
Noojee
Dandenong
Drouin
Warragul
Geelong
Frankston
Winchelsea
Queenscliff
Rosebud
Anglesea
Korumburra
Cowes
Leongatha
San Remo
Lorne
Wonthaggi
Copyright © Deakin University 2018
Land Suitability Index
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Water Bodies
Public Land
Study Boundary
Rivers
Urban Areas
Data Source: DEM - NASA & USGS, 2015
Soil - AVR 2018, Soil & Landscape Grid of Aus, TERN, 2015
Climate - Bureau of Meteorology, WorldClim and CSIRO, 2015
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Kilometers
Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Map produced by the Center for Regional and Rural Futures
N

Warm Climate Grapes

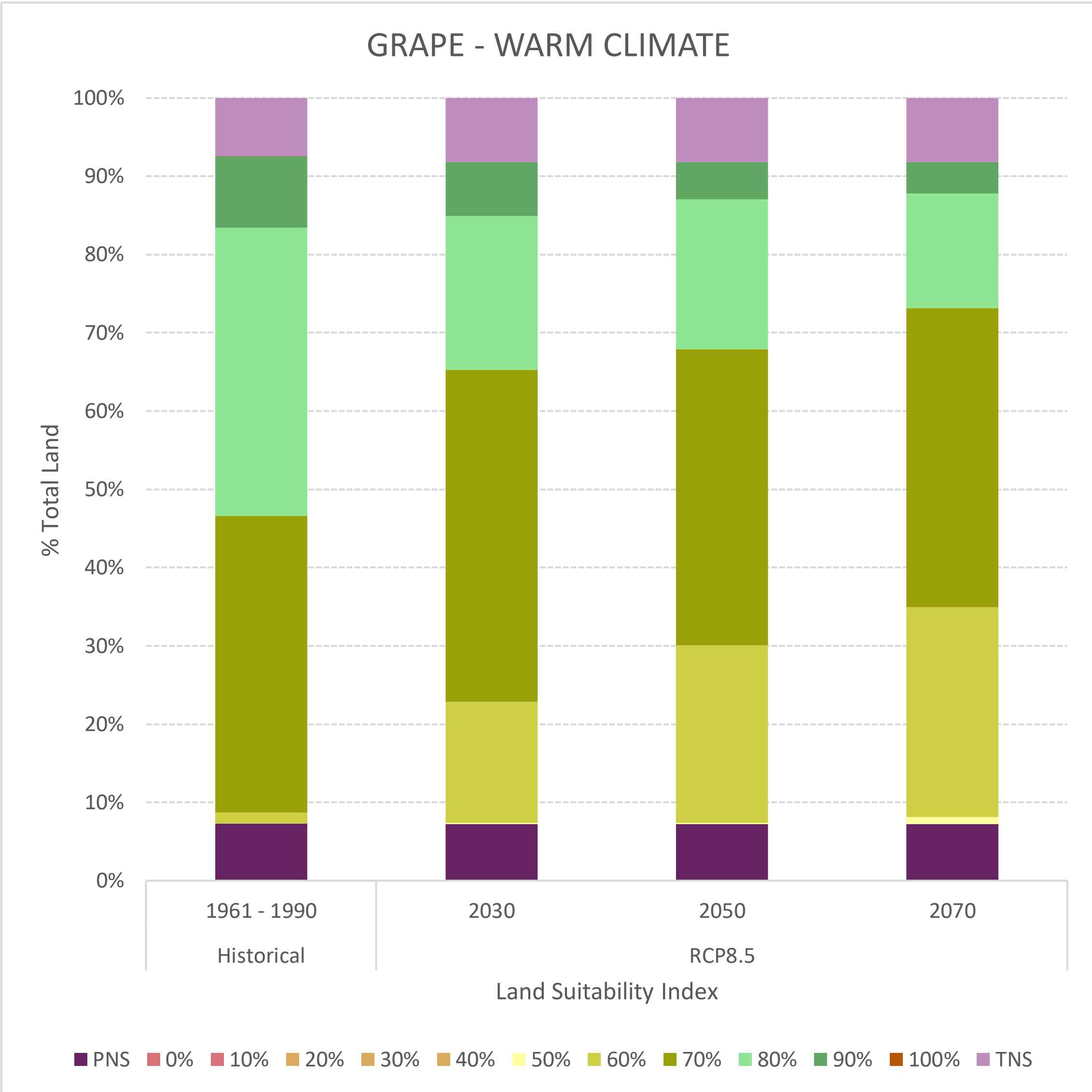
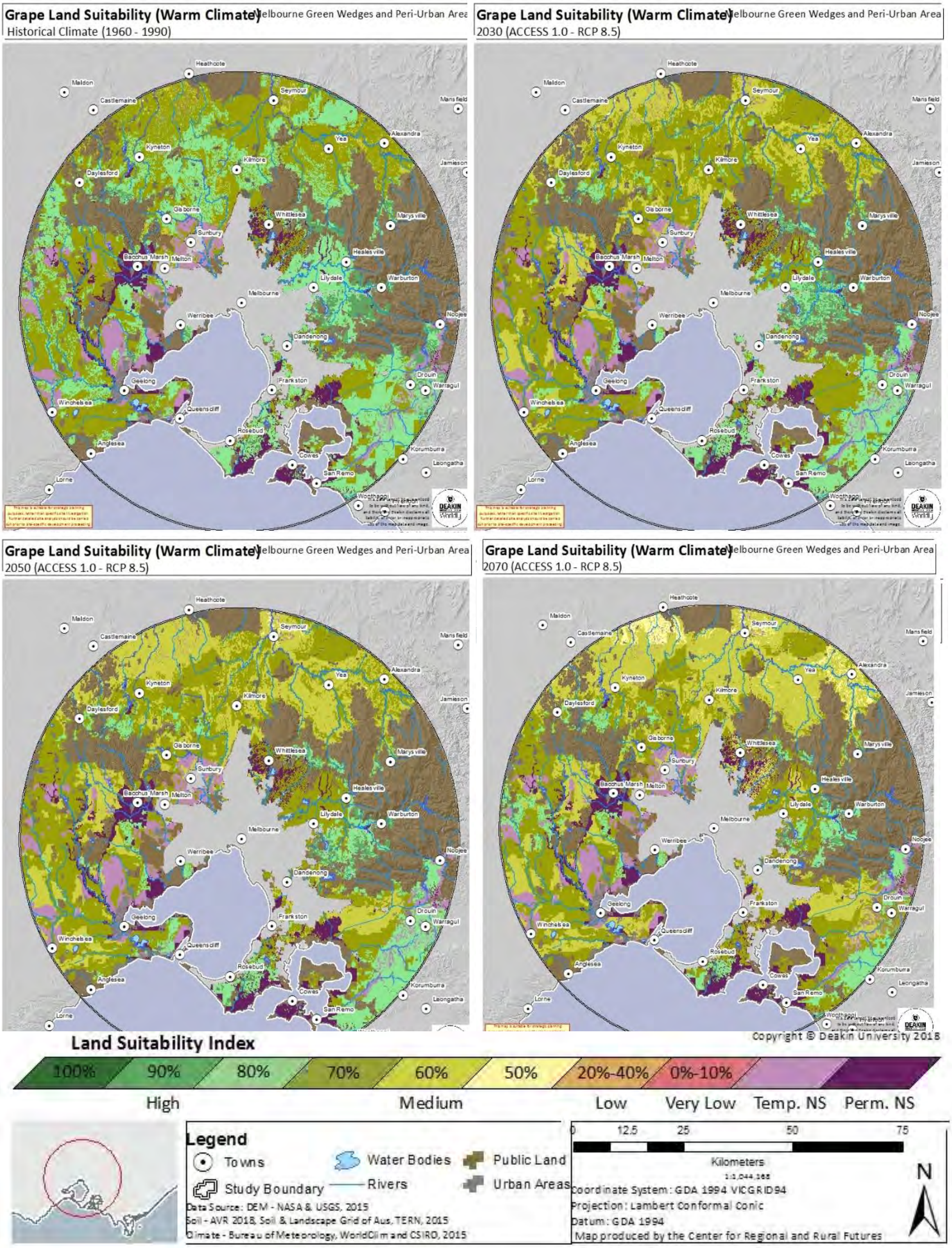


Figure 7.8 Warm Climate Grape Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 27: Mapping Outputs


Grape Land Suitability (Warm Climate) Melbourne Green Wedges and Peri-Urban Area
Historical Climate (1960 - 1990)
Grape Land Suitability (Warm Climate) Melbourne Green Wedges and Peri-Urban Area
2030 (ACCESS 1.0 - RCP 8.5)
Grape Land Suitability (Warm Climate) Melbourne Green Wedges and Peri-Urban Area
2050 (ACCESS 1.0 - RCP 8.5)
Grape Land Suitability (Warm Climate) Melbourne Green Wedges and Peri-Urban Area
2070 (ACCESS 1.0 - RCP 8.5)
Copyright © Deakin University 2018
Land Suitability Index
100%
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Data Source: DEM - NASA & USGS, 2015
Soil - AVR 2018, Soil & Landscape Grid of Aus, TERN, 2015
Climate - Bureau of Meteorology, WorldClim and CSIRO, 2015
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Kilometers
Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Map produced by the Center for Regional and Rural Futures
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7.7.1.2. Pome Fruit

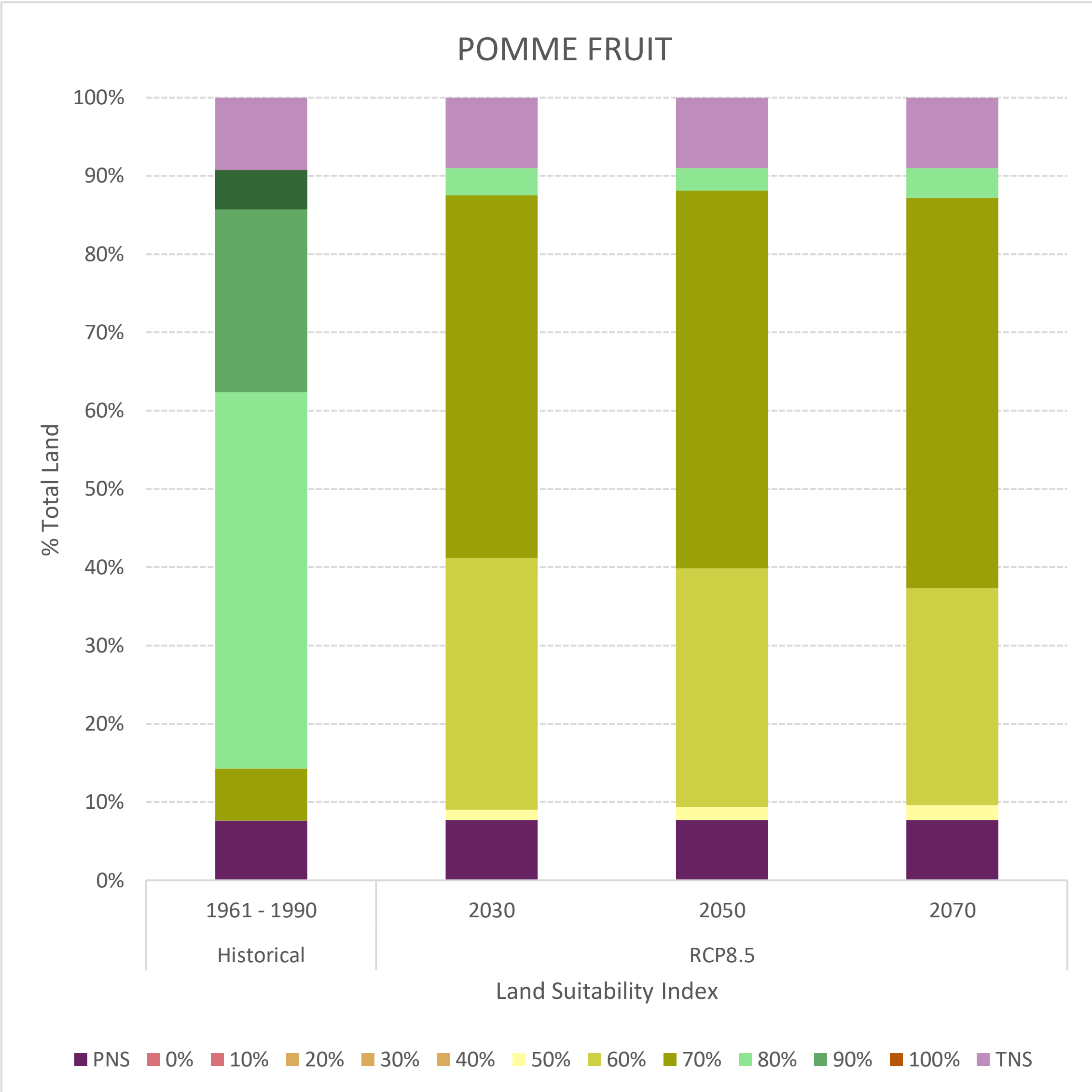
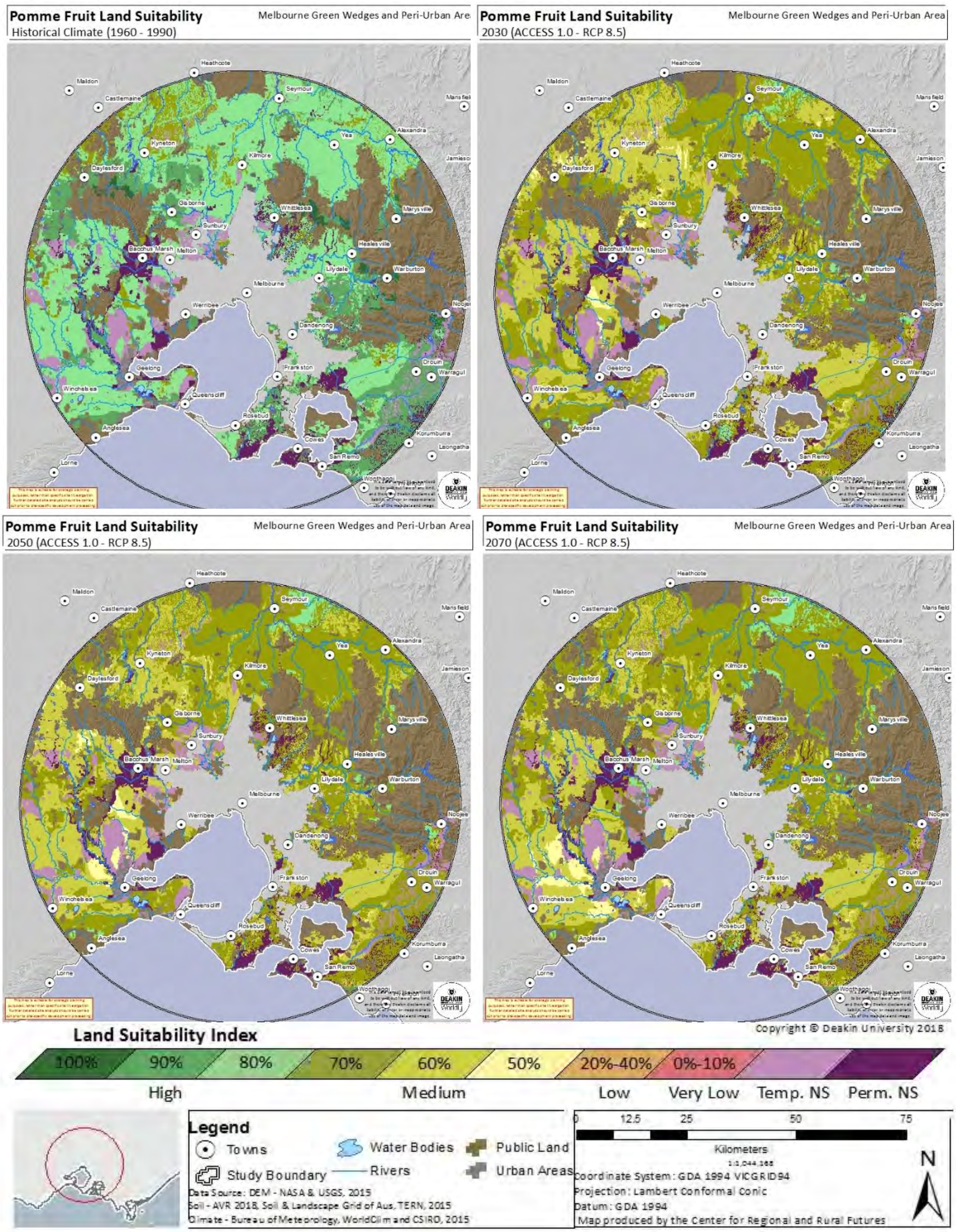


Figure 7.9 Pomme Fruit Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 29: Mapping Outputs


Pomme Fruit Land Suitability
Historical Climate (1960 - 1990)
Melbourne Green Wedges and Peri-Urban Area
Pomme Fruit Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Pomme Fruit Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Pomme Fruit Land Suitability
2070 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Copyright © Deakin University 2018
Land Suitability Index
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Data Source: DEM - NASA & USGS, 2015
Soil - AVR 2018, Soil & Landscape Grid of Aus, TERN, 2015
Climate - Bureau of Meteorology, WorldClim and CSIRO, 2015
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Kilometers
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Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Map produced by the Center for Regional and Rural Futures
N

7.7.1.3. Stone Fruit

Early Season Stone Fruit

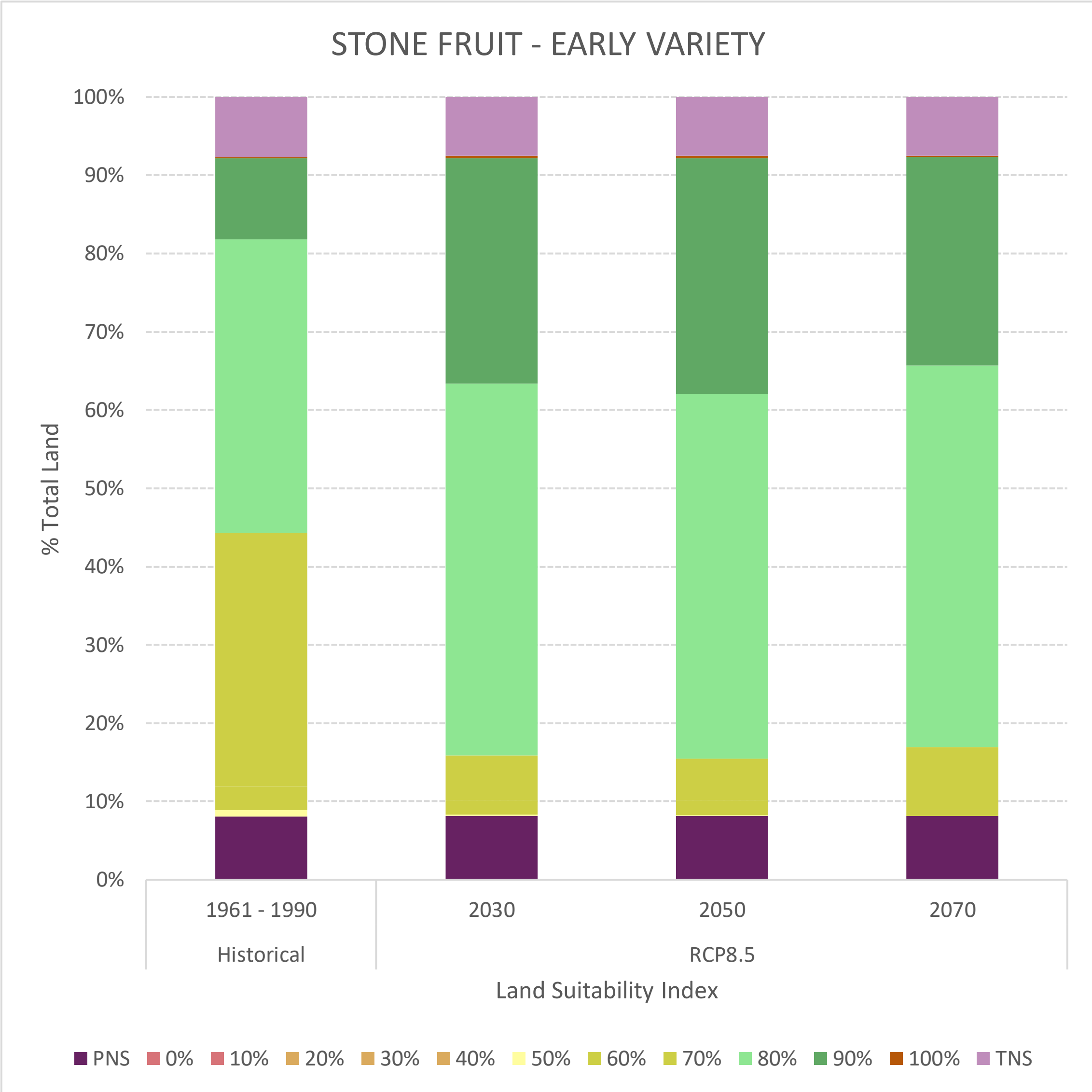
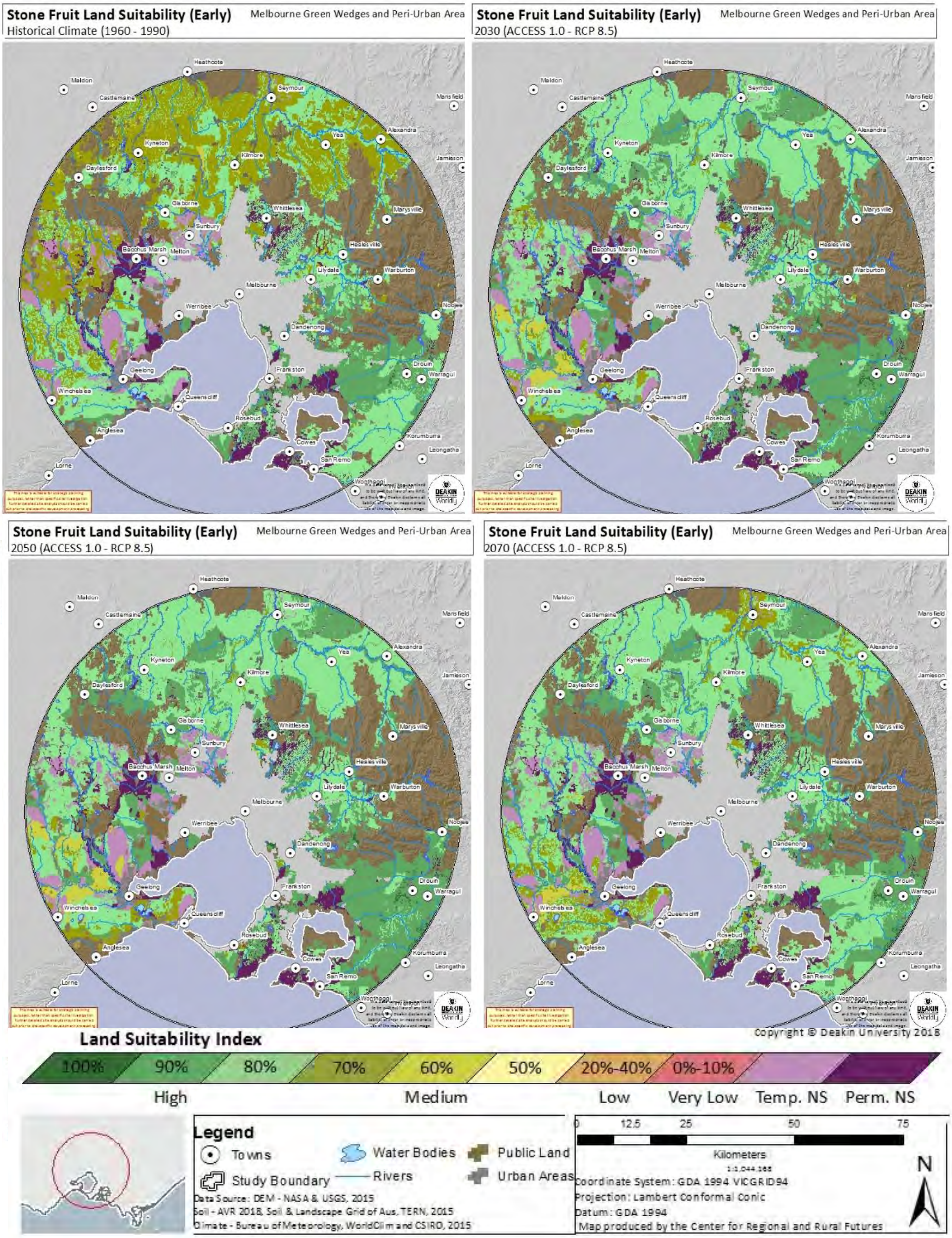


