

An objective basis for temperate nut industries' expansion

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Introduction

The Australian temperate nut industries (almond, chestnut, hazelnut, pecan, pistachio and walnut) have experienced unprecedented growth over the last decade. The farm-gate value of the Australian temperate nut industry 2014/15 crop farmgate value reached \$1.2 billion thanks to global demand, strong Australian production and an increasing market value for nuts and nut products. The high quality and relatively low pest and disease issues make Australian nuts a highly valued product in international markets and industry expansion is expected to continue.

Many regions are capable of supporting nut tree growth; however, growing highly productive and profitable nut crops requires optimal climatic and agronomic conditions. We have modelled potentially suitable regions for temperate nut industries' expansion throughout using bioclimatology – the study of the effects of climate on living organisms. Primary parameters employed in this model constitute chill and heat accumulation, water availability and soil properties – all key components to tree growth. The aim of this work is to provide an objective basis for expanding the Australian temperate nut industries.

Winter chill accumulation was determined as a critical factor limiting regional suitability for temperate nut productivity. Nut trees require chill accumulation throughout dormancy (1 May–1 September), to break dormancy, initiate reproductive processes and ultimately synchronise nut maturation. Chill requirements are commonly quantified as the minimum number of hours between 0 °C and 7.2 °C, or chill hours. Heat has a cancelling effect on chill accumulation (Pope, 2015) which alters the chill accumulation in warmer climate regions, like Australia. The Dynamic Model of Chill Portions (Dynamic Model) quantifies chill, while accounting for the cancelling effect of heat and has been used in the present work.

Water is required for tree growth, nut growth and quality (Iniesta, 2008). Sufficient water is critical to reliably produce high quality nuts, helps plants survive through frost and heat events and promotes vegetative and tree growth. Water availability has been added to this model as an additional layer incorporating irrigation schemes, rainfall contours, and river catchment areas.

Nut trees grow best in deep, well drained, fertile soils. Soil properties can vary dramatically within a small area and are often amendable. While there is some awareness of the ideal soils for horticultural use, limited research has been conducted on the scope of soils suitable for nut production in Australia. Soil suitability has been incorporated into this study as a very approximate guideline and is not a substitute for site analysis.

This information package is supplementary to high-resolution maps available online. The information provided should be used as a guide to narrow down potential regions for expansion. Specific and comprehensive site analysis must precede the final decision regarding site suitability for tree nut orchard establishment. A further use of this work would be to provide information on suitable regions for sentinel plantings to determine those most appropriate for expansion of Australian nut industries.



Bioclimatology model

The bioclimatology model was based on the nut tree phenology requirements. The Dynamic Model quantifies chill hours (hours between 0 °C and 7.2 °C) accounting for the cancelling effect of heat. This model has been extensively tested on many crops in Australia and California (Luedeling, 2011; Zhang, 2011). Chill portions were determined as the most limiting factor to regional suitability, hence were the primary factor to be modelled.

Temperature Data

Interpolated temperature data was obtained from the Bureau of Meteorology (BoM) (Jones, Wang & Fawcett, 2009). This data consisted of interpolated minimum and maximum daily temperatures for each 5 km × 5 km grid (equivalent to 0.05° × 0.05°) covering the mainland and Tasmania from 1911 to 2014. The interpolated dataset overcomes the spatial and temporal discontinuities in Australia's temperature records.

Dynamic Model for Chill Portions

The Dynamic Model was used to calculate chill portions based on estimated hourly temperatures for each day. Hourly temperatures are predicted from the daily minima and maxima temperature, taking into account the latitude of the midpoint of each grid.

Chill portions were calculated for the period from 1 May–September 30 and heat units for the period 1 October–30 April.

Chill portions were calculated as follows:

- estimate hourly temperature for each year and day for each grid
- calculate chill portions from 1 May to 30 September for each year for each grid
- calculate the mean chill portion for 20 years (1983-2014) for each grid.

The chill portion contour map below (Figure 1) was generated using the Dynamic Model.