Figure 7.10 Early Season Stone Fruit Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 31: Mapping Outputs


Stone Fruit Land Suitability (Early)
Melbourne Green Wedges and Peri-Urban Area
Historical Climate (1960 - 1990)
Stone Fruit Land Suitability (Early)
Melbourne Green Wedges and Peri-Urban Area
2030 (ACCESS 1.0 - RCP 8.5)
Stone Fruit Land Suitability (Early)
Melbourne Green Wedges and Peri-Urban Area
2050 (ACCESS 1.0 - RCP 8.5)
Stone Fruit Land Suitability (Early)
Melbourne Green Wedges and Peri-Urban Area
2070 (ACCESS 1.0 - RCP 8.5)
Copyright © Deakin University 2018
Land Suitability Index
100%
90%
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70%
60%
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20%-40%
0%-10%
High
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Temp. NS
Perm. NS
Legend
Towns
Water Bodies
Public Land
Study Boundary
Rivers
Urban Areas
Data Source: DEM - NASA & USGS, 2015
Soil - AVR 2018, Soil & Landscape Grid of Aus, TERN, 2015
Climate - Bureau of Meteorology, WorldClim and CSIRO, 2015
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12.5
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Kilometers
Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Map produced by the Center for Regional and Rural Futures
N

Late Season Stone Fruit

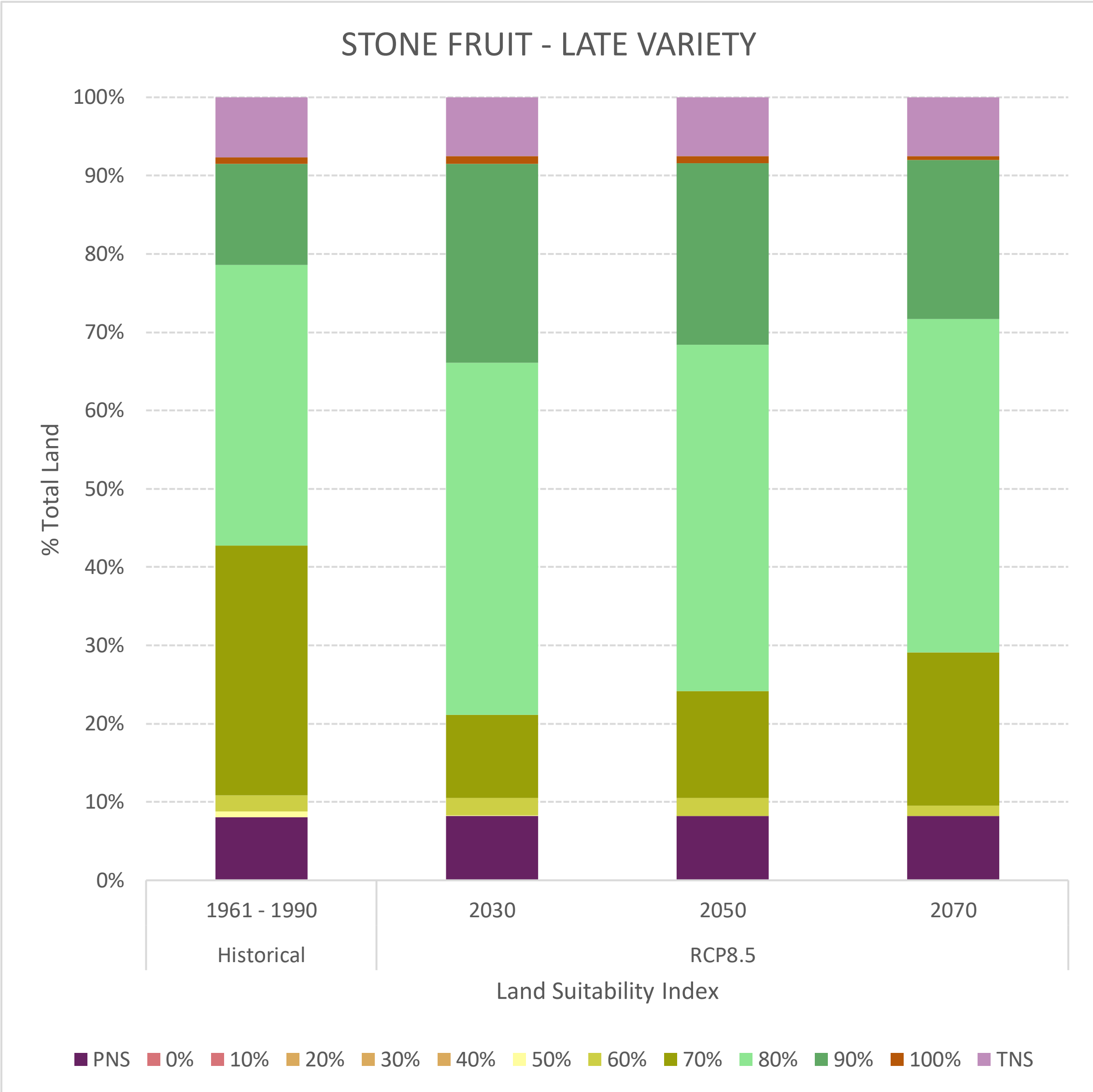
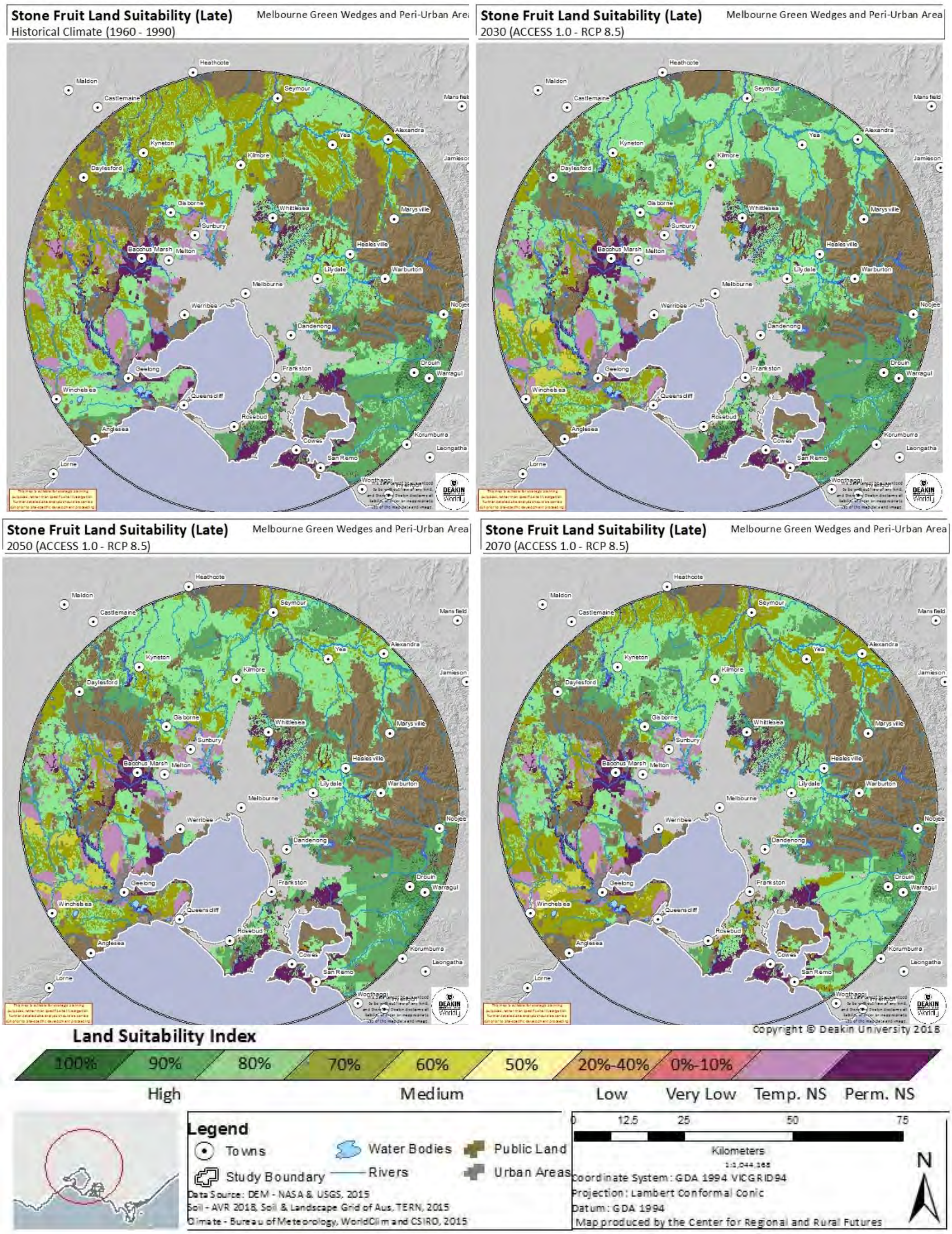


Figure 7.11 Late Season Stone Fruit Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 33: Mapping Outputs


Stone Fruit Land Suitability (Late)
Melbourne Green Wedges and Peri-Urban Area
Historical Climate (1960 - 1990)
Stone Fruit Land Suitability (Late)
Melbourne Green Wedges and Peri-Urban Area
2030 (ACCESS 1.0 - RCP 8.5)
Stone Fruit Land Suitability (Late)
Melbourne Green Wedges and Peri-Urban Area
2050 (ACCESS 1.0 - RCP 8.5)
Stone Fruit Land Suitability (Late)
Melbourne Green Wedges and Peri-Urban Area
2070 (ACCESS 1.0 - RCP 8.5)
Heathcote
Maldon
Castlemaine
Seymour
Mansfield
Kyneton
Yea
Alexandra
Kilmore
Jamieson
Daylesford
Gisborne
Whittlesea
Marysville
Sunbury
Bacchus Marsh
Melton
Healesville
Lilydale
Warburton
Melbourne
Werribee
Noojee
Dandenong
Geelong
Frankston
Drouin
Warragul
Winchelsea
Queenscliff
Rosebud
Anglesea
Cowes
Korumburra
Leongatha
Lorne
San Remo
Wonthaggi
DEAKIN
Copyright © Deakin University 2018
Land Suitability Index
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Data Source: DEM - NASA & USGS, 2015
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Climate - Bureau of Meteorology, WorldClim and CSIRO, 2015
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Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Map produced by the Center for Regional and Rural Futures
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7.8. Pastures – perennial ryegrass and Lucerne

Lucerne and Perennial Ryegrass were selected to represent pastures systems in Melbourne's Green Wedge and Peri-Urban areas, which used as proxy for the suitability of livestock production. The biophysical model outputs depicted in Figure 7.12 and Figure 7.13 show the suitability of the region to produce these commodities. Both models were run without an irrigation component, with relevant growing season rainfall accounted for by effective rainfall.

The Lucerne model output show that suitability is moderate to low in much of the study region but that will not change over time as climate changes.

Conversely, the Perennial Ryegrass model shows more favourable results, with around 60% of the land area showing high levels of suitability and around 25% being very highly suitable (100% suitable). This model only shows slight levels of decline in the projected climate scenarios, with highly suitable area remaining around 40% in 2050 and 2070. The south-east of the study region is significantly more suitable than other areas, with the majority of the low-moderate suitability (50% suitable) occurring in the south west of the region.

The percentage area of the region that falls within each suitability rating (for example, 80% suitable) at each time point is also displayed in Figure 7.12 and Figure 7.13 which gives a good indication of degree of change over time.

7.8.1.1. Lucerne

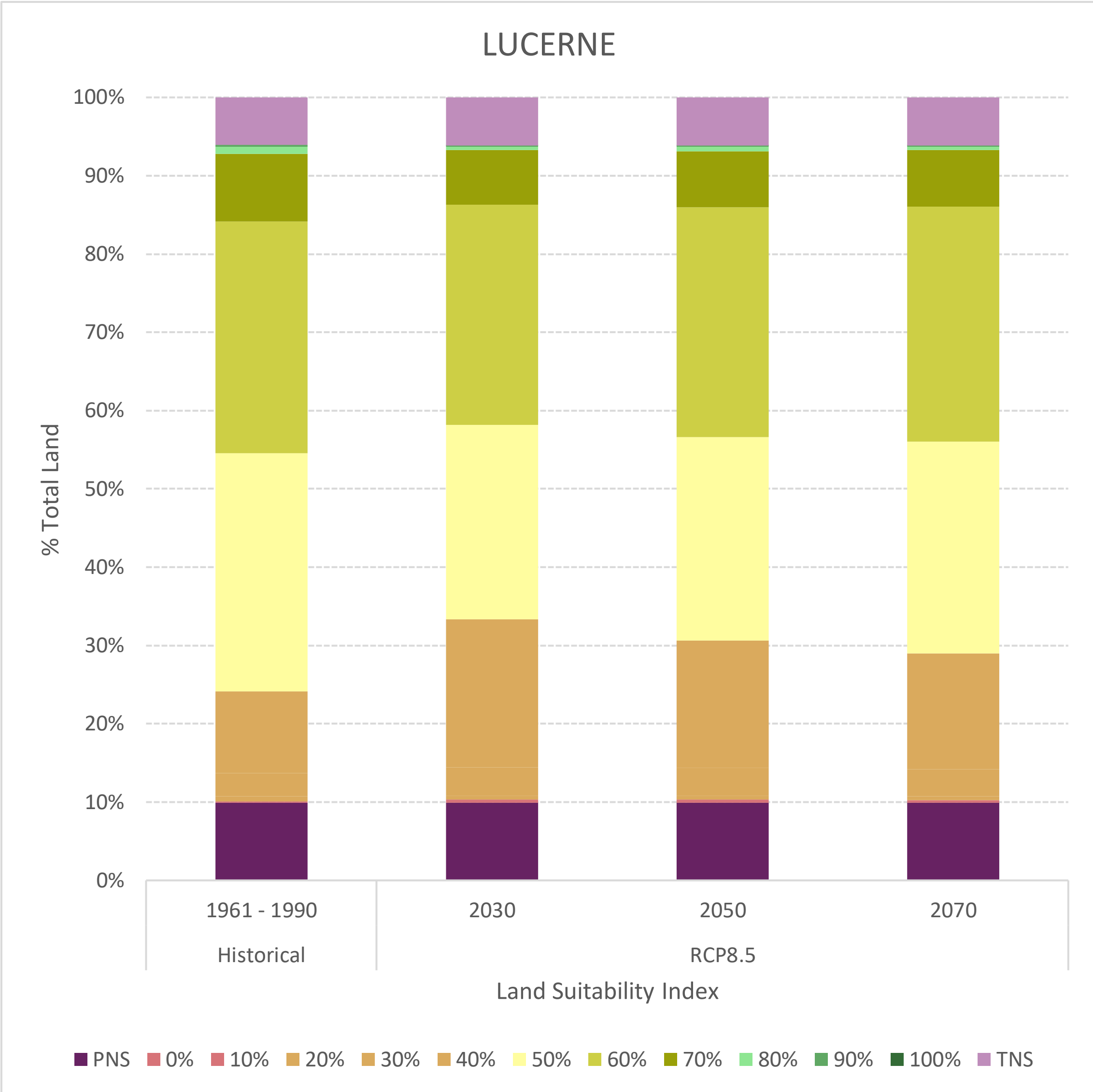
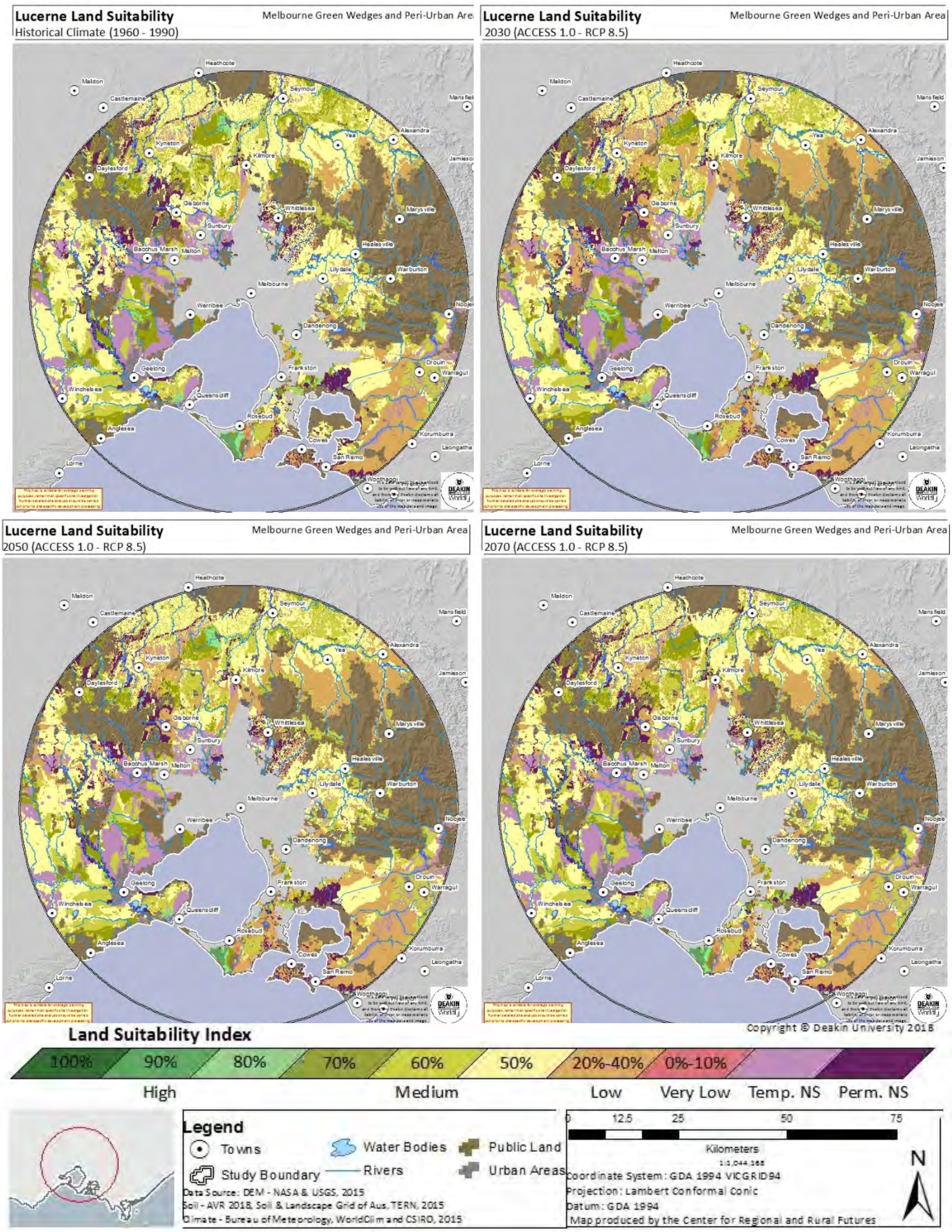


Figure 7.12 Lucerne Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 36: Mapping Outputs


Lucerne Land Suitability
Historical Climate (1960 - 1990)
Melbourne Green Wedges and Peri-Urban Area
Lucerne Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
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Copyright © Deakin University 2018
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Coordinate System: GDA 1994 VICGRID94
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Map produced by the Center for Regional and Rural Futures
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7.8.1.2. Perennial Ryegrass

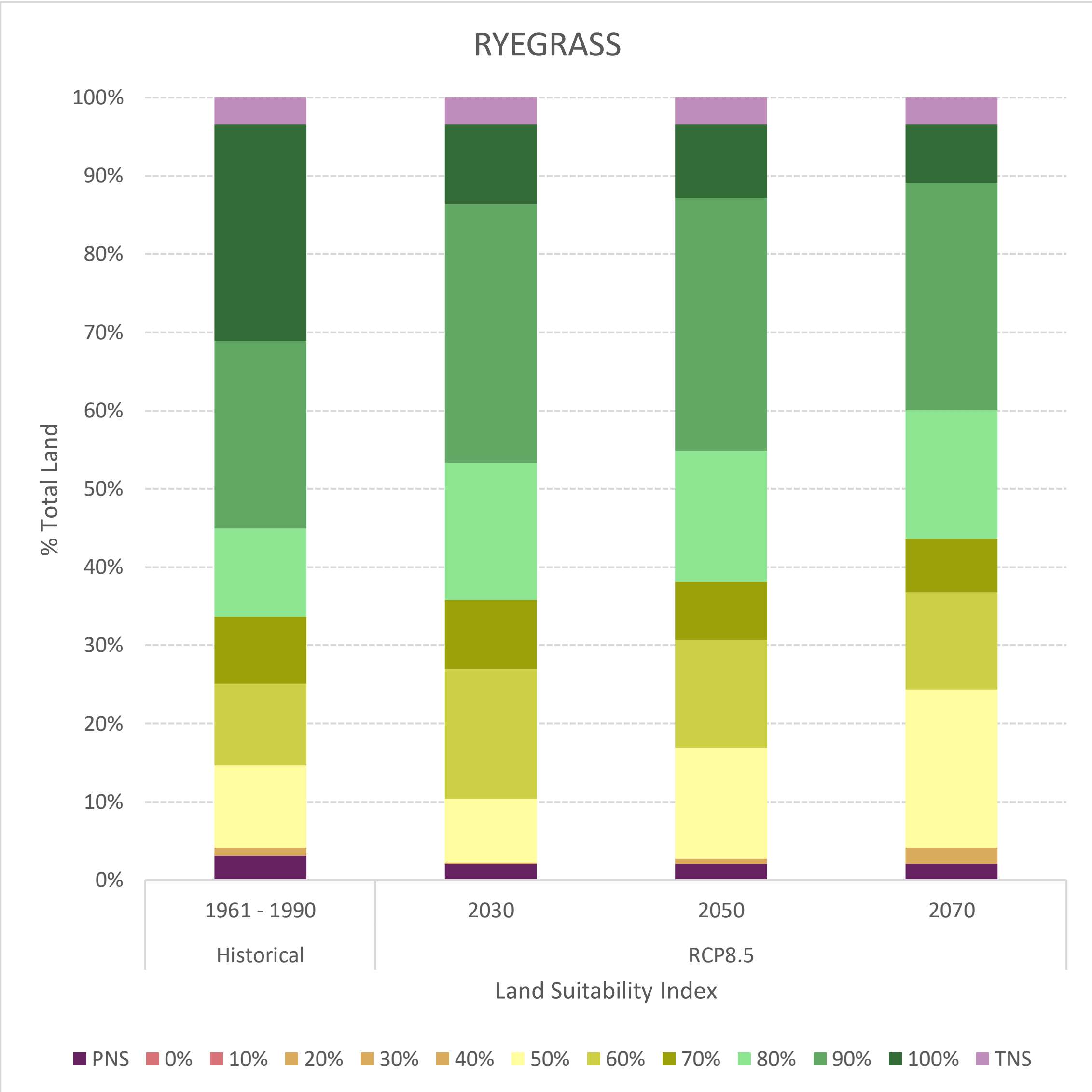
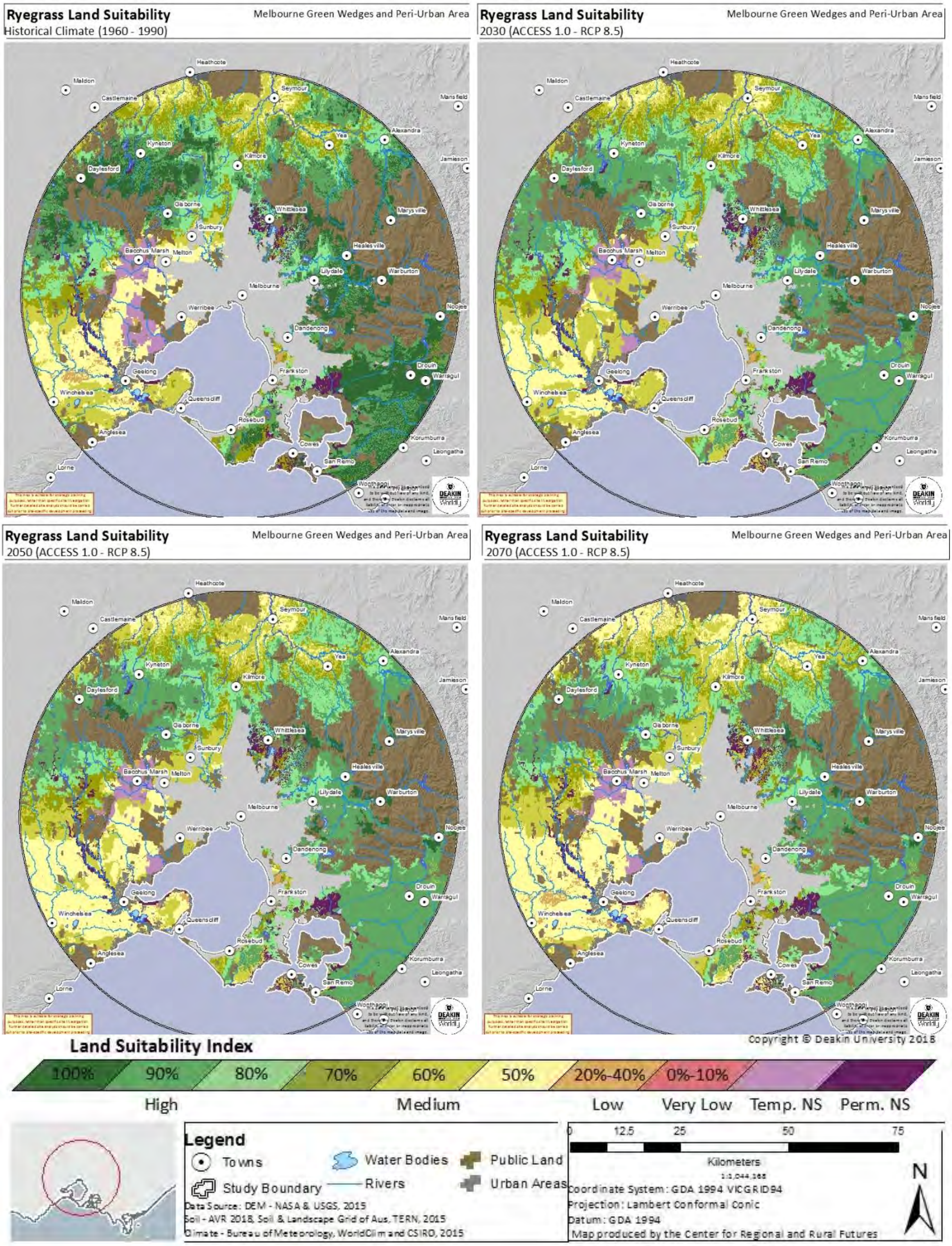


Figure 7.13 Ryegrass Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 38: Mapping Outputs


Ryegrass Land Suitability
Historical Climate (1960 - 1990)
Melbourne Green Wedges and Peri-Urban Area
Ryegrass Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Ryegrass Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Ryegrass Land Suitability
2070 (ACCESS 1.0 - RCP 8.5)
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Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Map produced by the Center for Regional and Rural Futures

7.9. Vegetables – brassica, lettuce and tomato

Brassica, Lettuce and Tomatoes were selected to represent vegetable horticultural systems in Melbourne's Green Wedge and Peri-Urban areas (albeit that tomato is not a vegetable). These are intended to represented general vegetable horticulture in the area, and as such, a generic brassica model was incorporated, which broadly covers a number of specific varieties, including broccoli, cauliflower and cabbage. The biophysical models depicted in Figure 7.14 to Figure 7.16 determine the suitability of the region to produce these commodities. All models were run with an irrigation component, calculated within each relevant growing season, and coming into effect only if effective rainfall thresholds were not met.

The Brassica model output relative to historical climate indicates that the region will improve in suitability out to 2070. Currently the region is largely suitable for brassica production, with approximately 45% of the land area suitable (80% suitable or higher). Moving to the projected future climate scenarios, 2050 and 2070, this increases substantially, to around 75% of the land area being highly suitable (80% suitable and higher). In particular, the very highly suitable areas increase from about 10% of the land area to nearly 30% of the land area. This very highly suitable area is largely concentrated on the fringe of metropolitan Melbourne in the east. Areas of low suitability in the west are likely to be a result of poor soil input data available in this region, and not necessarily a reflection of the existing biophysical qualities of this area.

The Lettuce model output relative to historical climate indicated a slightly less favourable suitability when compared with Brassica. Around 30% of the land area is currently suitable (80% suitable and higher) for lettuce production and this remains relatively stable in the projected future climate scenarios, with 2030 showing the largest increase in suitability (around 10% of the land area). Most of the suitable areas (80% suitable and higher) are again located in the south east and also the north east of the area.

Tomato (fresh) production in the area is likely to remain very highly suitable, both historically and into the future climate projected scenarios out to 2070. There is little fluctuation across the future scenario and there is an even spread of the highly suitable areas across the whole area. The large area of unsuitable areas to the west of the area are again likely to be influenced by the quality of the soil input data available in this area. Tomatoes, however, are a special case and are difficult to model. Production of fresh tomatoes in cooler parts of Victoria is currently shifting to glasshouses where climate is controlled, while in the hotter northern parts of the state where processing tomatoes are produced, the preferred location, according to farmers, is one where there is zero rain but access to sufficient irrigation water (personal communication, Kagome Australia, Echuca) – this ensures crop maturation can be managed in terms of timing and that harvesting can occur without the interference of rain and mud.

The percentage area of the region that falls within each suitability rating (for example, 80% suitable) at each time point is also displayed in Figure 7.14 to Figure 7.16 which gives a good indication of degree of change over time.

7.9.1.1. Brassica

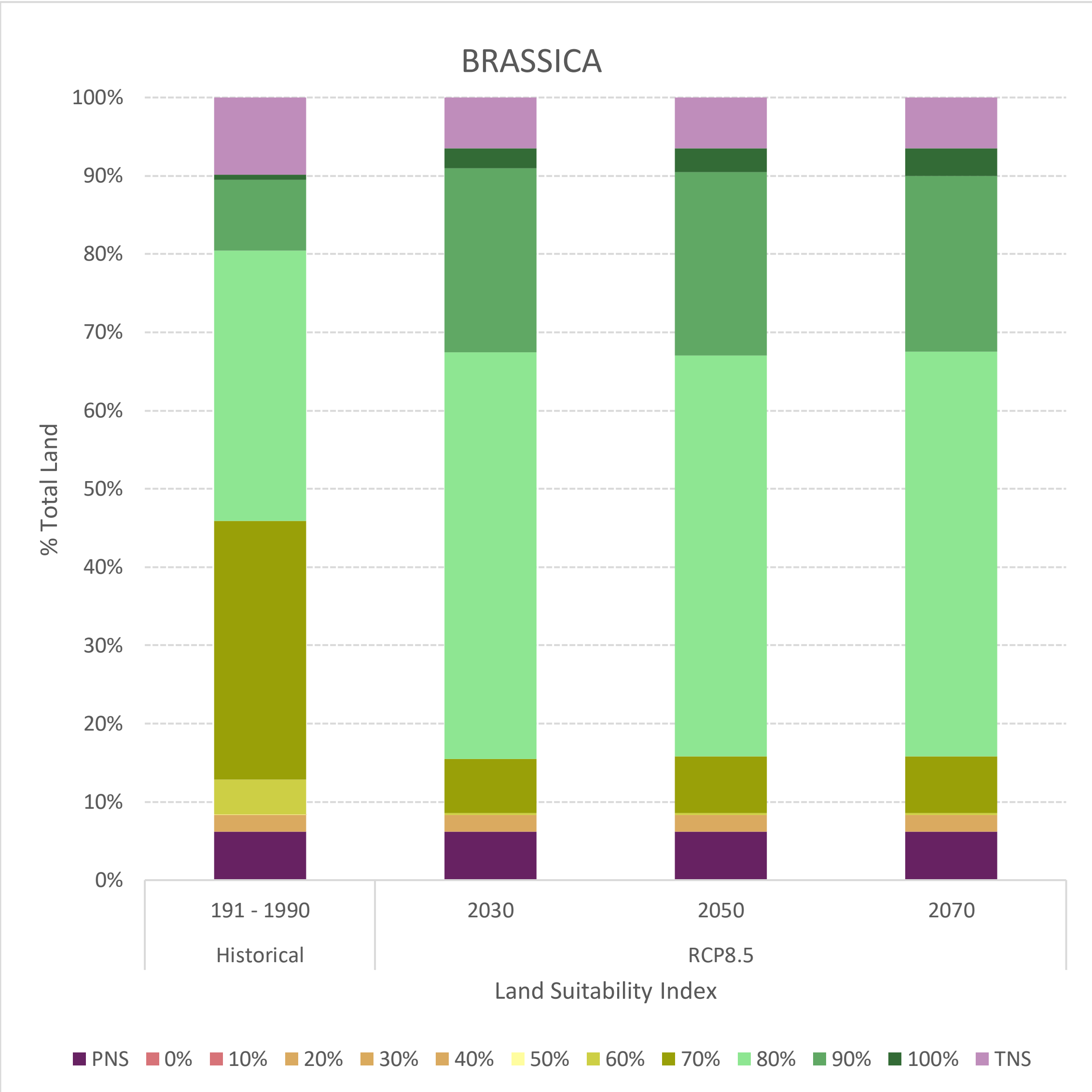
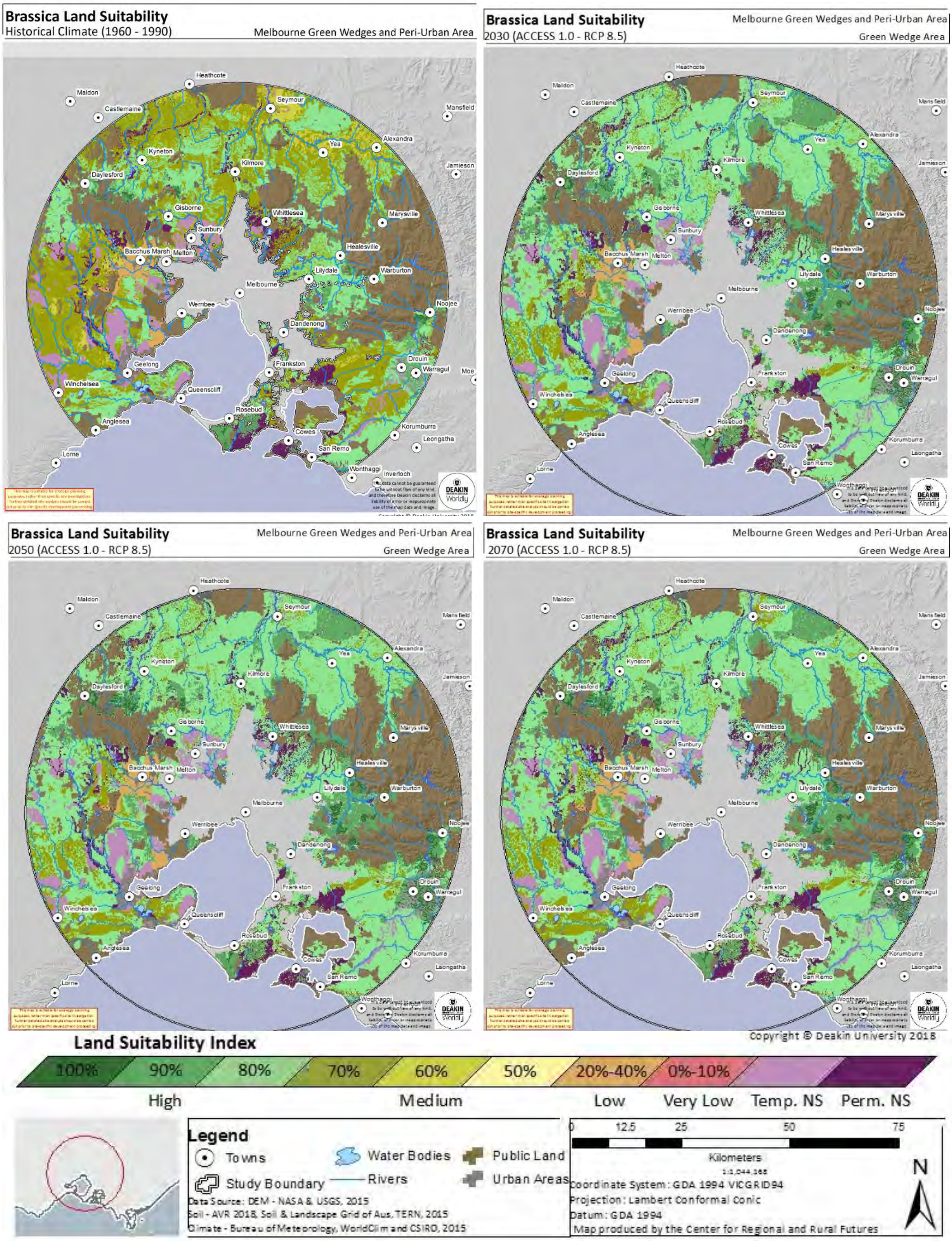


Figure 7.14 Brassica Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 41: Mapping Outputs


Brassica Land Suitability
Historical Climate (1960 - 1990)
Melbourne Green Wedges and Peri-Urban Area
Brassica Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Green Wedge Area
Brassica Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Green Wedge Area
Brassica Land Suitability
2070 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Green Wedge Area
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Daylesford
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Sunbury
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Geelong
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Land Suitability Index
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Water Bodies
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Data Source: DEM - NASA & USGS, 2015
Soil - AVR 2018, Soil & Landscape Grid of Aus, TERN, 2015
Climate - Bureau of Meteorology, WorldClim and CSIRO, 2015
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Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Map produced by the Center for Regional and Rural Futures
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7.9.1.2. Lettuce

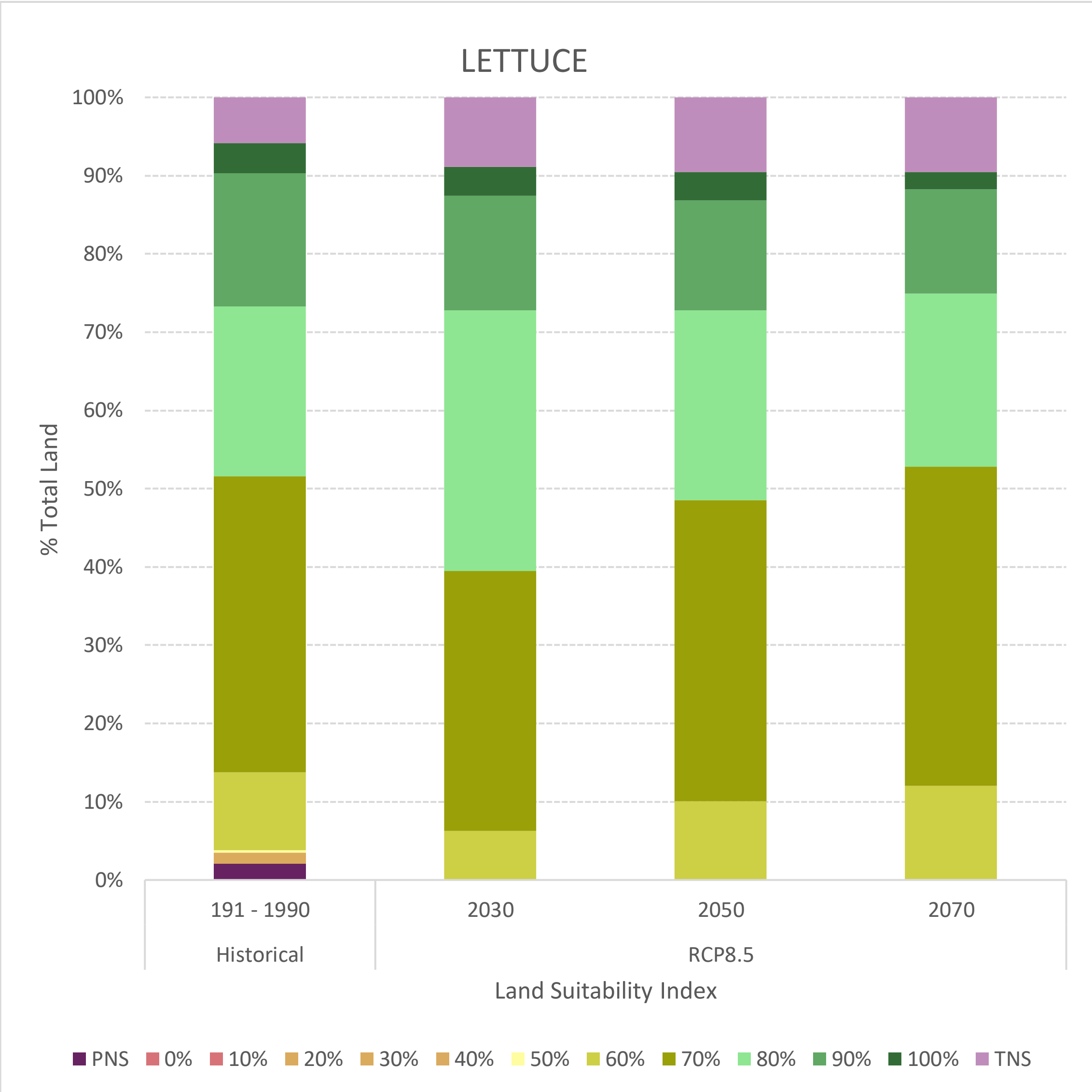
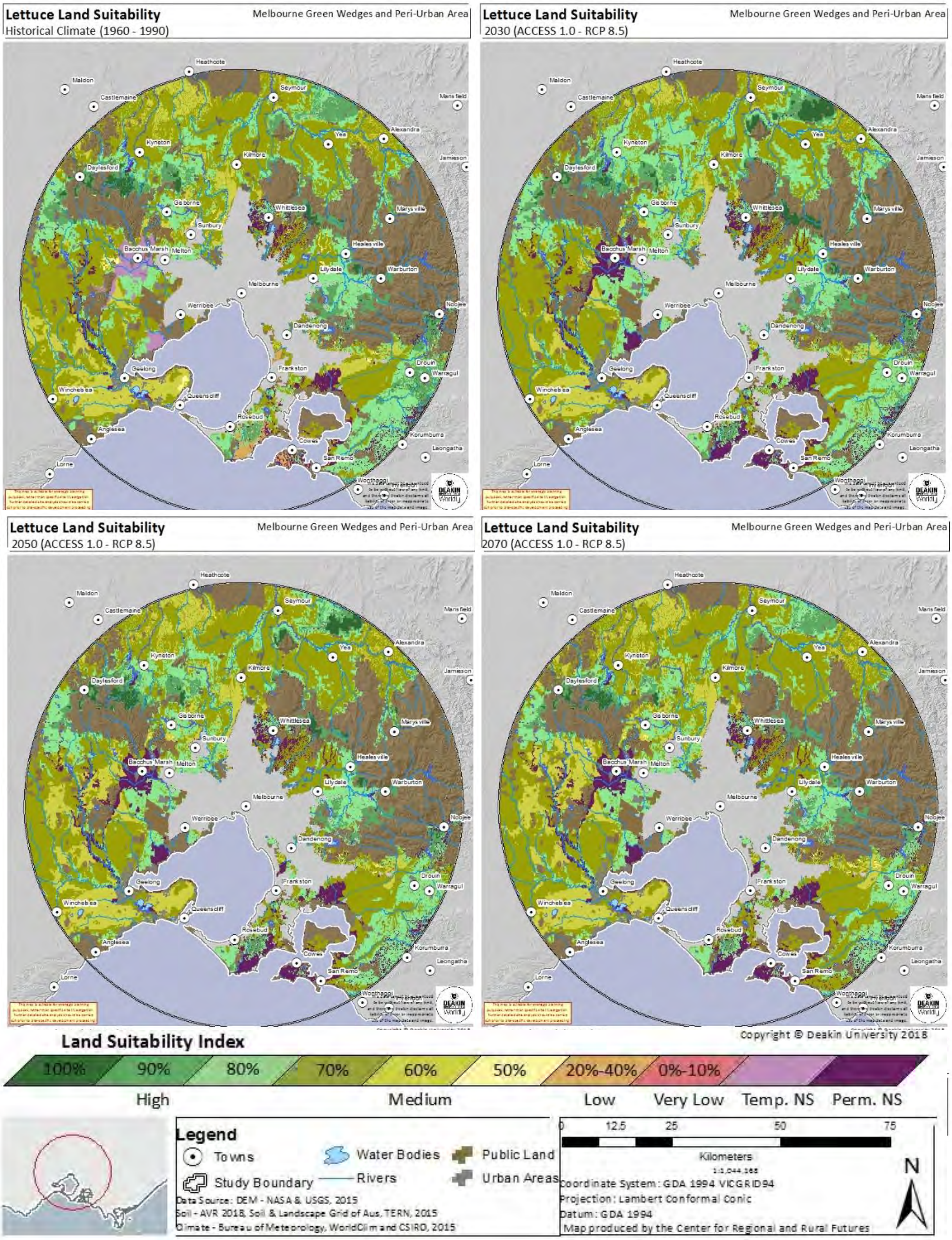


Figure 7.15 Lettuce Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 43: Mapping Outputs


Lettuce Land Suitability
Historical Climate (1960 - 1990)
Melbourne Green Wedges and Peri-Urban Area
Lettuce Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Lettuce Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Lettuce Land Suitability
2070 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Heathcote
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Data Source: DEM - NASA & USGS, 2015
Soil - AVR 2018, Soil & Landscape Grid of Aus. TERN, 2015
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Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Map produced by the Center for Regional and Rural Futures
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7.9.1.3. Tomato