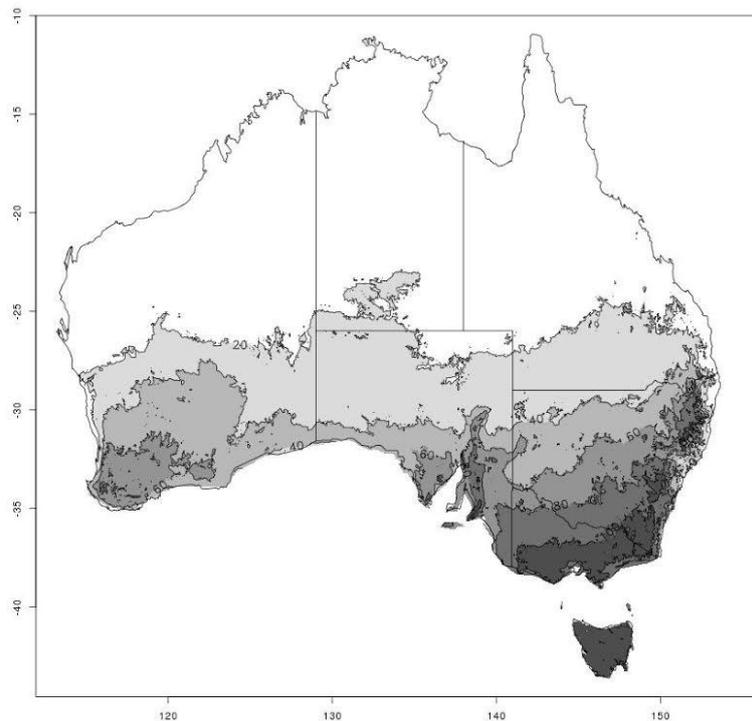


Figure 1. Chill portion map of Australia. Contours are marked at 0, 20, 40, 60, 80 and 100 chilling portions with darker shades indicating higher chilling portions.

Data validation

The Moree site in NSW was selected to compare chill portion estimates derived from the interpolated data with those calculated using actual recorded daily temperatures. There was good agreement between the two methods.

Model generation

The 'R' statistical package was used to plot dark green chill portion contour lines on a digital map of Australia for each of six temperate nut industries (Figure 2). The upper dark green contour represents the minimum chill requirement and the lower dark green contour represents the maximum chill requirements for a range of commercial cultivars for each nut type. Additional layers were added to the chill portion map to incorporate water availability and soil suitability. Water availability has been added in the form of blue contour lines for rainfall, blue shaded vectors for irrigation schemes, and grey lines show the river catchment areas. The depth of green shading increases with increasing soil suitability.