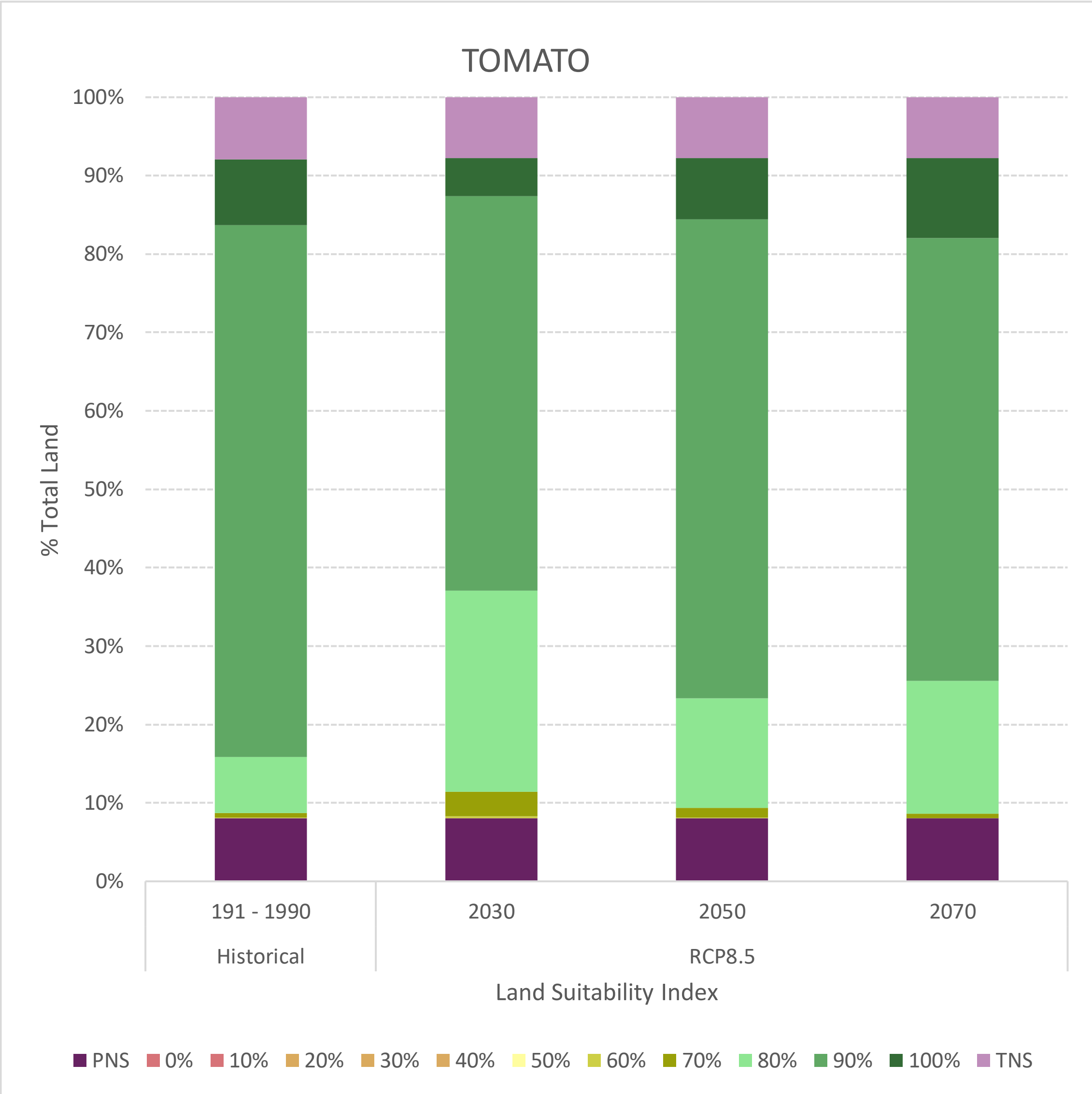
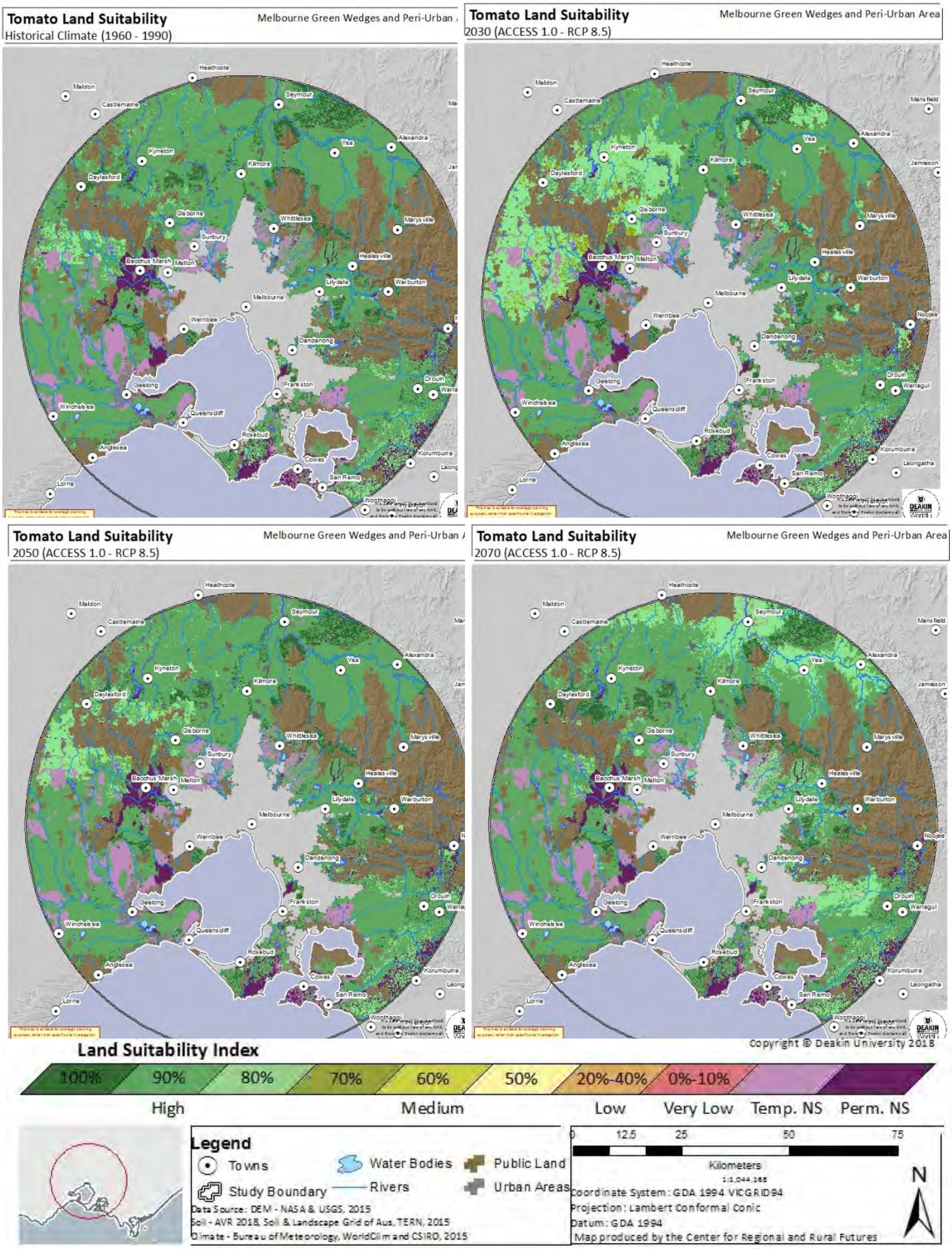


Figure 7.16 Tomato Land Suitability Analysis

a) Graph: Percentage of Total Land
b) Overleaf, pg 45: Mapping Outputs


Tomato Land Suitability
Historical Climate (1960 - 1990)
Melbourne Green Wedges and Peri-Urban Area
Tomato Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Tomato Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Tomato Land Suitability
2070 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Copyright © Deakin University 2018
Land Suitability Index
100%
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Data Source: DEM - NASA & USGS, 2015
Soil - AVR 2018, Soil & Landscape Grid of Aus, TERN, 2015
Climate - Bureau of Meteorology, WorldClim and CSIRO, 2015
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Kilometers
Coordinate System: GDA 1994 VICGRID94
Projection: Lambert Conformal Conic
Datum: GDA 1994
Map produced by the Center for Regional and Rural Futures
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7.10. Agricultural Versatility

Agricultural Versatility is used to identify areas that are well suited to support a number of different commodities. Figure 7.17 to Figure 7.21 show the outputs of the versatility models. These used the historical and future climate projection scenario in 2050, to overlay the existing outputs from individual commodity models. These were overlayed with equal weightings in a GIS to create a composite map of suitability, indicating the versatility of the area, or the ability of the land to support more than one commodity. The scale range is the same as for the suitability outputs: a very high value of 100% (dark green) indicates the land is very highly suitable to support more than one commodity, a moderate value of 60% (gold) indicates the land is less suitable to support more than one commodity, but does not discount this land in supporting one individual commodity (check individual maps). Areas are automatically considered not suitable (both temporary and permanently) if any one input contained a not suitable layer.

Three versatility scenarios were modelled:

1) **Total Versatility** – each of the 12 commodities were equally weighted.
2) **Vegetable Versatility** - each of the three vegetable commodities were equally weighted.
3) **Brassica and Lettuce Vegetable Versatility** - only Lettuce and Brassica were modelled (equally weighted).

Two additional versatility maps (Figure 7.20 and Figure 7.21) were developed to highlight only those areas of the study region that showed very high (80% and above) suitability for selected aggregated commodities.

4) **Warm and Cool Climate Grapes – areas with suitability of 80% and above** (highly suitable)
5) **Brassica and Lettuce and Tomato (vegetables) - areas of suitability of 80% and above** (highly suitable)

A high level of suitability was determined to be 80% and higher due to the index of factors developed in partnership with farmers and experts as part of the validation process. There was a general consensus that a high yield was obtained with 80% of the total expected yield. It is important to note that moderate suitability (in the order of 70% suitability) did not necessarily mean a poor yield, and on many occasions a producer could be satisfied with a moderate yield depending on the condition of the growing and harvesting seasons. For the purposes of this study however, a general threshold of 80% suitability was considered to mean a high suitability

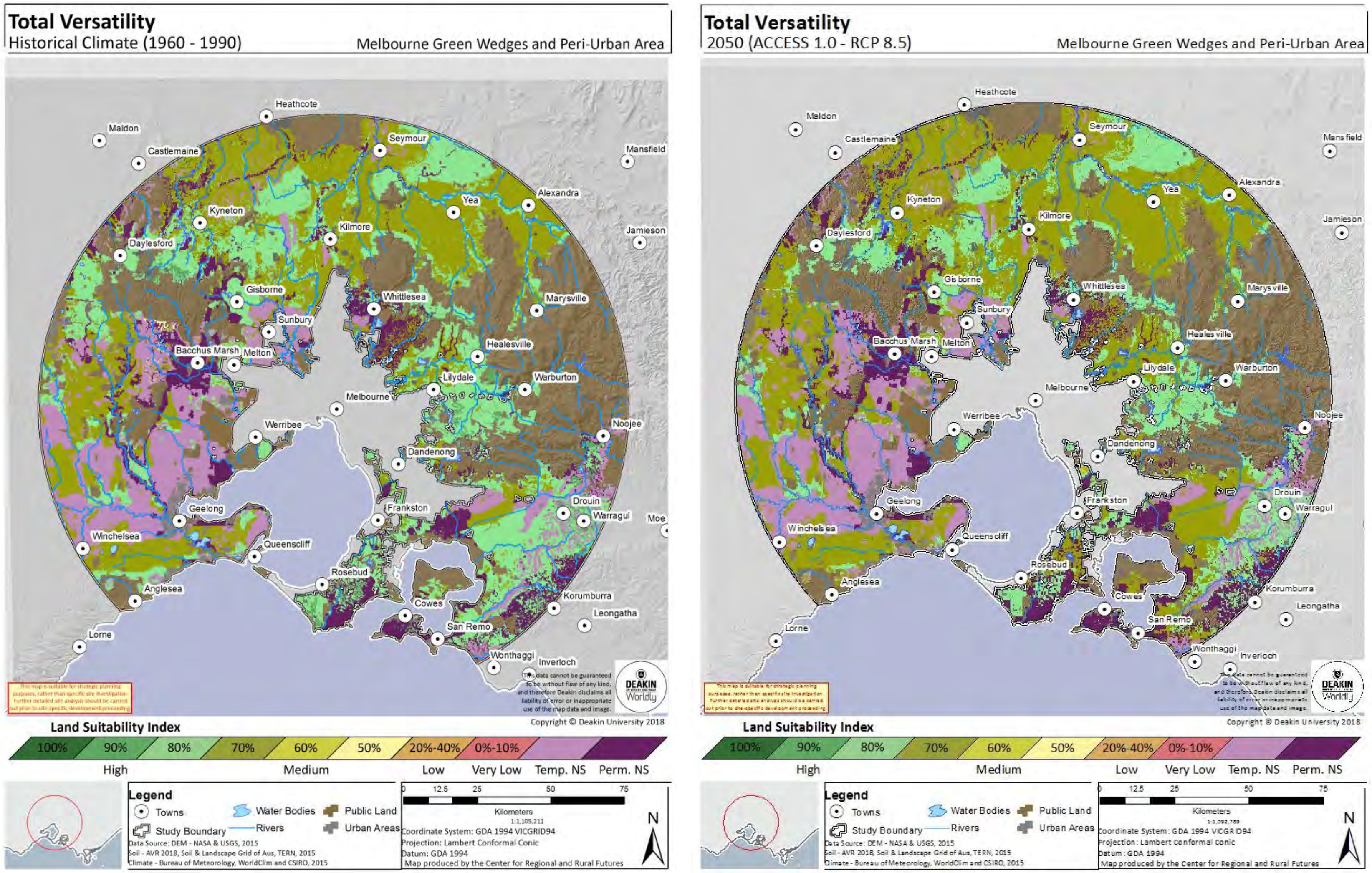


Figure 7.17 All commodity Agricultural Land Versatility

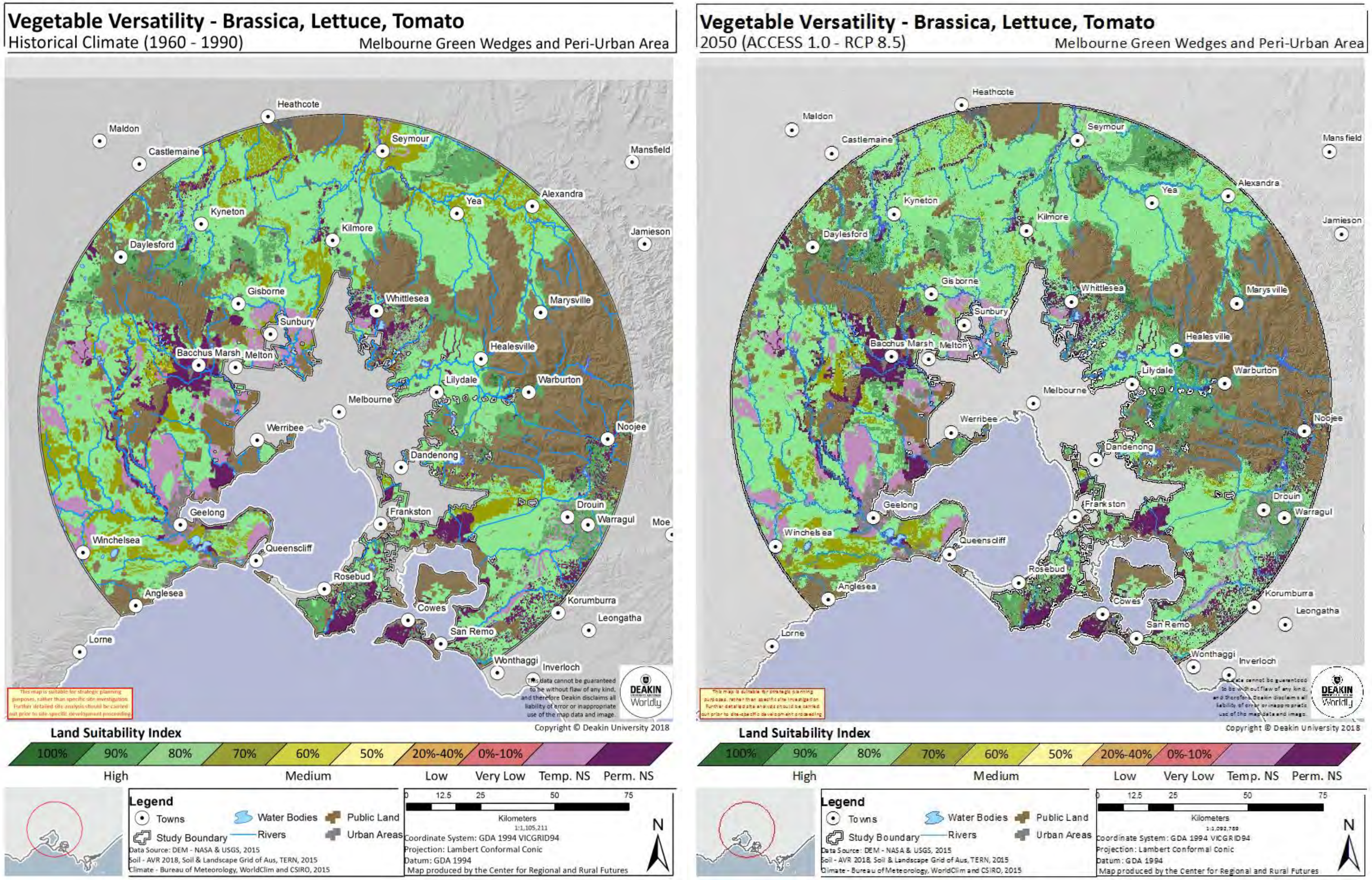


Figure 7.18 All Vegetable Agricultural Land Versatility

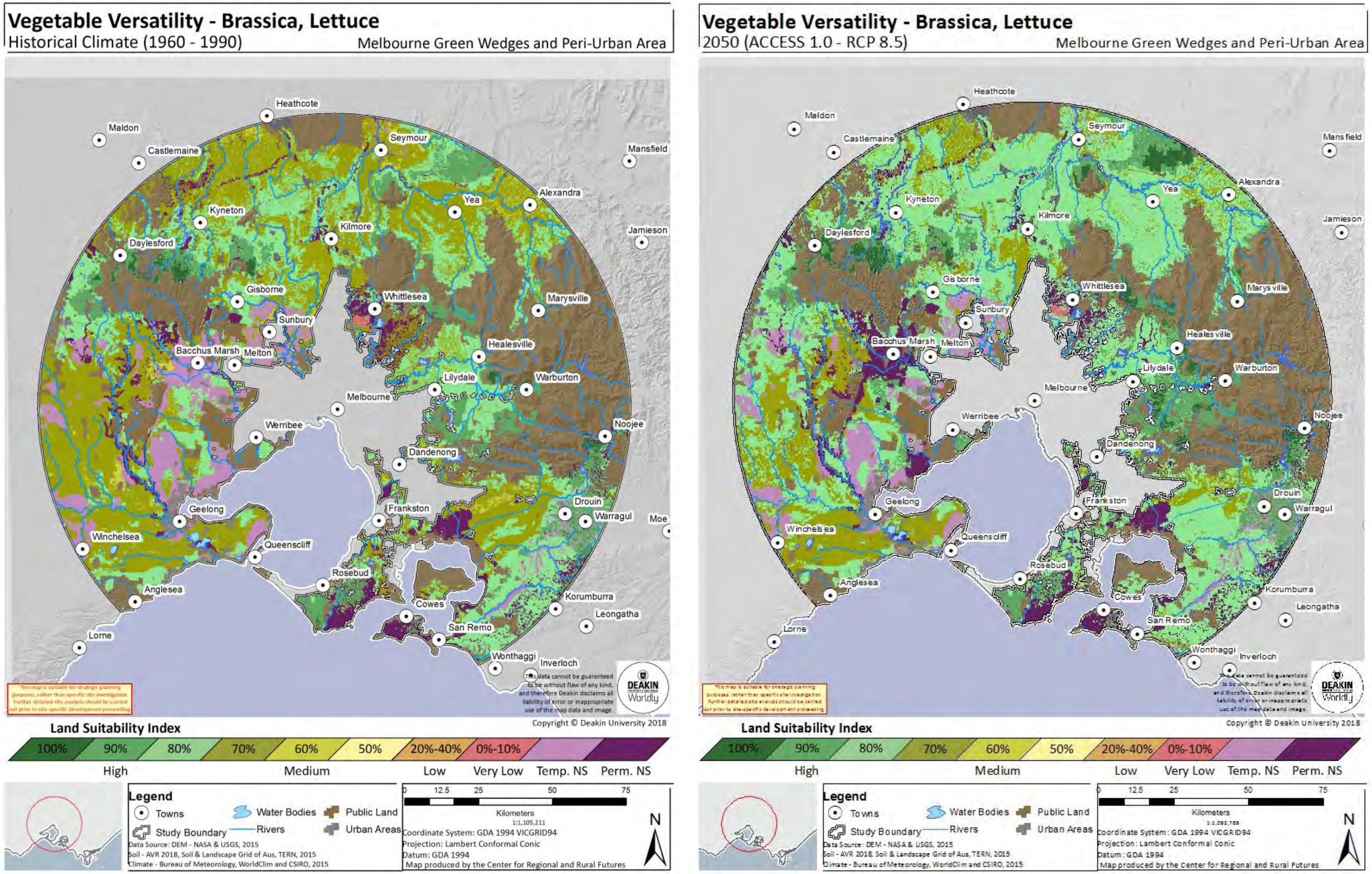


Figure 7.19 Green Vegetable Agricultural Land Versatility

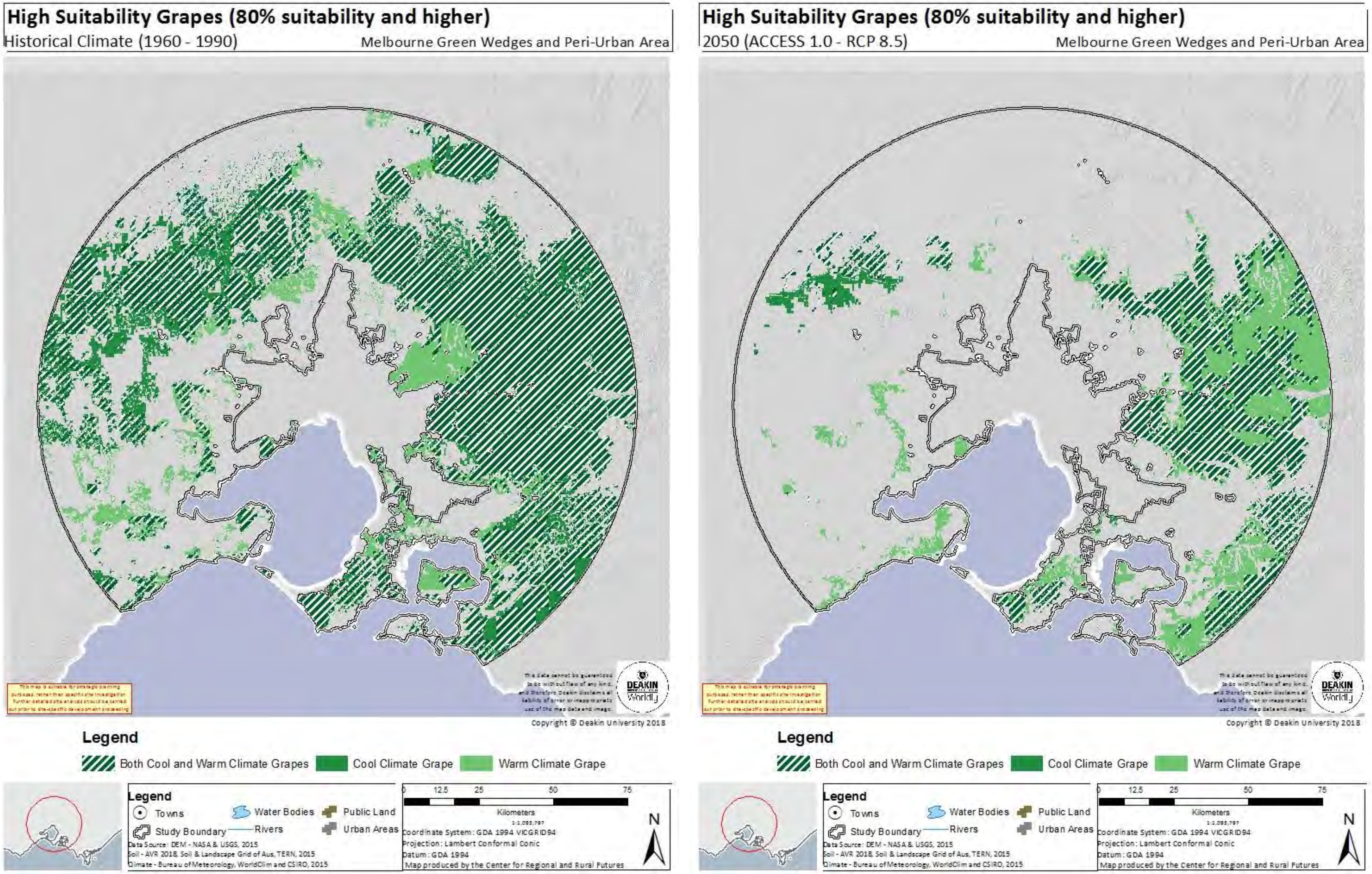
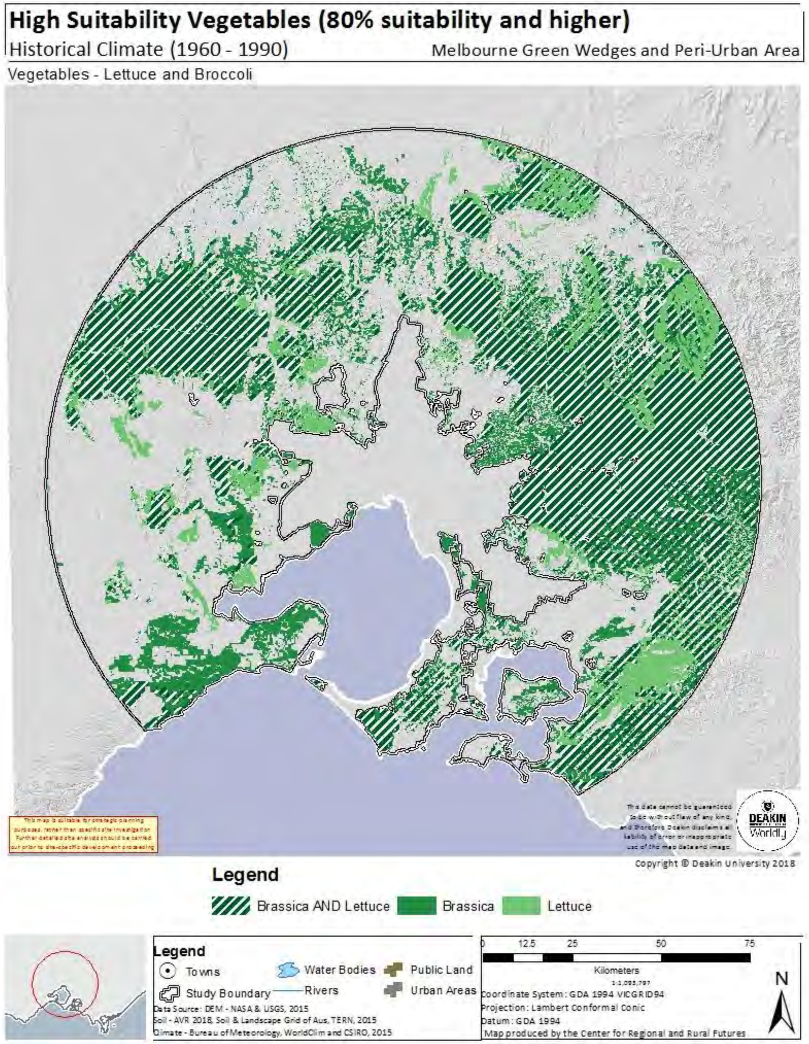


Figure 7.20 High Suitability Areas for Grapes



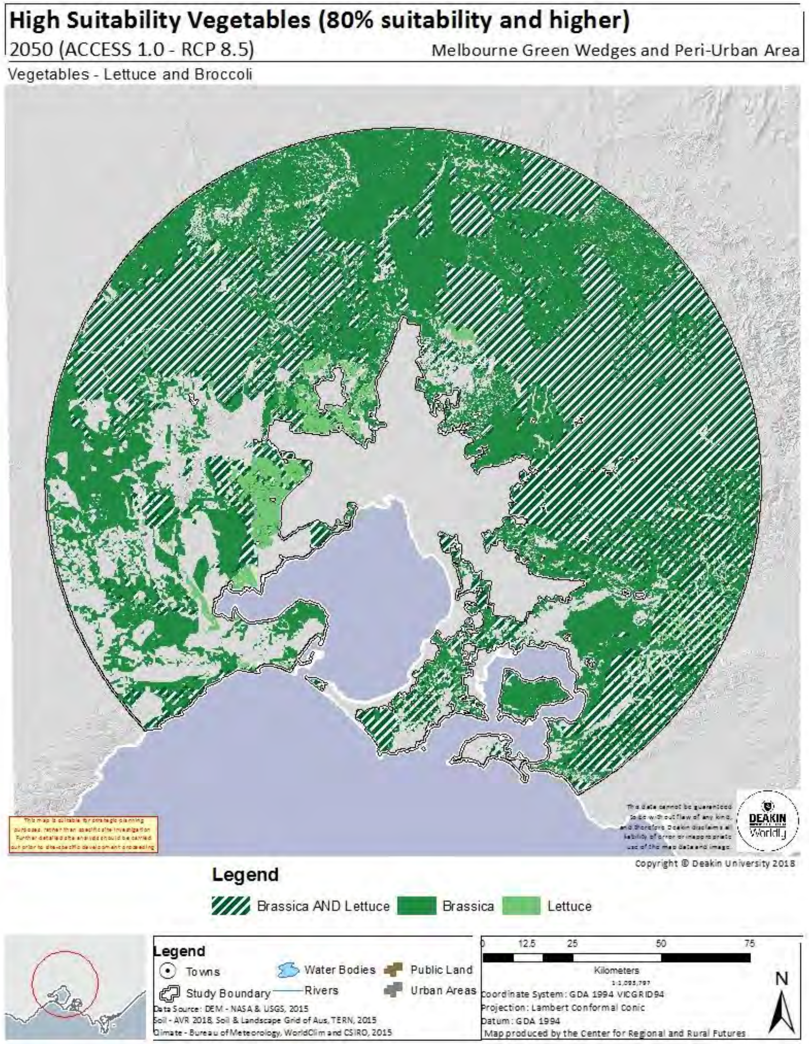


Figure 7.21 High Suitability Areas for Vegetables

7.11. Alternative Scenario - Increased Water– 20% Increase in Projected Rainfall

To investigate the effect that increased water availability may have on suitability, a +20% water scenario was modelled. This was implemented in the models simply by adding 20% additional rainfall as a proxy for farmers having access to 20% additional rainfall from other (non-rainfall) sources. Therefore, this scenario aims to represent an alternative future where an additional 20% of water is made available to agriculture in the study region by some means (provision of new irrigation infrastructure, access to alternative water sources or groundwater, etc). This serves two purposes: 1) to highlight those commodities where suitability is more influenced by water availability than other factors and 2) to help identify areas that could benefit most from the introduction of water infrastructure or access to new water sources. The outputs of these models can be found in Appendix II. The 20% figure was selected primarily because that amount will potentially be needed to offset recent and future rainfall declines as a result of climate change. Since the 1970's, rainfall in southeast Australia has shown a declining trend (and has already declined approximately 15% in that time) (Climate Council, 2018). According to climate modelling, that trend will continue and may in fact accelerate. Together with the expected increase in high heat days (which will necessitate increased irrigation to ensure crop survival), 20% additional water represents a useful benchmark to examine agriculture development opportunities today and also a useful threshold for future climate adaptation in the agriculture sector.

The cropping models showed slight fluctuations in moderately suitable areas, with little overall change in highly suitable areas (80% suitable and higher). The situation was similar for Pome Fruit, with little change, while suitability for both early and late season stone fruit actually decreased slightly with small areas (shifting from 90% to 80% suitable). The Lucerne also showed little change in the alternative scenario. Of the commodities modelled, these are the more susceptible to waterlogging and therefore this is not a surprising result. This scenario could be re-run with modified commodity models that incorporate improvements to soil drainage, to simulate management of waterlogging by farmers (for example, through the use of raised beds as is sometimes the practice in southwest Victoria with canola, precisely do deal with excess water) – we may see that once drainage is managed, the additional water results in a yield increase.

Both cool and warm climate grapes were shown to increase slightly under the alternative water scenario, however these changes were seen most apparently in 2030, where suitable areas (80% suitable and higher) increased by around 10%, but with less change in 2050 and 2070. Brassica suitability improved marginally, with an increase of about 5% of the land area shifting to high suitability (80% and higher) and lettuce improving by an additional 10%. Ryegrass also showed an increase in suitability under the alternative scenario, increasing suitable areas (showing 80% suitable or higher) by approximately 10%. This indicates that additional water will be a benefit to vegetable production and viticulture. Livestock production that is underpinned by irrigated pasture will also benefit.

To understand the Alternative Water scenario in the context of agricultural versatility, a similar model for total versatility was run for the 2050 outputs (as discussed in Section 7.10). That is, the final LSA outputs for each of the alternative water scenario models were overlayed with equal weights to produce a composite map of suitability indicating the versatility of the area, or the ability of the land to support more than one commodity. This was computed for all twelve commodities only, to be comparable with the original versatility outputs. The comparison is summarised in the bar graph in Figure 7.22 as well as 7Table 7.1. The graph and table describes the percentage of total land in the Green Wedge and Peri-Urban areas that fall within the LSA suitability classes.

In general, the alternative water versatility scenario sees a 25% increase in highly suitable areas for versatility (80% and higher suitable for more than one commodity) (shown in green in the bar graph). In addition, a 10% increase in 70% suitability for multiple commodities is observed. Most significantly there is a 20% and 80% decrease respectively in the Temporary and Permanently not suitable areas, due to the increase in available water modelled in this scenario.

While the model applies water directly regardless of source, as discussed in Section 6.3.2**,** alternative water sources may be utilised in the future to meet the biophysical demand to improve suitability as shown by the outputs of this modelling.

DELWP has established Integrated Water Management Forums across metropolitan and regional Victoria. The forums bring together organisations with an interest in water cycle management (local government, water corporations, catchment management authorities, DELWP and others) to collaboratively identify, coordinate and prioritise integrated water management opportunities.

Key areas of interest emerging from the forums in relation to alternative water for agriculture are the Western Irrigation Network, Whittlesea Community Farm, Coldstream, Kingston Green Wedge, Bunyip Food Belt, Tyabb and Somerville, The Briars and the Mornington Peninsular Hinterland, all which fall within the Green Wedge and Peri-Urban area of Melbourne.

An additional and secure water supply to these areas may influence the suitability of these areas and should be considered further as part of project feasibility assessments. The provision of additional water may particularly benefit specific crops such as fruit and vegetable horticulture.

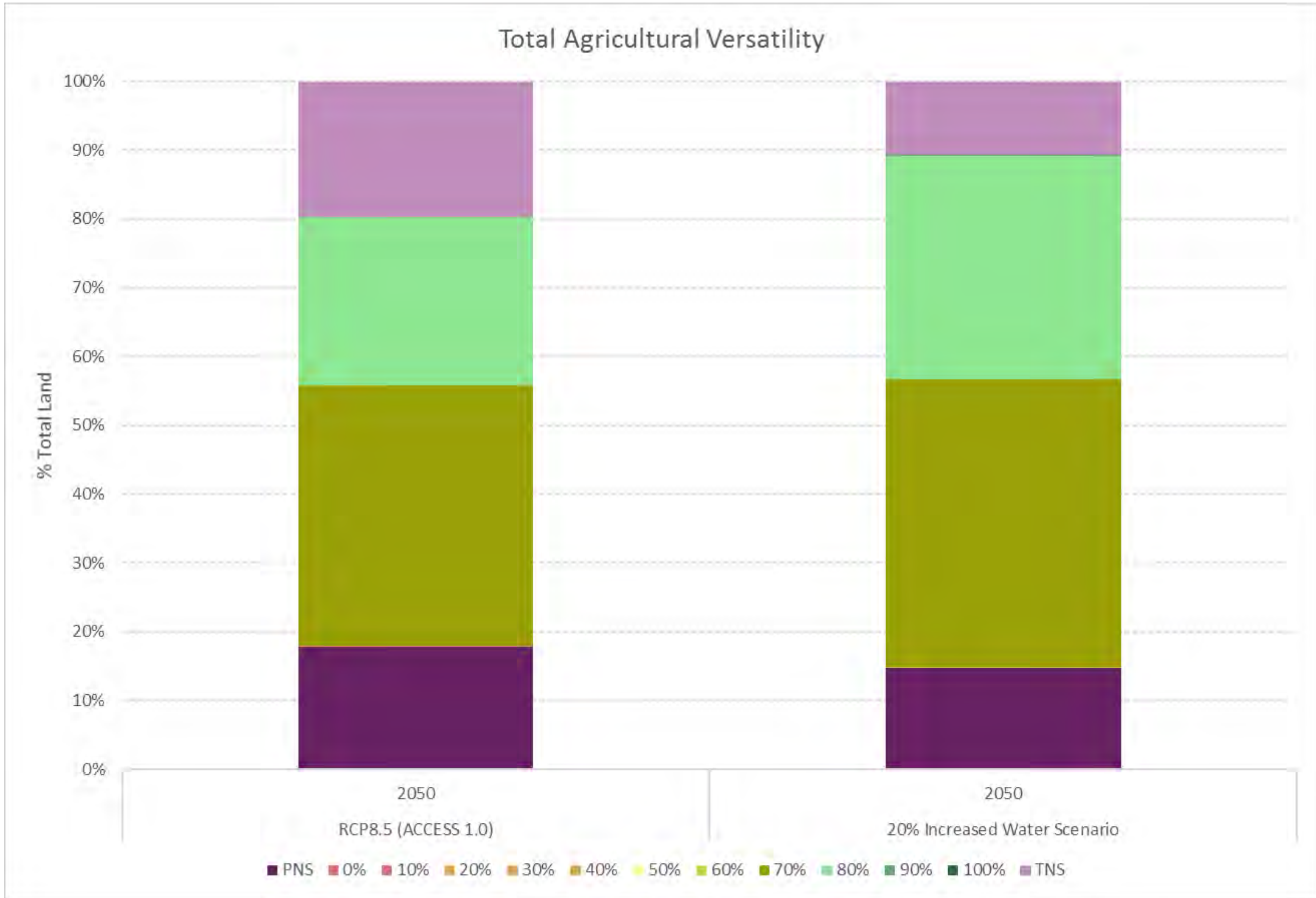


Figure 7.22. Percentage of Total Available Land within LSA classes RCP8.5 and Alternative Water Scenario

7Table 7.1. Percentage of Total Available Land within LSA classes

Percentage of Total Available Land within LSA Classes	**RCP8.5**	**20% Increased Water Scenario**
	2050	
PNS	18%	15%
0%	-	-
10%	<1%	-
20%	-	-
30%	-	-
40%	<1%	<1%
50%	<1%	<1%
60%	<1%	<1%
70%	38%	42%
80%	24%	33%
90%	<1%	<1%
100%	-	-
TNS	20%	11%

8. PLANNING CONTEXT

8.1. Planning Context

This report does not analyse the possibility of land use and planning overlay change, but presents the outputs of land suitability analysis in consideration to agriculture spatially. The results of this report could be used in conjunction with other relevant spatial information, including land use, planning overlays, biodiversity or other points of interest to garner a more complete picture of the planning context these outputs sit within.

For example, the agricultural land suitability analysis outputs can be both complementary and restrictive with respect to planning overlays. Whilst Land Subject to Inundation overlays may have some restrictions, these may not be as likely to restrict agricultural activities, and at times, be beneficial to agricultural activities requiring irrigation. Similarly, environmental significance overlays may restrict broad scale agricultural activities. Consideration on an individual basis may need to be made.

For land identified as suitable for agriculture there may be other considerations to be made, such as planning discussed above or environmental overlays, or other spatial analysis done regarding biodiversity. For example, DELWP's *NaturePrint* project models the strategic biodiversity value of Victoria, categorising locations into areas of an index of between high and low strategic biodiversity values. This may be used in conjunction with other work undertaken on Ecological Vegetation Classification across Victoria, to identify areas of native vegetation types and their conditions to identify priority areas for protection and conservation. The relationship spatially between areas highlighted by these other spatial datasets may be integrated into the information presented into this report for careful consideration.

8.2. Distribution Centres

A case study proximity analysis was carried out (Figure 8.1) to show the key areas of intersection for the vegetable industry in the southeast of the study area, where highly suitable land sits within a maximum 50km radius of *representative* distribution centres.

This assumes that there is some advantage to smaller vegetable farmers associated with being close to a distribution centre. During validation, no farmer indicated that distance from distribution centres was critical or, by extension, that transport costs were problematic. In fact, the project team spoke to two growers (one vegetable and one fruit grower) that had relocated from the southeast quadrant of the Green Wedge and Peri-Urban area to Cobram East along the Murray, more than 260km away – even this distance was not considered a disadvantage, provided that they planned well and made the daily time cutoffs for delivery of produce to Melbourne. Both growers, however, managed very large farms and had achieved substantial efficiencies in scale that offset transport costs. So, for the purposes of this study, we assumed that a radius of 50km from a distribution centre was advantageous by providing transport and storage cost-savings.

Representative distribution centres in Melbourne's southeast were used to characterise the distribution network in the south of Melbourne's Green Wedge and Peri-Urban Areas (Stage 1, South East). Five key centres in the south east region, along with the Melbourne Markets were selected (Table 8.1), using a database complied by the Australian horticultural exporters and importers association (AHEA, 2018). A proximity analysis at a 15, 30 and 50km radius of these key areas was undertaken to correspond to the key areas of vegetable versatility. The high value vegetable areas (areas able to support more than one vegetable crop at high suitability) (Section 7.10) was selected to be the base of the analysis, to highlight both the versatility and widespread suitability of vegetable horticulture industry across the area.

Representative distribution centres were used as an illustrative example of a proximity analysis as, in this study, the 100km radius of the study area was deemed to not restrict the transport of commodities. The exception to this, however, is French Island, which, due to its remoteness and accessibility only by passenger ferry is deemed to be restricted. Figure 8.1 shows French Island hatched dark grey as *restricted accessibility* to reflect this.

Table 8.1 Key Representative Distribution Centres

Name	**Location**	**Comment**
Melbourne Fresh Markets	Epping	Metropolitan Melbourne
Dandy Fresh	Clayton South	Peri-Urban Melbourne
Greenlands	Kilsyth South	Peri-Urban Melbourne
South Eastern Distribution Centre	Dandenong	Metropolitan Melbourne
Simply Fresh Fruit	Carrum Downs	Peri-Melbourne

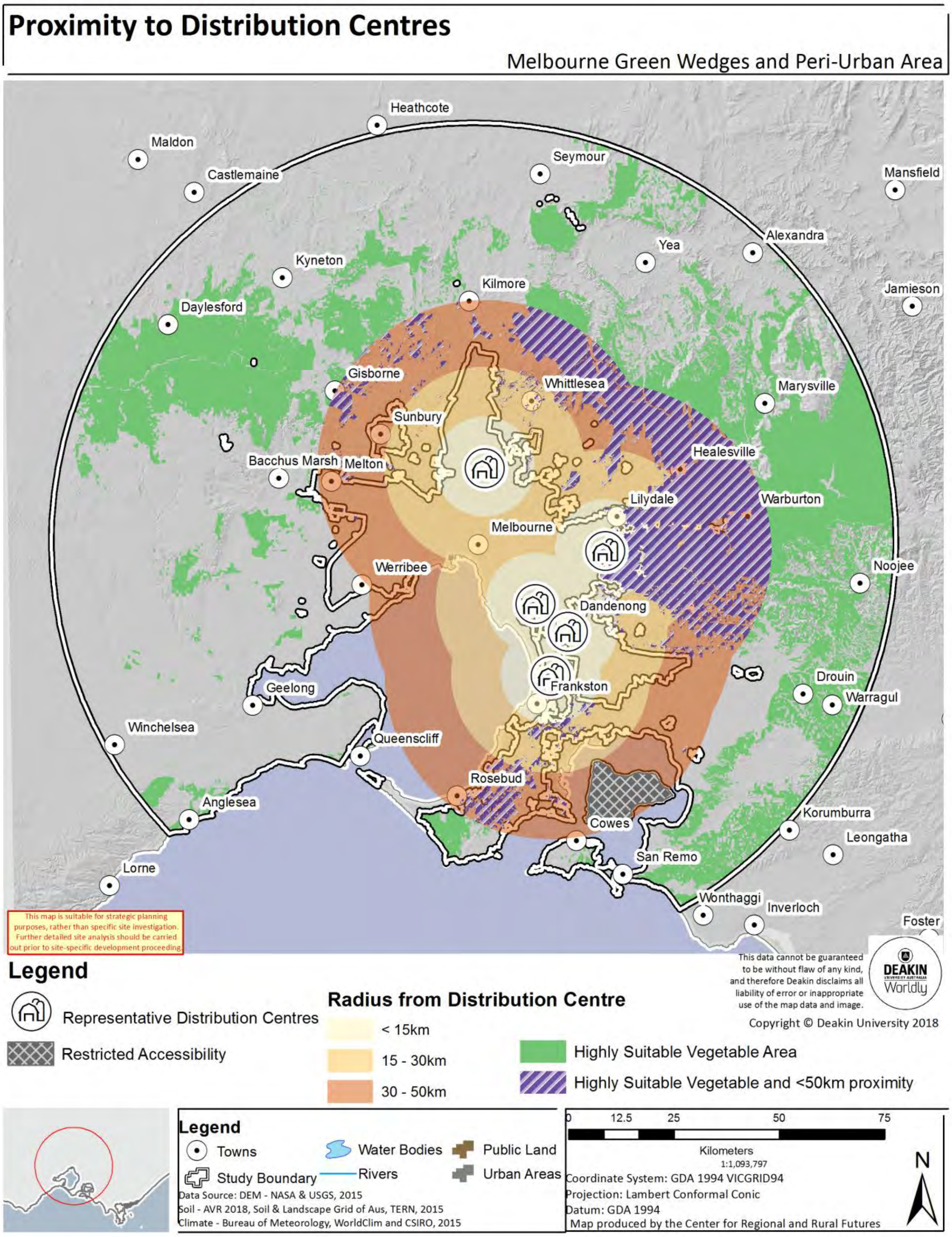


Figure 8.1 Proximity to Representative Distribution Centres

8.2.1. Key Infrastructure and water

Stage 1, the South East Region of the Green Wedge and Peri-Urban areas of Melbourne was used as a case study to identify key infrastructure that may be influential in the selection of key agricultural land. To support this, the highly suitable agricultural land for vegetables was used as a base.

Figure 8.2 shows the key infrastructure in relation to a possible highly suitable vegetable industry. For this case study, the areas of Drouin and Warragul are well serviced to support the region that is likely to support a vegetable industry considering the high value vegetable analysis (for more than one commodity) undertaken in Section 8.5. Drouin in particular appears to be supported with pipeline access, important for irrigation purposes for a vegetable industry.

Despite depicting a pipeline in this mapping (obtained from Victoria Data Resources Online), it is likely this pipeline data is incomplete, and showing potable water only. Figure 8.2 should be used as an indicative representation of the types of analysis this outputs of this report can be undertaken if appropriate datasets are available. Further discussion about access to Integrated Water management infrastructure can be found in Section7.11.

A note on water and in particular ground water. As discussed earlier, water is treated as a parameterised value in the models to account for possible water infrastructure changes that make water available to new geographical areas in the future. In fact, land-suitability analyses, and other modelling, can be used to underpin or inform investment cases for the development of water infrastructure, including new access to ground water resources. However, a more detailed assessment of the water layer is well beyond the scope of this study. For example, a report by the Victorian Auditor General (Sustainable Management of Victoria's Groundwater Resources, 2010) concluded that Victoria's the former Department of Sustainability and Environment, together with water authorities, did not know if groundwater use was sustainable. The report states "While a robust planning framework and planning tools have been developed, their effectiveness is undermined by inadequate groundwater data and monitoring, and delayed development and implementation of management tools. Licensing, metering and compliance monitoring activities are not rigorous enough to assure DSE or water corporations about who extracts groundwater and how much they extract. There is also insufficient data about groundwater reserves and sustainable extraction rates." Since the report was released, monitoring of groundwater resources in Victoria has declined further, making the situation worse. In response, Deakin's Centre for Regional and Rural Futures began an investigation on the impacts of climate change on groundwater resources in southwest Victoria, in conjunction with Wannon Water, the Glenelg Hopkins Catchment Management Authority, and the assistance of Agriculture Victoria. A full time PhD student has worked for three years to understand the dynamics of one aquifer (recharge in the current and future climate under different land uses). Understanding the dynamics and sustainable management options of groundwater across the whole of the Green Wedge and Peri-Urban area would be require a substantial effort from well-resourced hydrogeologists.

The situation is similar for recycled water. Reclaimed effluent water and stormwater runoff as a result of an increase in urban and concreted areas are the only fresh water resources that are actually increasing over time. But, understanding the future availability of the various fit-for-purpose alternative water products, and their delivery to urban and peri-urban customers (including agriculture), constitutes a separate and substantial project.