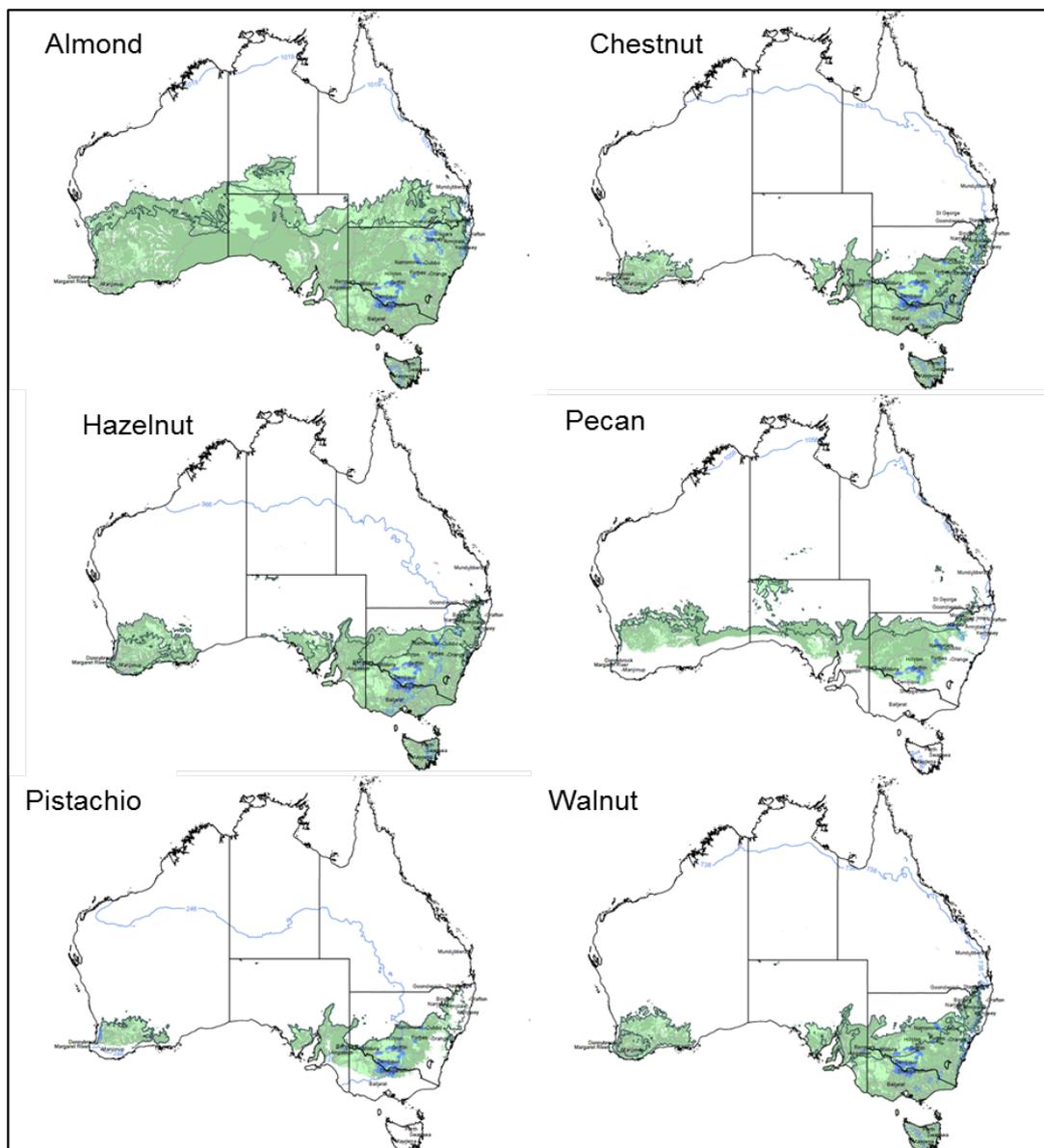


Figure 2. Bioclimatology maps for indicating predicted regional suitability.

Water availability

Water availability has been incorporated into the bioclimatology models and when making recommendations:

- Irrigation schemes are the most reliable source of water for perennial horticulture, including nut crops and have been incorporated into the bioclimatology models as blue contours.
- Rainfall in Australia is irregular and unreliable. The inclusion of rainfall contours in the bioclimatology model indicated regions that receive a quantity of rainfall that could sustain trees, but does not necessarily support productive crops.
- Catchment areas are outlined in grey on the bioclimatology maps (Figure 2). Due to the dynamic nature of water availability in some catchment areas these are provided as a guide from which to seek further information. For example, Figure 3 shows a section from the pecan bioclimatology map of the Paroo River, Lake Bancannia and Darling River catchment regions near the NSW/Queensland (QLD) border.

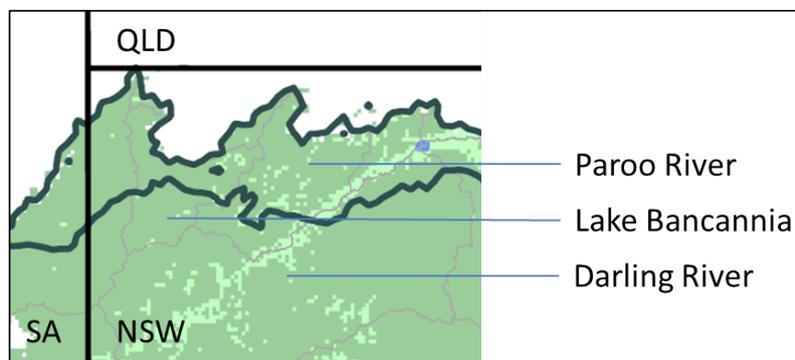


Figure 3. River catchments: Example from pecan bioclimatology map.

Nut quality is intrinsically linked to water management (Iniesta, 2008). The feasibility of employing different water management options depends on the size of the orchard, site features, climate and local infrastructure.

Perennial rivers

There are some river catchment areas that are highly suitable for establishing nut tree plantings. The most suitable river catchment areas contain perennial rivers that constantly flow and are relatively reliable sources of stable water, compared with non-perennial or seasonally flowing rivers (Figure 4).

The main perennial river systems with the capability to supply water for irrigation are the Murrumbidgee and Murray rivers which run through NSW, Victoria and South Australia (SA). There are also coastal perennial river systems on the east coast of Australia and small perennial rivers in south-western Western Australia (WA).

It should also be noted that there are other ways to obtain water, such as dams, which can increase the regional suitability beyond the scope of these models.

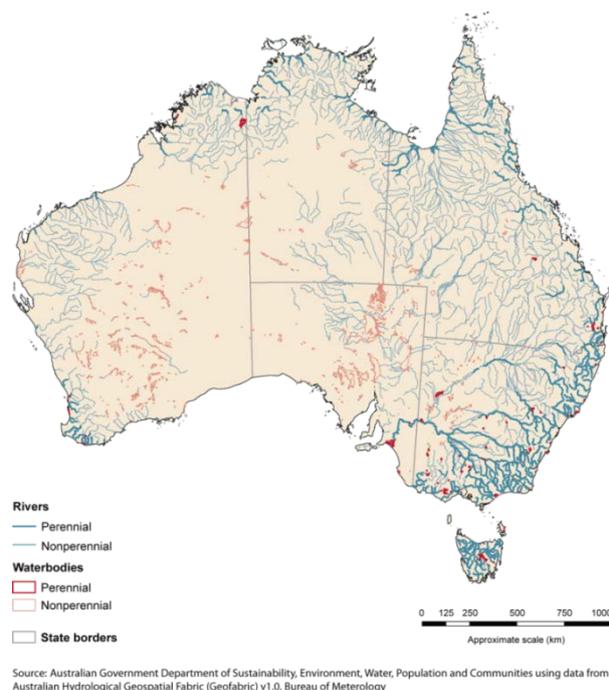


Figure 4. Australian perennial and non-perennial river systems and water bodies (SoE, 2011).

Soil suitability

Nut trees grow best in deep, well drained, loamy soils with approximately neutral pH. Preferable sites selected for orchard establishment will have soils that are highly fertile, have low salinity levels and low clay content. Unfortunately, such descriptions cannot commonly be applied to Australian soils. With chemical and physical amendments and additions, the scope of potentially suitable and productive soils is broadened. Using the Australian Soils Classification and data obtained from Australian Soil Resource Information System (ASRIS, 2011) the soil layer was added as a 5th layer to the nut bioclimatology model maps.

Each soil order represents multiple profiles with some common attributes, for example soil profiles of the order ferrosols have high iron content. As there is high variability in soil profiles within small areas, soil orders have been mapped throughout Australia, and specific locations would need a separate analysis to determine specific profile details (McKenzie, 2004). Increasing depth of green shading in bioclimatology models (Figure 2) indicates increasing soil suitability. White regions indicate soil orders with no suitable soil profiles.

Risk factors

Temperate nut crops can be negatively affected by certain risk factors including late spring frosts, high heat events, and rainfall during harvest, but there are many other risks that affect different locations. The severity of the risk posed by these factors varies from region to region. These factors are not incorporated into the model due to the high variability between years and within locations. Furthermore, the risk posed by risk factors is potentially negated or reduced by orchard management strategies, and can be influenced by orchard size and local infrastructure.

Late spring frosts

Nut trees mostly flower in late winter–late spring, depending on phenology, chill accumulation and variety. During flowering, fine pistillate flowers are produced. Pistillate flowers are damaged by late spring frosts, which can significantly reduce crop yield.

Historical frost day data can be used to judge region suitability based on average annual frost days (Figure 5). Higher annual frost incidence (number of potential frost days) indicates an increased risk of late spring frosts. This map (Figure 5) is an example of the resources available online from the [Bureau of Meteorology](#) website (BoM, 2015).

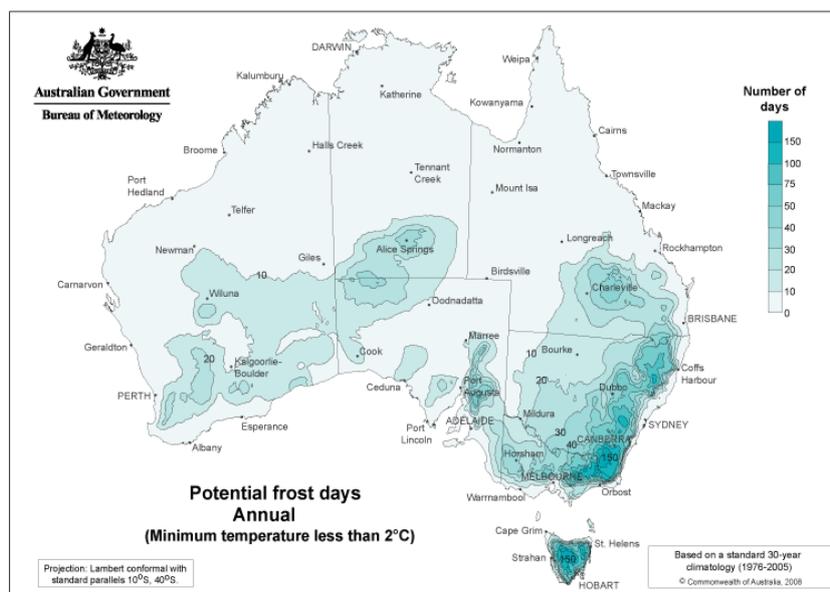


Figure 5. An example of data available online that is useful in understanding trends in late spring frosts. This image is from the BoM page “Annual average potential frost days throughout Australia”.

High heat events

High heat during certain times of phenology can burn reproductive tissues, causing decreased nut set and, therefore, yield. High heat events also increase water stress on trees, affecting water availability requirements and water management costs in orchards. The BoM provides historical information on annual and monthly heating days. For example, it is possible to look up the 30-year average for heating days during November, with a base temperature of 18 °C (Figure 6).