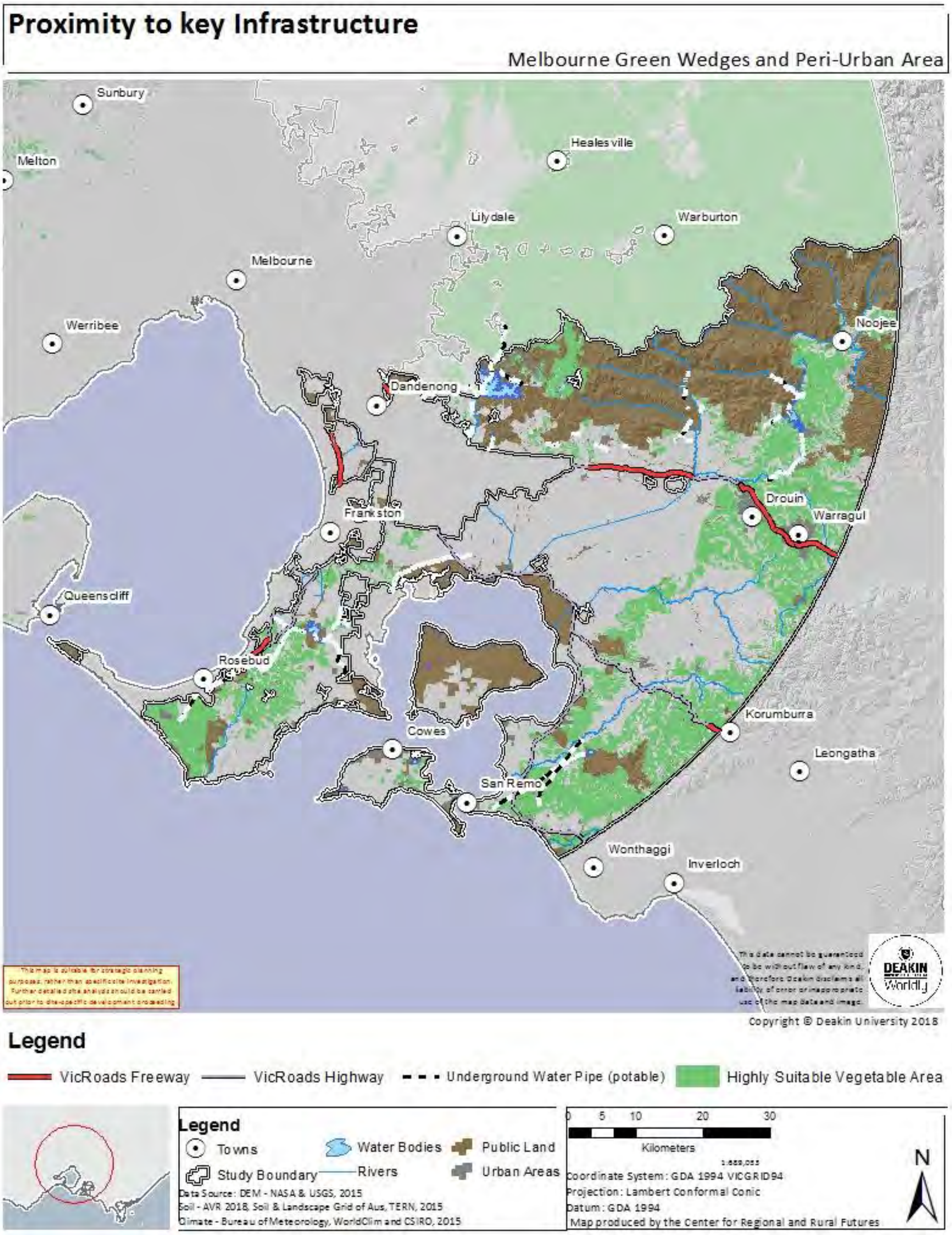


Figure 8.2 Proximity to Key Infrastructure

9. DISCUSSION AND CONCLUSIONS

This report presents an analysis of the agricultural potential of Melbourne's Green Wedge and Peri-Urban areas, as it relates to climate change, using a biophysical 'Land Suitability' approach. The results are intended to inform better, evidence-based planning decisions over the short to medium term in relation to land-use in the Green Wedge and Peri-Urban region, where urban-expansion is rapidly transforming the landscape.

The production of horticultural crops on the edge of cities was historically essential because of the perishable nature of produce and the limitations in early transport systems. The need to get highly perishable fruits and vegetables to Melbourne consumers quickly, meant that intensive horticulture grew on the available fertile soils of the urban fringe (Burke, 2009), especially during the latter half of the 19th century and first half of the 20th century. But, technological advances have seen transport become faster and more cost effective, and with the concomitant economies of scale achieved by agriculture over time, Melbourne's 'foodbowl' is now a much expanded and geographically larger concept.

Urban sprawl and its impact on agriculture and food production is an issue all over the world and has been the subject of much research. Brueckner (2000) argued that urban spatial expansion is the result of a growing population, rising incomes and declining transport costs, and therefore urban sprawl is simply the market deciding that land is more valuable for urban uses than it is for other uses such as agriculture. The situation can potentially be reversed if agriculture becomes a more valuable land use (if we ignore the likelihood that concrete-and-house covered soil will be returned to agriculture). As per Brueckner's model, in recent years Melbourne's population has grown, incomes have risen and transport costs have declined. Together with plentiful land and a highly adaptable and productive agricultural sector, the market has decided that Melbourne's land is more valuable for urban land-uses.

What Breuckner's model lacks is consideration of the likely impacts of climate change on the *future* value of land for a particular use. As we have seen in this and other recent studies, climate change will most likely result in the suitability of Green Wedge and Peri-Urban areas of Melbourne for agricultural production increasing over time, while the suitability of more traditional agricultural zones in the north of the state decline (Faggian et al 2016). Therefore, if Melbourne's urban expansion continues into a climate-changed future, the area available for food production will effectively be squeezed from north and south. In this situation, the *future* market value of peri-urban land for food production is substantially higher than it is relative to today. This premise is underpinned by the fact that soil is a finite resource and is generally lost to food production once subjected to urban land-use.

Here, we have added a strategic (temporal) biophysical layer to the argument by showing that the suitability of certain commodities will increase over time as the climate changes. Context is important and understanding how land-use will change outside the Green Wedge and Peri-Urban boundary is key, particularly from climate-driven changes to regional agricultural production. Temperatures across the state are expected to increase (Figure 6.1) and rainfall is expected to decrease (Figure 6.2), with the most severe impacts in the north of Victoria, which constitutes the State's foodbowl today (specifically, the irrigation districts in Sunraysia and the Goulburn-Broken catchment). In the event that agricultural production in those regional areas declines in a climate-changed future, then food security may become a driver for the protection of agricultural land in the less affected parts of the state, including within the Green Wedge and Peri-Urban region.

According to the analysis the geographical areas projected to have the most suitable biophysical conditions (e.g. soil, water, landscape, climate) and greatest versatility into a climate-changed future, while still producing high yields, are:

1) Parts of the Dandenong ranges, extending down to the Bunyip food belt and up through the Yarra Valley to Healesville and Warburton;
2) The Gippsland region around Warragul and Drouin, extending up to Neerim North and south to Poowong;
3) Parts of the Mornington Peninsula, particularly around Rosebud and Red Hill;
4) Whittlesea and the region extending east through Kinglake and through to Toolangi;
5) Parts of the Central Highlands region, including Daylesford and surrounds, through to Tylden/Woodend and Kyneton in the north;
6) Gisborne and areas north bounded by Kilmore and Tooborac;
7) Parts of the region extending from Seymour/Tallarook through to Yarck;
8) Werribee South.

The listed locations generally encompass areas of high suitability (80% and higher) for more than one commodity when considering the twelve commodities (total agricultural versatility as discussed in Section 7.10) assessed in this study. Other considerations such as the various planning overlays and strategic areas for biodiversity were not included in this report given the focus on biophysical parameters for crop production. However, the outputs of this analysis can be integrated into the broader planning context by overlaying other data sources to generate composite maps.

Also, this analysis covers only a small proportion of the commodities currently produced in Melbourne's Green-Wedge and Peri-Urban areas. Modelling of additional commodities may result in changes to the extent, or number, of geographical areas that are considered most suitable into the future.

Furthermore, some of the models represent very generic crop varieties in order to capture the largest range of possible climate impacts. But, it is possible to quickly amend any of the models so that they represent specific varieties or to investigate the specific queries of breeders. For example, the models could be quickly modified to account for new varieties that are more heat or drought tolerant, without the need for additional validation. This would allow rapid assessments of emerging innovations in breeding programs, or other farm management practices, that are not present today.

Finally, it should be remembered that this work represents modelling of a possible future where climate changes according to today's worst-case scenarios. This is one of many possible futures, all of which are dependent on a number of local, national and global variables.

10. REFERENCES

ABS 2005. 7121.0 - Agricultural Commodities, Australia, 2003-04. Australia: Australian Bureau of Statistics.

Adams, T. 1934. The Design of Residential Areas. Harvard University Press, Cambridge, Massachusetts.

AHEA. 2018. Australian Horticulture Association's Exporters' and Importers. https://www.ahea.com.au/importers-exporters [last accessed 16.07.18]

Al-Harbi, K. M. A. S. (2001). "Application of the AHP in project management." International Journal of Project Management 19(1): 19-27.

Armstrong, D. (2000). "A Survey of Community Gardens in Upstate New York: Implications for Health Promotion and Community Development." Health and Place 6(4): 319-327.

Banai, R. 1993. Fuzziness in geographical information systems: contributions from the analytic hierarchy process. International Journal Geographical Information Systems 7(4): 315– 329.

Banai-Kashani, R. 1989. A new method for site suitability analysis: the analytic hierarchy process. Environmental Management 13:685–693.

Berry, J. K. 1983. MAP-NEWS. The newsletter of Map Analysis Package (MAP) users, vol. 1, no. 1. Yale University, School of Forestry and Environmental Studies, New Haven, CT.

Brady, N. (1974) The nature and property of soils (8th Ed). New York: MacMillan.

Brueckner, J. K. (2000). "Urban sprawl: Diagnosis and remedies." International Regional Science Review 23(2): 160-171.

Burke, M. (2009) Constrained Harvests: a historical view of land use planning and nutrition in Australian cities, Paper presented at the Making Cities Livable Healthy Cities Conference – Gold Coast Queensland.

Burrough, P. A., R. A. MacMillan, and W. van Deursen. 1992. Fuzzy classification methods for determining land suitability from soil profile observations and topography. Journal of Soil Science 43:193–210.

Cheever, M. A., et al. (2009). "The prioritization of cancer antigens: A National Cancer Institute pilot project for the acceleration of translational research." Clinical Cancer Research 15(17): 5323-5337.

CSIRO; Bureau of Meteorology. CSIRO & TERN. 2015. Soil and Landscape Grid of Australia [Online]. Australia: CSIRO. Available: http://www.clw.csiro.au/aclep/soilandlandscapegrid/index.html 2015].

DELWP. 2018. Strategic Biodiversity Values. Nature Print. DELWP.

DSE. 2002. Victoria's Native Vegetation Management Framework. Melbourne, Victorian Government.

Elings, M. (2006). People-Plant Interaction. Farming for Health. J. Hassink and M. van Dijk. Netherlands, Springer: 43-55.

FAO 1976. A Framework for Land Evaluation, Rome, Italy, Food and Agriculture Organisation of the United Nations.

FAO 1993. Guidelines for Land-Use Planning, Rome, Italy, Food and Agriculture Organisation of the United Nations.

Fabos, J., C. M. Green, and S. A. Joyner. 1978. The METLAND landscape planning process: composite landscape assessment. Alternative plan formulation and plan evaluation. Part 3, metropolitan landscape planning model. Massachusetts Agricultural Experimental Station, Amherst, MA.

Faggian, R., Johnson, M., Sposito, V. & Romeijn, H. 2016. Climate Smart Agricultural Development in the Goulburn Broken Region: Technical Reports. Centre for Regional and Rural Futures, Deakin University, Burwood.

Faggian, R., Sposito, V. & Romeijn, H. 2016. Future Landscapes: Regional Agricultural and Biodiversity Climate Adaptation and Opportunities Plan. Centre for Regional and Rural Futures, Deakin University, Burwood.

Frumkin, H. (2001). "Beyond toxicity: Human health and the natural environment." American Journal of Preventative Medicine 20(3): 234-240.

Goodchild, M. F., B. Parks, and L. Steyaert (eds.). 1993. Environmental Modeling with GIS. Oxford University Press, New York.

Groenewegen, P., A. van den Berg, et al. (2006). "Vitamin G: effects of green space on health, wellbeing, and social safety." BMC Public Health 6(1): 149.

Independent Expert Panel of Interim Targets (IEPIT) 2017. Independent Expert Panel" Interim Emissions Reduction Targets for Victoria (2021-2030). Victoria, Department of Environment, Land, Water and Planning.

Intergovernmental Panel on Climate Change (IPCC) 2018. Global Warming of 1.5^{o}C. Special Report Summary for Policymakers. IPCC, Incheon, Republic of Korea.

Lyle, J., and F. Stutz. 1983. Computerized land use suitability mapping. Cartographic Journal 20:39–49.

Jeffrey, S. J., Carter, J. O., Moodie, K. B. & Beswick, A. R. 2001. Using spatial interpolation to construct a comprehensive archive of Australian climate data. Environmental Modelling & Software, 16, 309-330

Lewis, C. A. (1995). "Human health and well-being: the psychological, physiological, and sociological effects of plans on people." Acta Horticulturae (ISHS) 391: 31-40.

McDonald, G. T., and A. L. Brown. 1984. The land suitability approach to strategic land use planning in urban fringe areas. Landscape Planning 11:125–150.

McHarg, I. L. 1969. Design with nature, Garden City, N.Y., Published for the American Museum of Natural History [by] the Natural History Press.

McHarg, I. (1992) Design with Nature. 25th anniversary edition. John Wiley & Sons, New York.

MacDougall, E. B. 1975. The accuracy of map overlays. Landscape Planning 2:23–30.

Malczewski, J. 1996. A GIS-based approach to multiple criteria group decision-making. International Journal Geographical Information Systems 10(8):955–971.

Miller, W., M. G. Collins, F. R. Steiner, and E. Cook. 1998. An Land-Use Suitability Analysis 619 approach for greenway suitability analysis. Landscape and Urban Planning 42:91–105.

Nieman, T. J., and D. S. Meshako. 1983. An analytical approach to weighting attributes for landscape planning. Working paper, University of Kentucky, Department of Horticulture and Landscape Architecture, Lexington, KY.

Pereira, J. M., and L. Duckstein. 1993. A multiple criteria decision-making approach to GIS-based land-suitability evaluation. International Journal of Geographic Information Systems 5:407–424.

Relf, D. (1992). "Human Issues in Horticulture." HortTechnology 2(2).

Saaty, T. L. 1980. The Analytic Hierarchy Process: Planning Priority Setting, Resource Allocation. McGraw-Hill, New York.

Sheehan, D. E. 1979. A discussion of the SYMAP program. Harvard Library of Computer Graphics 1979, mapping collection, vol. 2: Mapping software and cartographic databases.

Soderback, I., M. Soderstrom, et al. (2004). "Horticultural therapy: the 'healing garden' and gardening in rehabilitation measures at Danderyd hospital rehabilitation clinic, Sweden." Developmental Neurorehabilitation 7(4): 245-260.

Steiner, F. (2008) *The Living Landscape – An Ecological Approach to Landscape Planning*. Island Press, New York.

Steinitz, C., P. Parker, and L. Jordan. 1976. Hand drawn overlays: their history and prospective uses. Landscape Architecture 9:444–455.

Sullivan, W. C. and F. E. Kuo (1996). Do trees strengthen urban communities, reduce domestic violence? Forestry Report R8-FR 56, University of Illinois.

11. APPENDIX I

Project Methodology Background

The earliest work on land suitability for planning, in the late nineteenth and early twentieth centuries, involved hand-drawn sieve mapping overlays. This combined soil and vegetation information with topography to infer relationships with other land-uses, and underpinned important town-planning activities such as the establishment of new circulation routes (Steinitz et al, 1974). This method was used through to the 1930s and 40s and formed the basis for the New York Regional Planning study (see Adams 1934), amongst others.

In the 1950's, the hand-drawn sieve mapping overlay method was subjected to academic discussion and development. An updated approach was presented in the textbook "*Town and Country Planning*" (Architectural Press, 1950), which contained an article by Jacqueline Tyrwhitt who is considered one of the founders of modern urban design. The article presented an advance on the overlay method that used four maps (relief, hydrology, rock types and soil drainage), drawn on transparent paper and combined into one 'land characteristics' map to inform planning. This approach was widely accepted and used extensively during the post-war, large-scale planning and development of Britain and North America (Lyle & Stutz, 1983).

Development of the method continued through the 60's and 70's, with the most noteworthy being the seminal work of Ian McHarg who incorporated the ecological inventory process (McHarg, 1969). McHarg introduced mapped information of the human-made influences on the landscape as well as the natural attributes of an area – these were overlaid to identify areas intrinsically suitable for broad land-use planning categories like conservation, recreation and urbanisation. On the basis of McHarg's work, many postgraduate students with an interest in planning flocked to study under him at Pennsylvania State University. As such, a significant body of applied research ensued on suitability analysis through the 1970s and 80s. During this phase, the number and type of maps being included in suitability studies increased, which made the analyses much more complex. This coincided with the rise of computers and therefore computer-assisted suitability analysis was developed.

The application of computer technology to suitability analysis was driven primarily by researchers from Harvard University (e.g. MacDougall, 1975; Sheehan, 1979; Berry, 1983) and generated the well-known SYNAP (syngraphic mapping system) and MAP (mapping analysis program) planning software packages. The University of Massachusetts was also active during this period and developed the METLAND suitability tool (Metropolitan Landscape Planning Model) (Fabos et al 1978). These computer-assisted suitability analyses formed the basis for the development of *Geographic Information Systems* (GIS), which is now an integral planning tool.

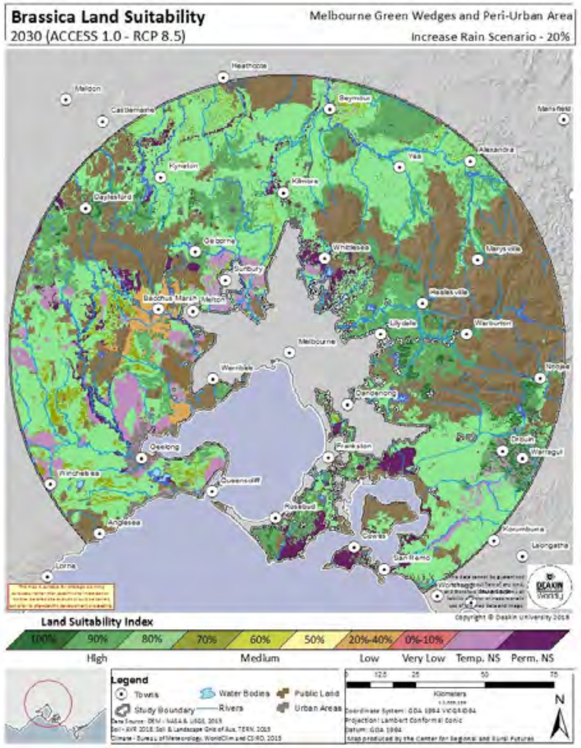
As suitability analyses become more complex, problems with the traditional Boolean land unit classification system became apparent. For example, Boolean land classifications assign precise definitions to a land unit and homogeneous land units with values that fall outside the definition are not included in the class. By contrast, fuzzy set theory dictates that the inclusion of a land unit within a particular class is a matter of 'degree of belonging' rather than strict classification according to precise definition. This is particularly evident when considering a soil's capacity to support agriculture and the influence that human-intervention (ie. farmer management practices) can have on said capacity. The integration of fuzzy set theory within suitability analysis and more broadly in GIS therefore became prominent through the 1980s and 1990s (see for example Banai, 1993; Burrough et al 1992; Goodchild et al 1993).

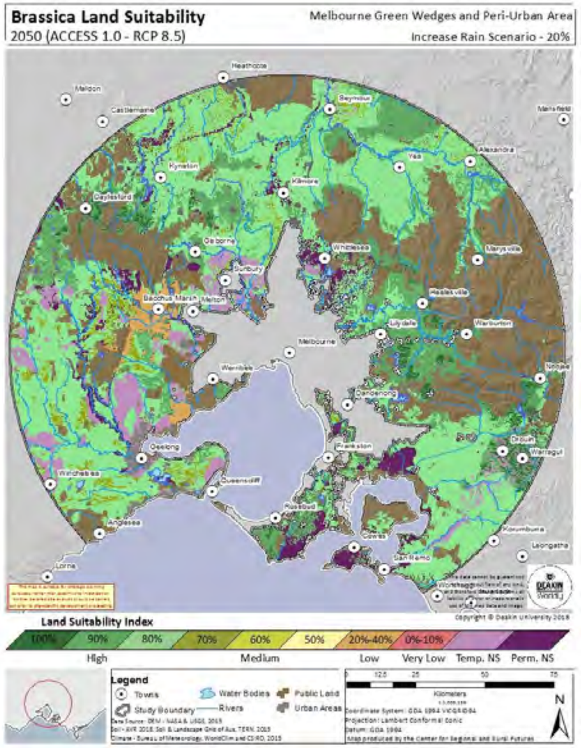
Similarly, it soon became necessary to find less restrictive methods to incorporate decision-makers' preferences within land-suitability analysis. The most well-researched approach was the integration of the multicriteria decision-making (MCDM) or multicriteria evalution (MCE) methods. For example, Pereira and Duckstein (1993) developed a method to evaluate alternative land-use decision options based on their closeness (distance) to the ideal point that served as a frame of reference. Banai (1993) then offered the integration of the *Analytic Hierarchy Process* (AHP) within a GIS environment as a means to rank options from among pairwise comparisons of many options. The AHP was initially developed by Saaty in the 1970s (Saaty 1980) and has since been used extensively around the world in planning and suitability analysis (for example, Nieman & Meshako 1983; McDonald & Brown 1984; Banai-Kashani, 1989; Banai 1993, Malczewski 1996; Miller et al 1998).

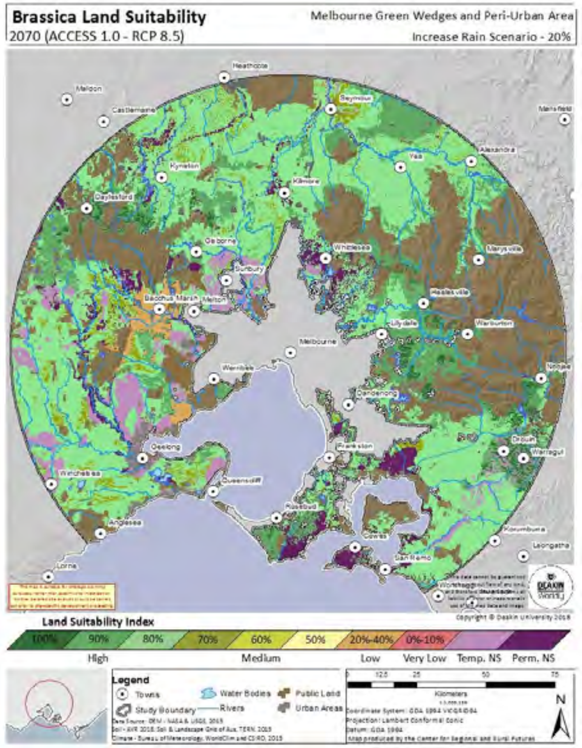
Today, the 'suitability' methodology is used to assist decision-making not only in land-use planning but a broad range of areas, from cancer research (Cheever et al, 2009) through to project management (Al-Harbi, 2001). An example of a recent local implementation for land-use planning, which is very similar to that being outlined in this report, is the work of the CSIRO (together with the CRC for Irrigation Futures and UNESCO) to determine the suitability of irrigated areas of the Murray Darling Basin. In that case, the suitability analysis was developed as a tool to inform investment decisions; such as upgrades to existing irrigation schemes, the establishment of new schemes or the retirement of others (Chen et al 2010).

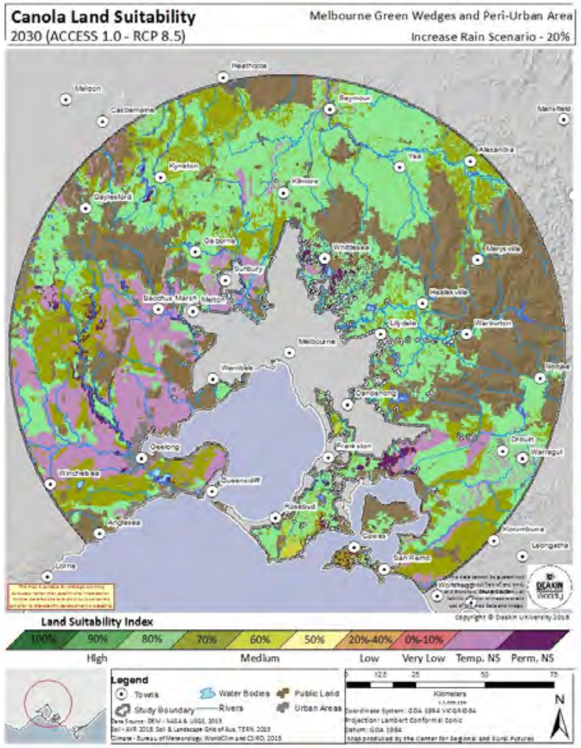
Our methodology of biophysical *Land Suitability Analysis* (LSA) is based on the universally-recognised approach of Ian McHarg (1992), as developed in his seminal book *Design with Nature*, and draws on elements of the Dutch Suitability Analysis system. It includes the consideration of soils, but also includes other factors that are critical to plant production such as climate and water availability as well as a specific treatment of the temporal component (climate change over time) to bring the results in line with medium- to long-term planning horizons. In short, an analytical hierarchy process is established that ranks and weights all major biophysical factors that are important to crop growth in space and time. Suitability is related to yield, where highly suitable land is considered able to support a crop that a farmer would consider high-yielding. The input data (climatic parameters, soil data and information, topographical information) originate from curated sources (and in this case, all soil data inputs originate from the complimentary study "Assessment of Agricultural Land Capability in Melbourne's Green Wedge and Peri-Urban Areas"), but how those factors are ranked and weighted relative to each other is driven by local knowledge (farmers). Further information is provided in Section 8 and can also be found in Sposito et al 2013.