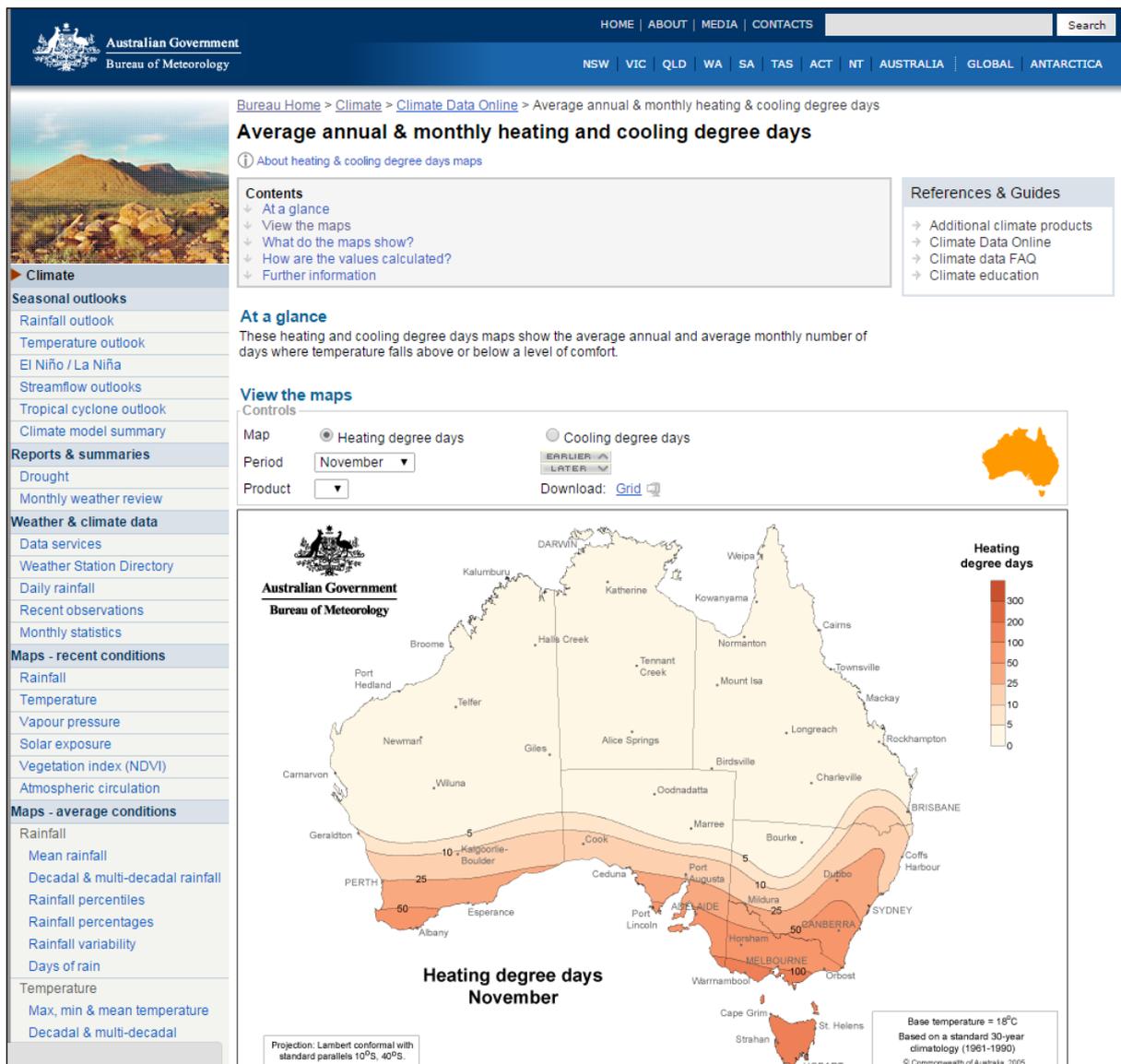


Figure 6. Screen print of the BoM webpage for the “Average annual heating degree days” as an example of the climatic information accessible online.

Rainfall during harvest

As nuts mature, hulls split and the nuts are either mechanically shaken from the tree or naturally drop to the ground. Nuts are harvested from the orchard floor. During this period wet weather can lead to increased incidence and spread of disease and some pests. Nut quality is negatively impacted by wet weather, which impedes the drying process.

Historical data on average monthly rainfall can be useful for determining the likelihood of wet weather during harvest at local areas, however, there is no guarantee that this will be the case every year. Resources and information pertaining to rainfall is also available from the BoM website (BoM, 2015). Many local services also provide information.

Online resources

We have developed six models to guide regional selection for nut tree plantings. Information packs have been created to accompany these models. These are web-based resources, available from both the NSW DPI and Australian Nut Industry Council (ANIC).

Online resources are accessible through the [NSW DPI Nuts](#) page in three formats, as high resolution models (PDF files), individual and multiple industry information packs and as layers on an interactive map. The PDF based models exclusively contain our bioclimatology modelling information and are a useful resource for identifying regions that are theoretically capable of supporting productive nut crops. The interactive map is useful for interrogation of local areas for nut production suitability with three chill portion layers generated using 30 years of historical data.

High resolution models as PDF documents

The models generated are available online as extremely high-resolution maps. These maps are able to be interrogated, by zooming, to a resolution of 5 × 5 km (Figure 7). The models are each based on bioclimatology and the phenological requirements of almonds, chestnuts, hazelnuts, pecans, pistachios and walnuts and include:

- Chill requirements: identified as the critical factor determining regional suitability, calculated using the Dynamic Model. Heat unit requirements limit regional suitability for pecans and pistachios only.
- Water availability: through incorporation of rainfall contours, river catchment areas and irrigation schemes.
- Soil suitability: included as general information only and not a limiting factor to regional suitability as soils vary significantly in small regions and are highly amendable.

There are some limitations in the models, which are addressed in the information packages. These include:

- Inclusion of filters or layers for risk factors (e.g. late spring frosts, excessive heat) – resources and information regarding these are included in the information packages.
- Australian-based information due to a limited pool of knowledge – the values and properties used to generate these models are largely based on international research.

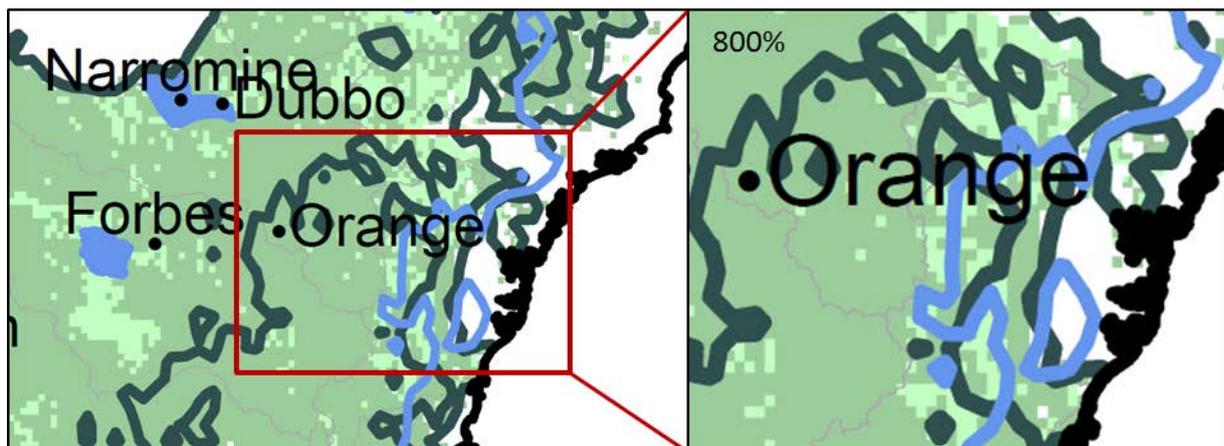


Figure 7. The high resolution bioclimatology models are available online. Example of the central tablelands region of NSW showing the level of detail available in bioclimatology model. Each grid represents a 5 × 5 km area of land. This is a section of the map zoomed to 800%.

Interpreting the model in PDF document

An example using the hazelnut industry

A sample section of the hazelnut industry map (Figure 8) outlines the key features of the bioclimatology models: chill portion contours, river catchment regions, rainfall contour, irrigation scheme areas and soil suitability. These are features common to each nut industry model. The two chill portion contours represent the range in chill portion requirements of the range of commercial cultivars for each nut crop (as describe further in the following sections for each specific nut crop).

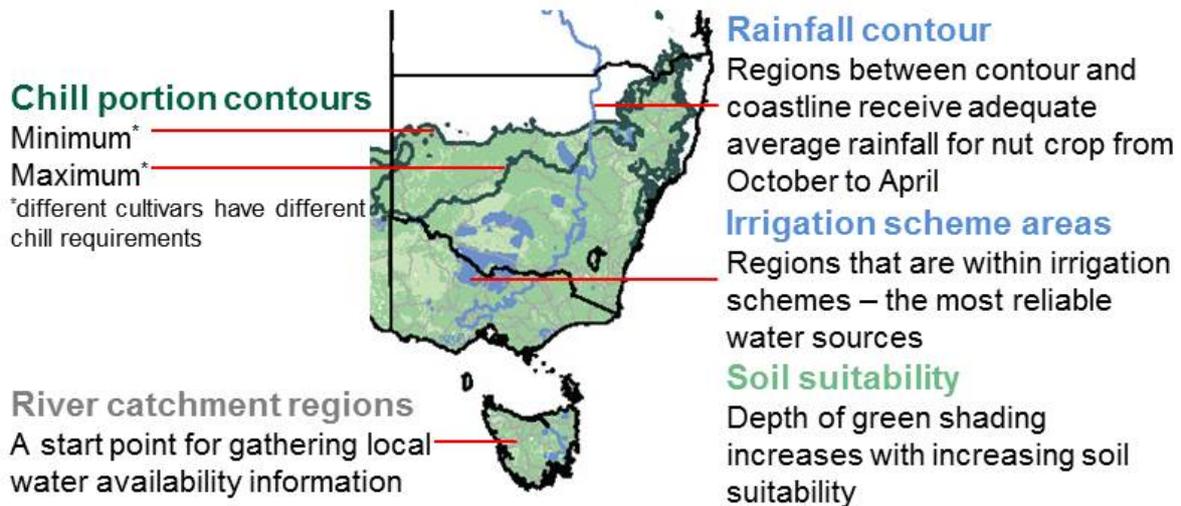


Figure 8. Key to interpretation of bioclimatology models. Example from hazelnut industry map