12. APPENDIX II





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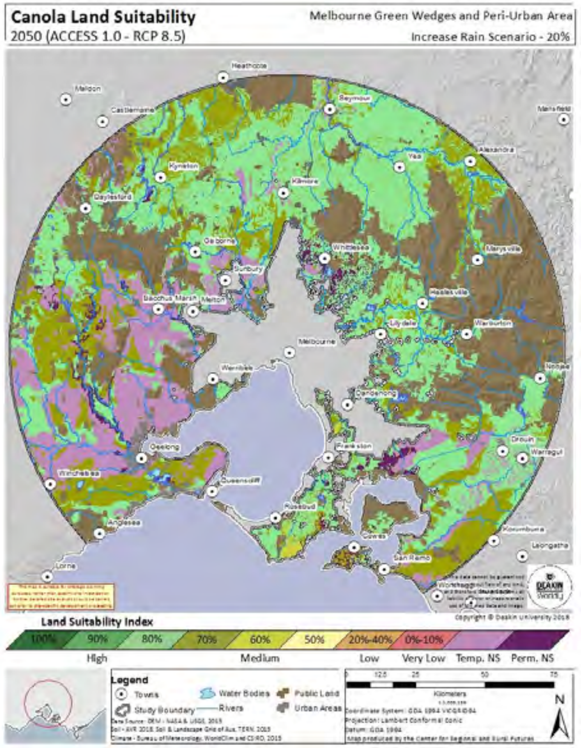
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
100% 90% 80% 70% 60% 50% 20%-40% 0%-10%
High Medium Low Very Low Temp. NS Perm. NS
Legend
Towns
Study Boundary
Water Bodies
Rivers
Public Land
Urban Areas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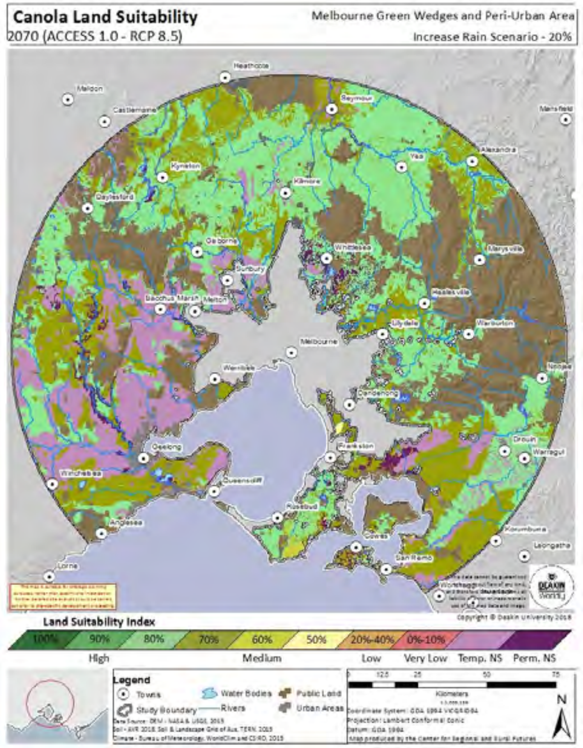
Towns
Study Boundary
Water Bodies
Rivers
Public Land
Urban Areas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Land Suitability Index
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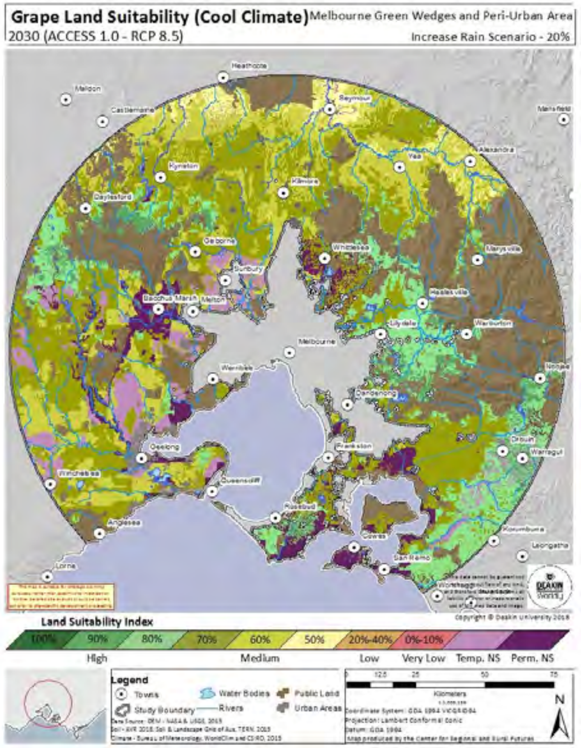
High Medium Low Very Low Temp. NS Perm. NS
Legend
Towns
Study Boundary
Water Bodies
Rivers
Public Land
Urban Areas