Interactive online map

The chill portion data was imported into ArcGIS (see <http://www.esri.com/>), and made available online according to Open Geospatial Consortium (OGC) standards (see www.opengeospatial.org for more information). We have shown 20 year minimum, average and maximum chill portions from BoM weather data from 1994-2014 as contour layers on either a topographical or satellite image map (Figure 9).

These contours are a historical guide to represent the chill portions experienced from 1994-2014 and are not intended to provide predictions for any area due to climate variability. The colours of the contours progress from red (0 chill portions) to blue (117 chill portions).

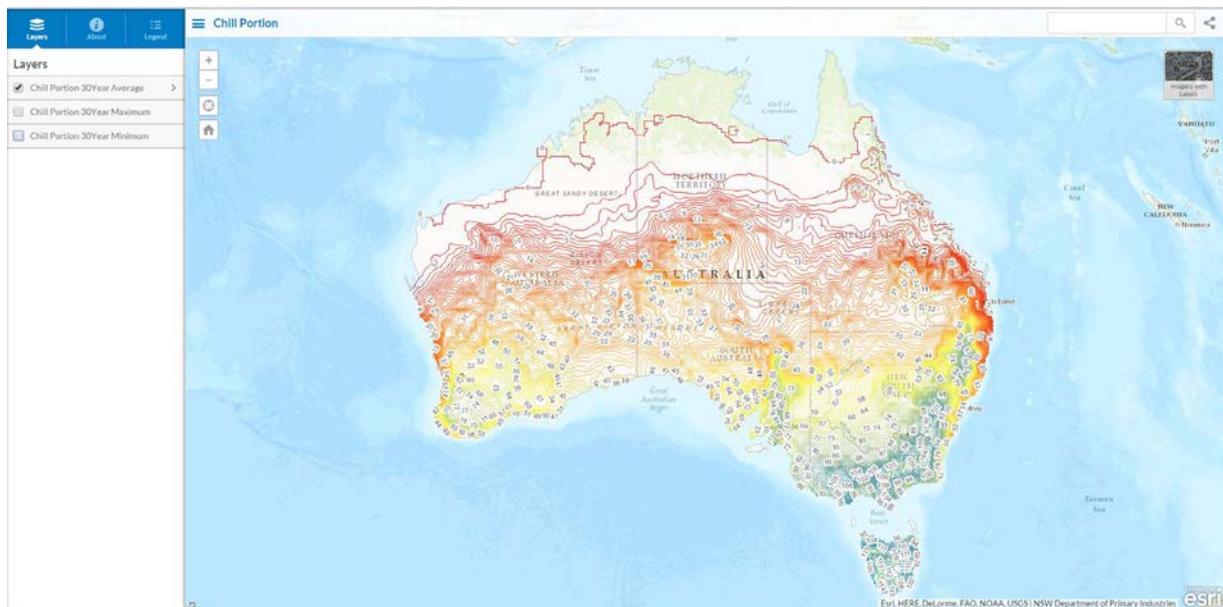


Figure 9. Chill portion contour layers showing on an online interactive map. The minimum, average and maximum chill portions derived from 20 years (1994-2014) of weather data are shown. The chill portion contours on this map are an indication of previous climate, and should not be relied upon as a predictive climate tool.

Using the interactive map

The interactive map is accessible with this document through the [NSW DPI Nuts page](#). On this map you can:

- Select the layers to view (minimum, average or maximum chill portions) on the left hand side of the map (Figure 10a, d-f)
- Zoom in and out using the + and – buttons (Figure 10a) and centre on your location, providing the device you are using or view the map has location/ satellite accessibility
- Switch between a topographic base map and a satellite imagery base map depending on your preference and the information you seek from the map (Figure 10 b and c).

We suggest this map is used to zoom in on a location and learn of the past climatic conditions in an area. The chill portions represented in this map are from past data and do not imply that every year will be the same as represented on this map, however it is more likely that a region that experienced an average of 48 chill portions will experience less chill portions than a region that has, on average, experienced 117 chill portions.