Grape Land Suitability (Cool Climate)
Melbourne Green Wedges and Peri-Urban Area
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Increase Rain Scenario - 20%
Land Suitability Index
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High Medium Low Very Low Temp. NS Perm. NS
Legend
Towns
Study Boundary
Water Bodies
Rivers
Public Land
Urban Areas
Kilometers
Projection: Lambert Conformal Conic
Datum: GDA 1994
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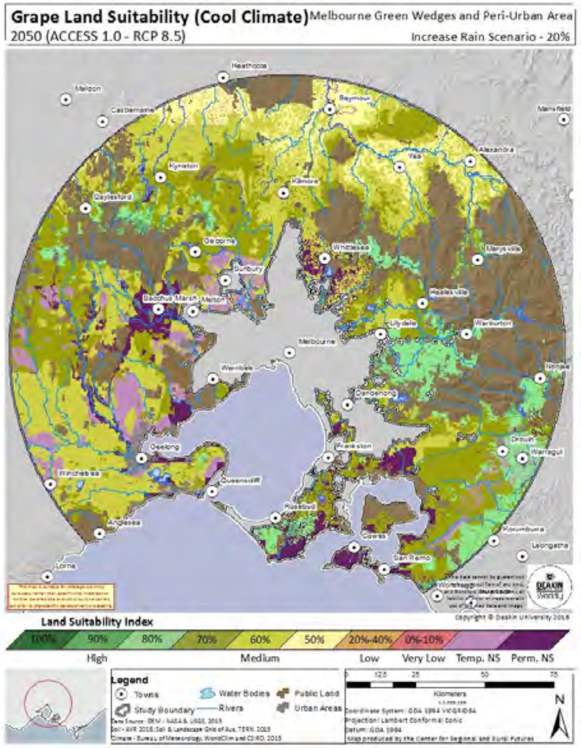
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Land Suitability Index
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High Medium Low Very Low Temp. NS Perm. NS
Legend
Towns
Study Boundary
Water Bodies
Rivers
Public Land
Urban Areas
Kilometers
Projection: Lambert Conformal Conic
Datum: GDA 1994
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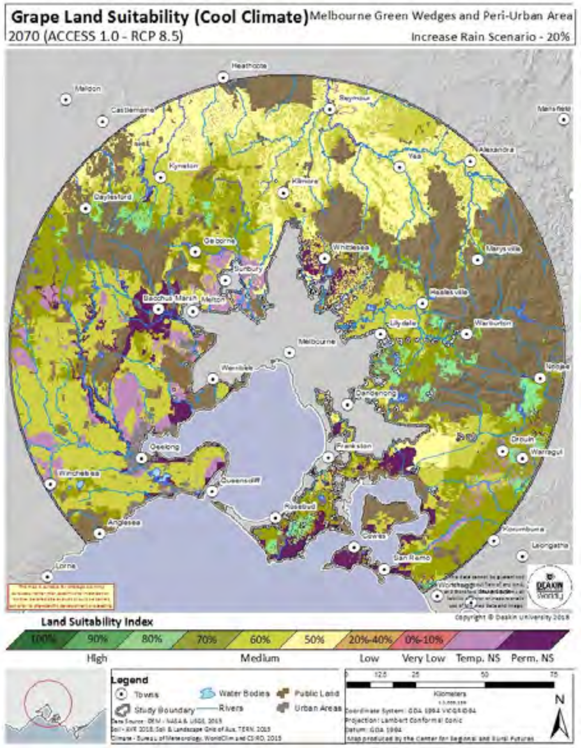
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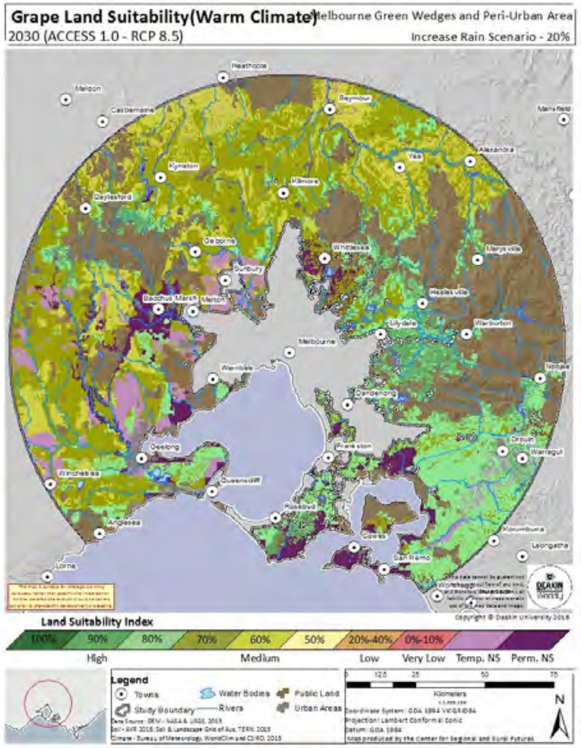
Grape Land Suitability(Warm Climate)
Melbourne Green Wedges and Peri-Urban Area
2030 (ACCESS 1.0 - RCP 8.5)
Increase Rain Scenario - 20%
Land Suitability Index
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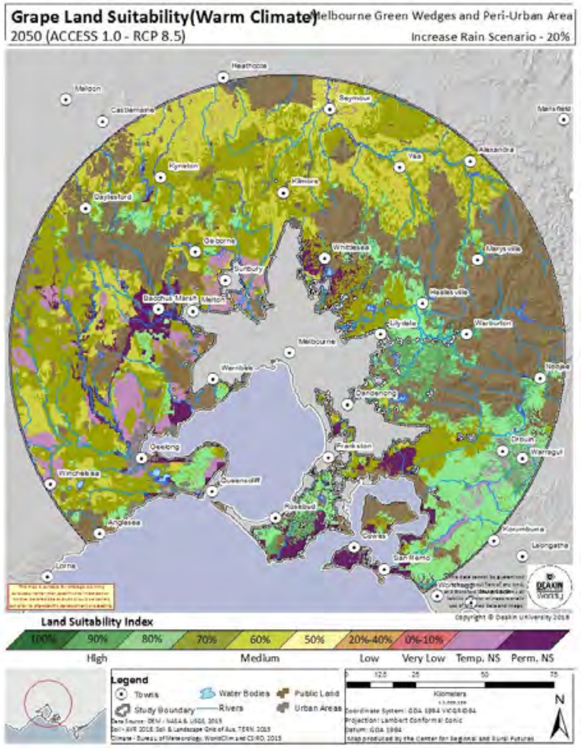
Grape Land Suitability(Warm Climate)
Melbourne Green Wedges and Peri-Urban Area
2050 (ACCESS 1.0 - RCP 8.5)
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Land Suitability Index
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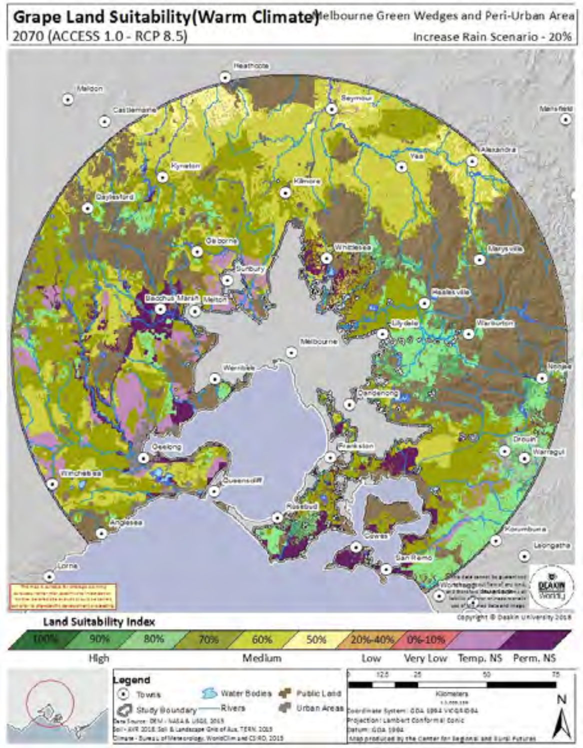
Grape Land Suitability(Warm Climate)
Melbourne Green Wedges and Peri-Urban Area
2070 (ACCESS 1.0 - RCP 8.5)
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Land Suitability Index
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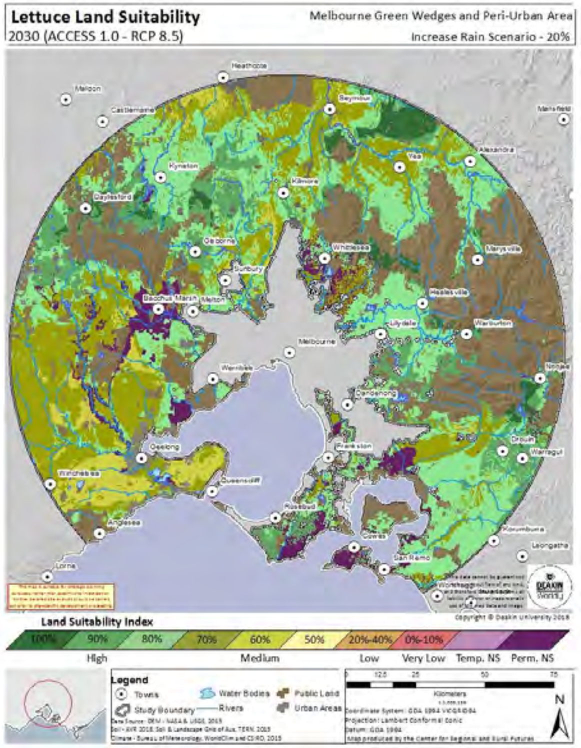
Lettuce Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
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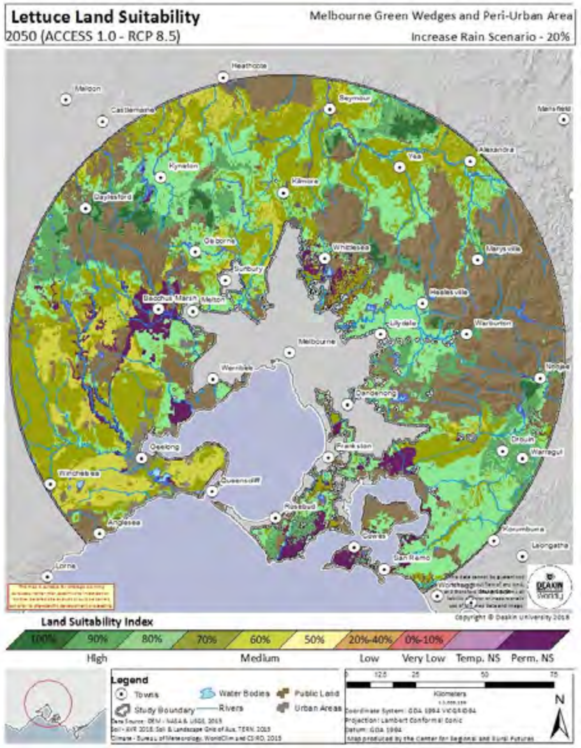
Lettuce Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
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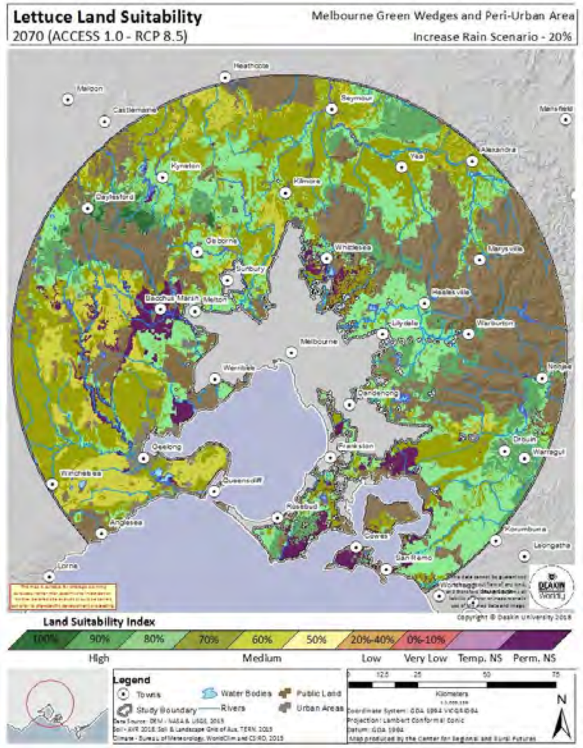
Lettuce Land Suitability
2070 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
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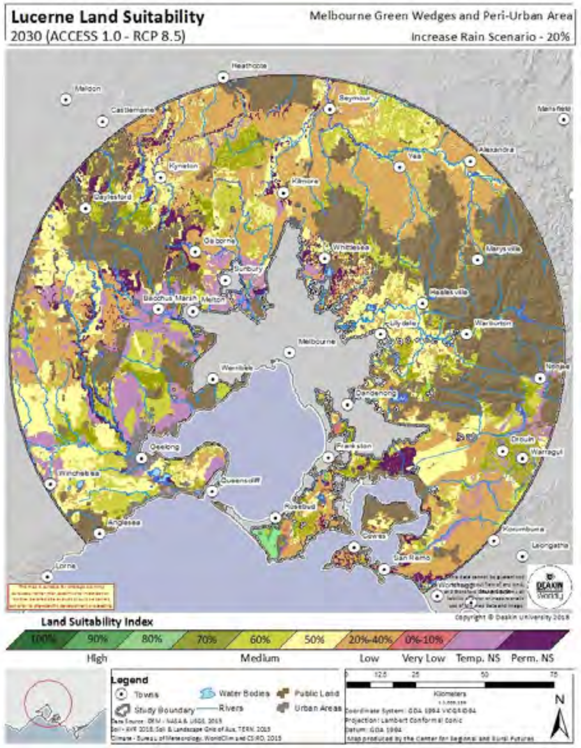
Lucerne Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
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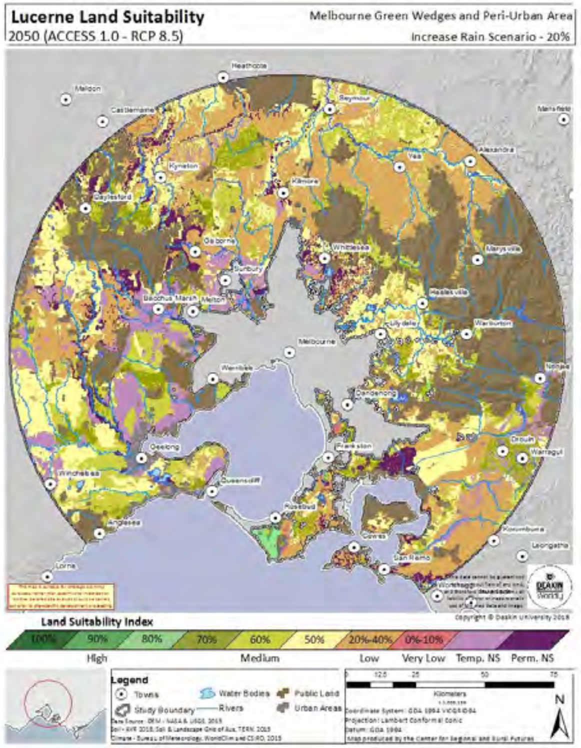
Lucerne Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
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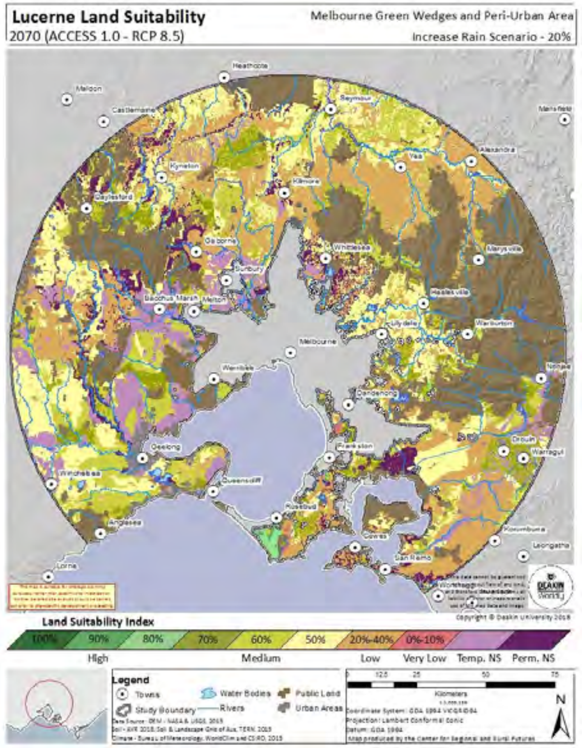
Lucerne Land Suitability
2070 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
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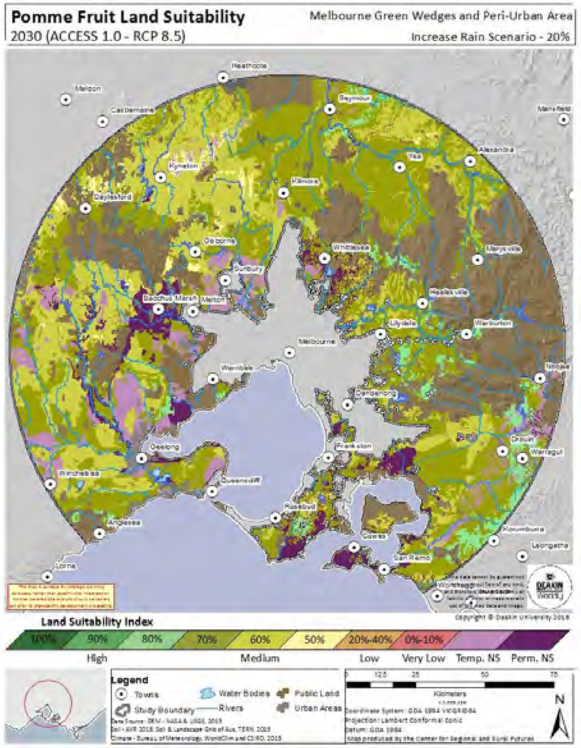
Pomme Fruit Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
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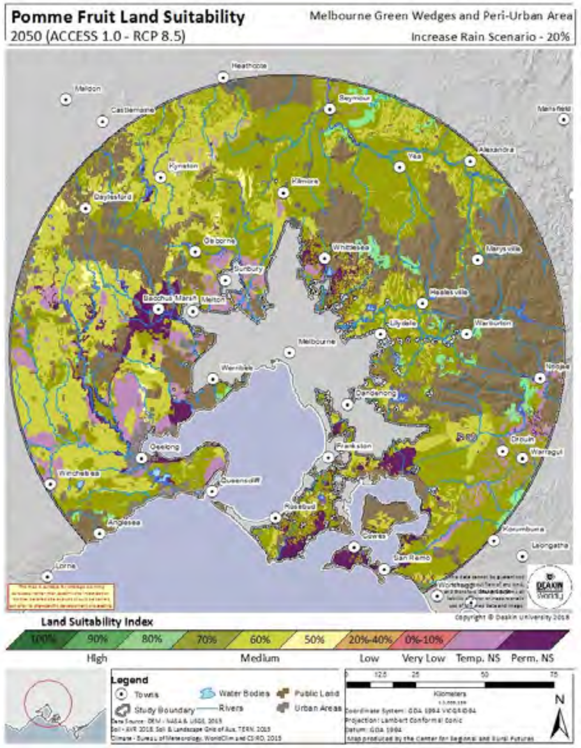
Pomme Fruit Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
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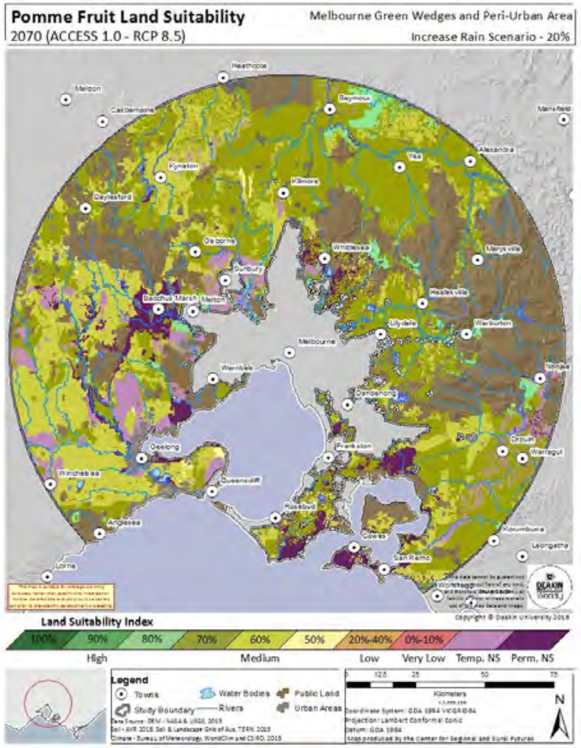
Pomme Fruit Land Suitability
2070 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
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Land Suitability Index
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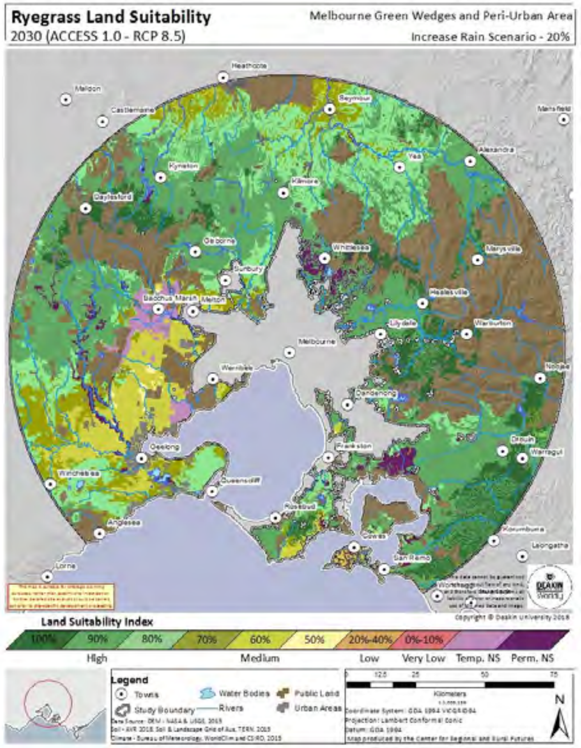
Ryegrass Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
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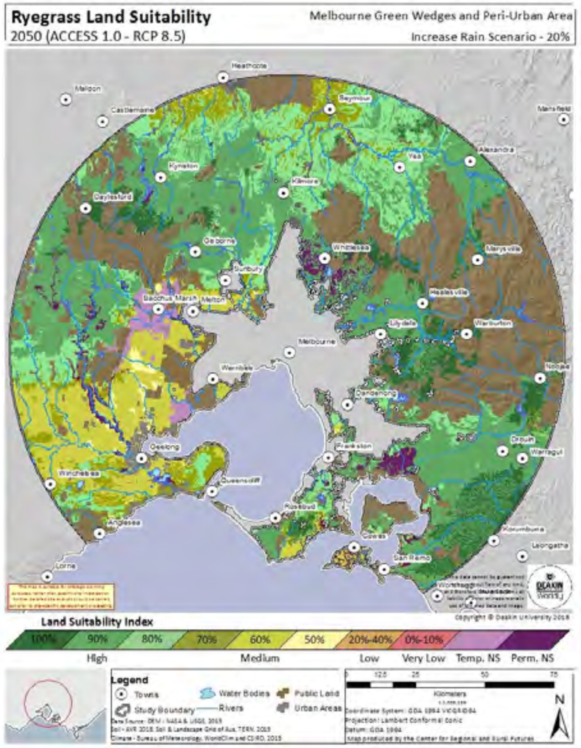
Ryegrass Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
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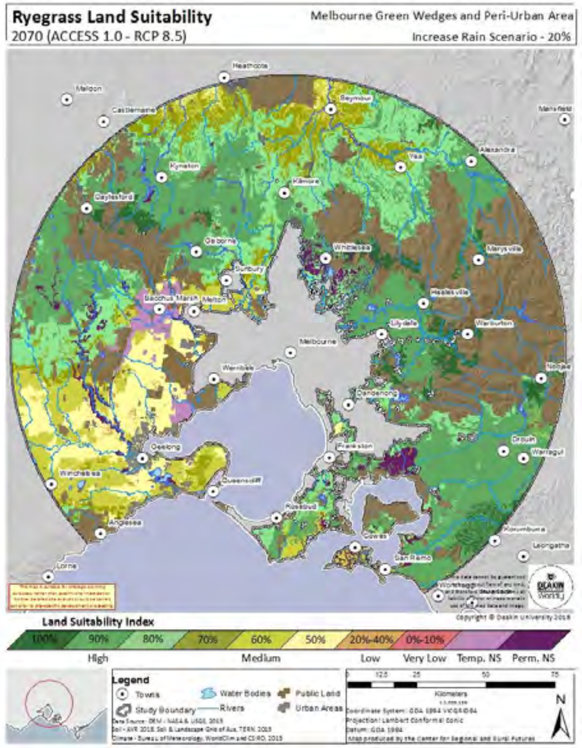
Ryegrass Land Suitability
2070 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
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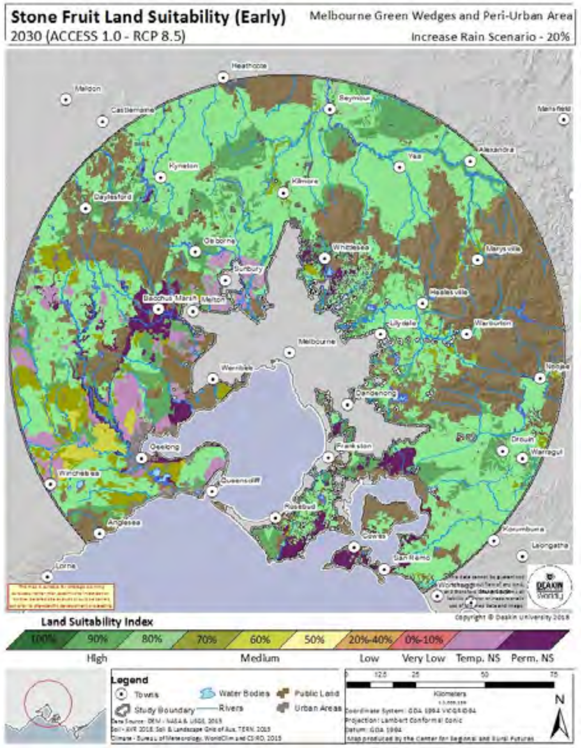
Stone Fruit Land Suitability (Early)
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
100% 90% 80% 70% 60% 50% 20%-40% 0%-10%
High Medium Low Very Low Temp. NS Perm. NS
Legend
Towns
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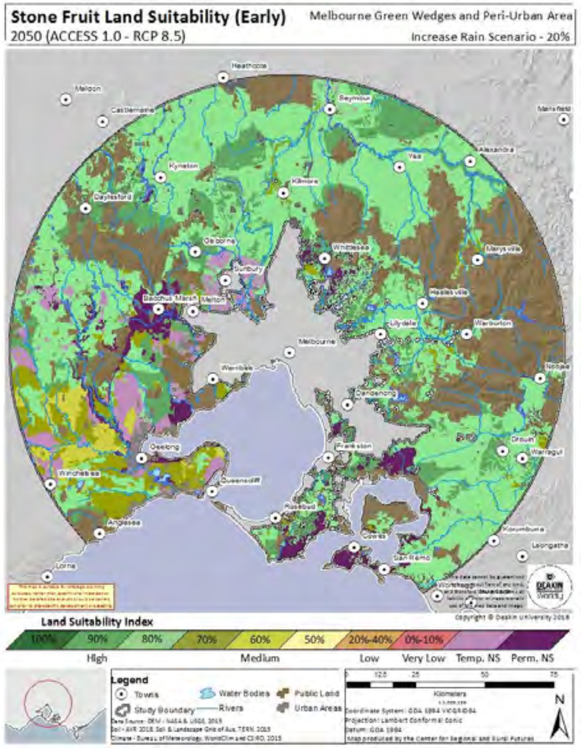
Stone Fruit Land Suitability (Early)
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Melbourne Green Wedges and Peri-Urban Area
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Land Suitability Index
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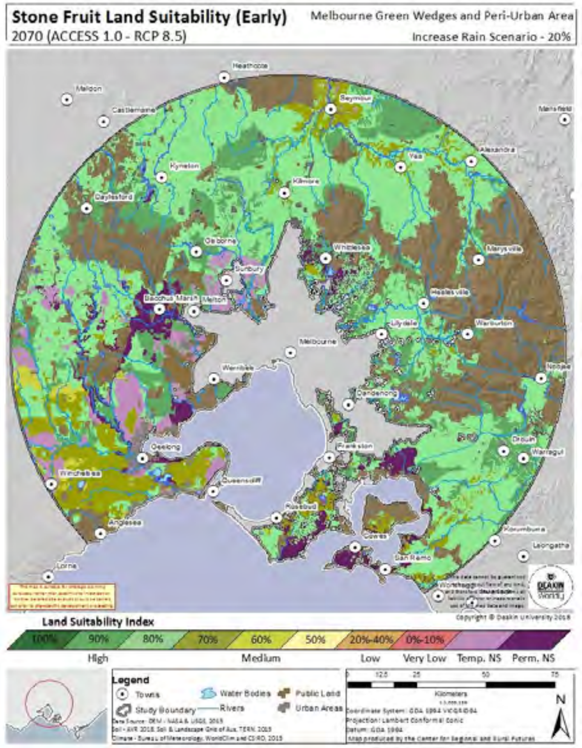
Stone Fruit Land Suitability (Early)
2070 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
100% 90% 80% 70% 60% 50% 20%-40% 0%-10%
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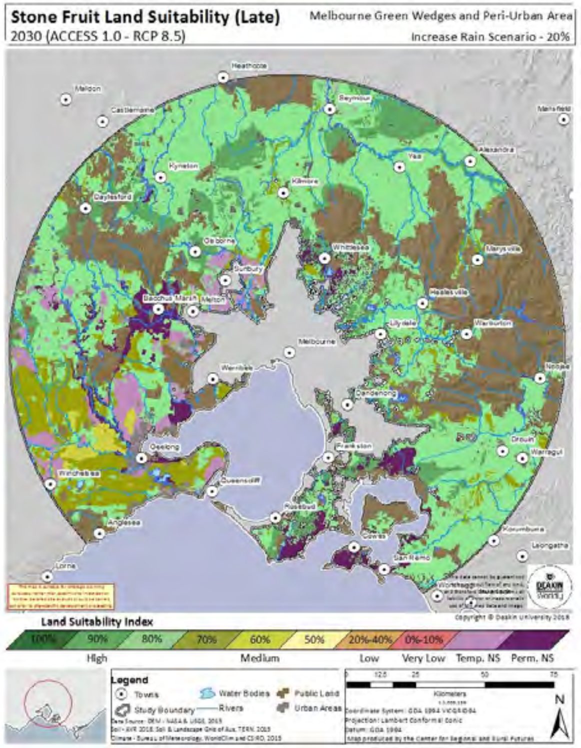
Stone Fruit Land Suitability (Late)
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
100% 90% 80% 70% 60% 50% 20%-40% 0%-10%
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Legend
Towns
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Kilometers
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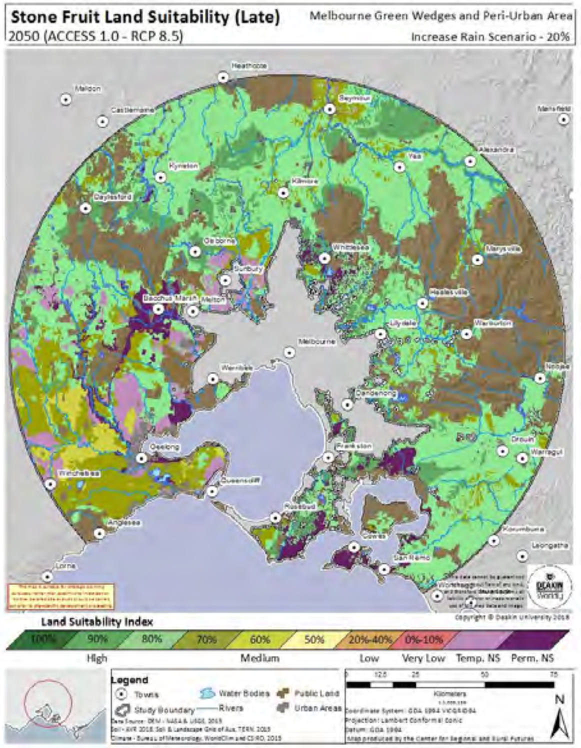
Stone Fruit Land Suitability (Late)
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Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
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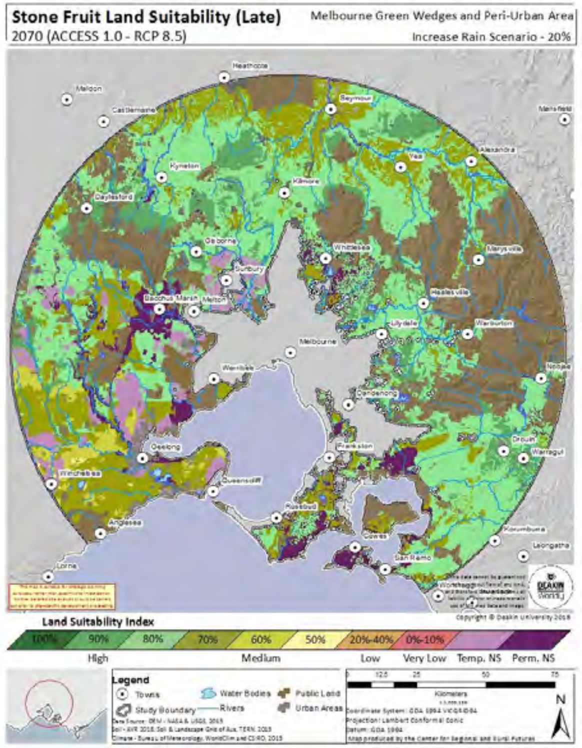
Stone Fruit Land Suitability (Late)
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Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
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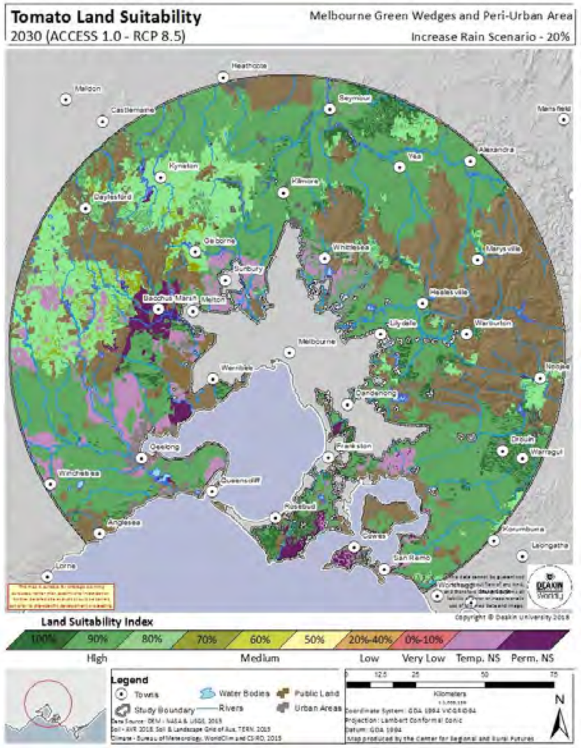
Tomato Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
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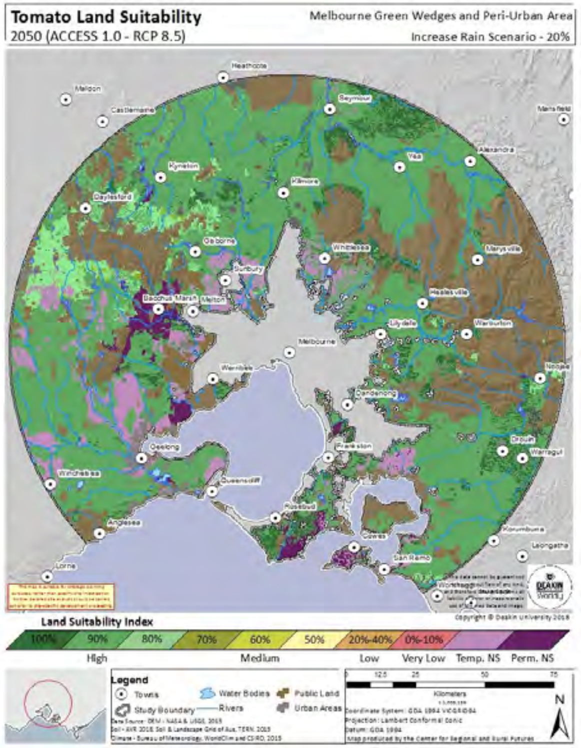
Tomato Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
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Land Suitability Index
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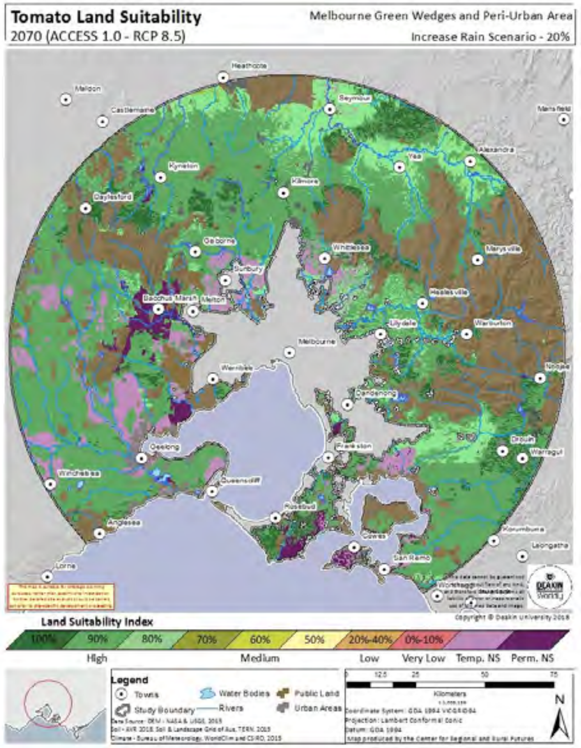
Tomato Land Suitability
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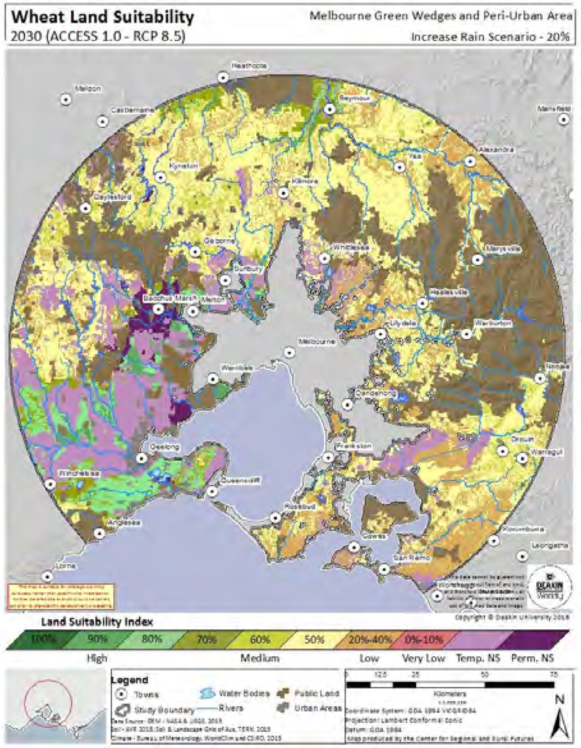
Wheat Land Suitability
2030 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
Increase Rain Scenario - 20%
Land Suitability Index
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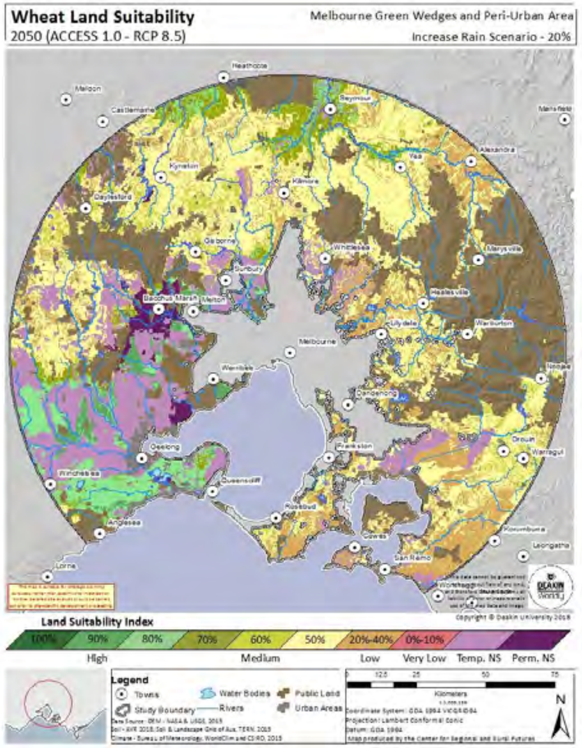
Wheat Land Suitability
2050 (ACCESS 1.0 - RCP 8.5)
Melbourne Green Wedges and Peri-Urban Area
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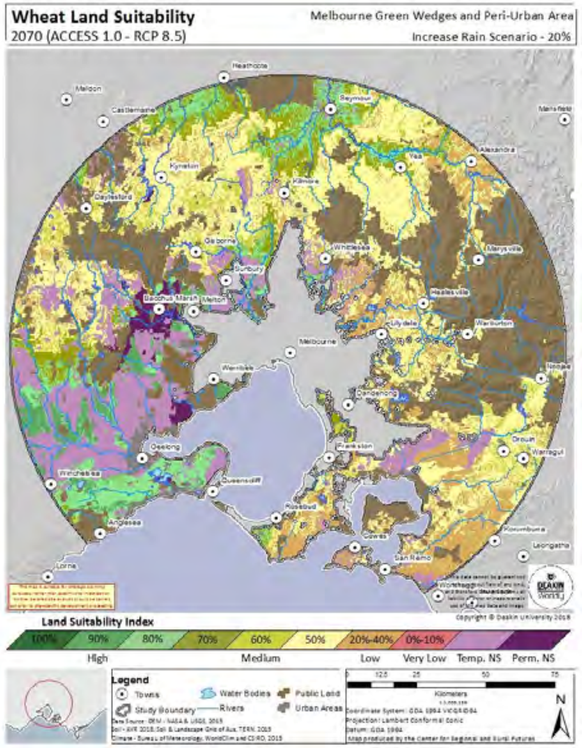
Wheat Land Suitability
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