Figure 10. The functions of the map that are useful for interacting with the information including the (a) tools to select layers, zoom, centre the map and view information regarding the map; (b) select the topographic base map by clicking on the button shown as an insert to this image; (c) the equivalent for the satellite map; and an example from near Borenore, NSW, of the 3 chill portion layers that may be selected (d) minimum, (e) average and (f) maximum for 20 years of historical data. Note: the chill portion numbers and place names etc. are easier to read online, this figure is a guide.

Almonds

The Australian almond Industry has recently surpassed the Spanish almond Industry as the second largest producer of almonds globally behind the US, approximately 80% of world almond production takes place in California. Almond production in Australia in 2006 was 23,000 tonnes in shell compared to 115,000 tonnes in shell in 2016. By 2025, Australian almond production is projected to be more than 185,000 tonnes in shell. Expansion of the Australian almond Industry is essential for reaching production forecasts and capitalising on the demand.

Almonds (*Prunus dulcis*) are native to the Middle East and southern Asia. Trees are small with heights of 4–10 m and trunks up to 30 cm in diameter. Almonds flower in August with white and pale pink flowers that have five petals. Almonds rely on bees for pollination; they are self-incompatible (self-sterile). Budburst occurs after flowering and small single leaves develop. In February, after the nuts have filled, matured, and the hulls have cracked, the nuts are mechanically harvested.

There are many different almond varieties; some of the most important in the Australian almond industry are listed in Table 1. Each variety has a different set of growth requirements and produces a slightly different nut. The Almond Board of Australia (ABA) conducts research into almond production enhancing the knowledge-base on growing almonds in Australia.

Table 1. Almond plantings (2014-2015) by variety (hectares) (ABA, 2015)

Variety	Hectares planted
Nonpareil	14,642
Carmel	9,160
Price	3,417
Other	1,748
Total	28,967

Parameters of the almond bioclimatology model

The quantity of chill portions required varies between cultivars and ranges from 23–32 (Table 2). Almonds require a minimum of 8.5–10 ML of water throughout the growing season (October–May), but as much as 14 ML could be required. Almonds prefer deep, well drained, fertile soils.

Table 2. Bioclimatology model parameters for almonds. Chill portions (low from cultivar Nonpareil, high from cultivar Ferragnes) and water (October – May mm) requirements of almond trees

	Requirement
Chill	23–32
Water	1,019

Chestnuts

The chestnut (*Castanea sativa* mill.) is a medium-sized tree, growing 20–35 m tall and 6 m wide. The tree has thick, oblong-lanceolate leaves and prefers mild summers and cool winters. Chestnut trees originated from Europe and Asia Minor and have a long-standing role in the human diet in Asian and European countries. In Europe, during medieval times, one chestnut tree was said to provide one person with a lifetime of sustenance and one tree was planted for every child born in towns under siege.

The monoecious flowers bloom in November and December and nuts are harvested between March and May. Catkins are bi-sexual with pistillate (female) flowers located at the base of the catkin. The remainder of the catkin is staminate (male) flowers (Warmund, 2010). Pollination, dispersed via wind, often occurs before pistillate flower receptivity, hence multiple cultivars are recommended. It is possible for each pistillate flower to develop into 1–3 nuts, with the cultivar influencing the quantity, therefore size of nuts, produced in each pistillate flower. The cotyledon, or edible portion of the chestnut, is encased in the pellicle, a hard shell, protected within an involucre, or spiny bur.

The Australian chestnut industry is largely (~70%) located in north-eastern Victoria. There are also chestnut production areas in NSW (Blue Mountains, Orange), SA (Adelaide Hills), WA (south-western area) and Tasmania. The production quantity is sufficient for local consumption, and only ~2% of the annual crop is exported to the Asian market. There is an opportunity to increase Australian chestnut production in response to a growing demand from the American, European and Asian markets. The 2015 production was approximately 1,200 tonnes in shell chestnuts. By 2025, this is expected to increase to 1,650 tonnes (ANIC, 2015).

Parameters of the chestnut bioclimatology model

The quantity of chill portions required varies between cultivars but ranges from 58-88 (Table 3). Chestnuts require a minimum of 5–7 ML water throughout the growing season (October – May). Chestnuts prefer deep well drained, fertile soils. Chestnuts do not response well to liming or poor drainage. It is recommended that Chestnut plantings are established on a slope to improve the drainage.

Table 3. Chill portions (from Mt Barker records 1956-2014), and water (October–May mm) requirements of chestnut trees

	Requirement
Chill	58–88
Water	633

Recommendations

Suitable regions for expansion of the Australian chestnut Industry (Figure 12, purple shading) are identified in:

- southern NSW and northern Victoria. Depending on the cultivars grown, the area from the east coast as far inland as Orange in NSW and Shepparton in Victoria including the Snowy Mountains, are suitable.
- most of Tasmania
- the Adelaide Hills (Angaston) and Remark regions of SA
- small areas in the northern NSW tablelands near Armidale
- regions of Australian Capital Territory (ACT)

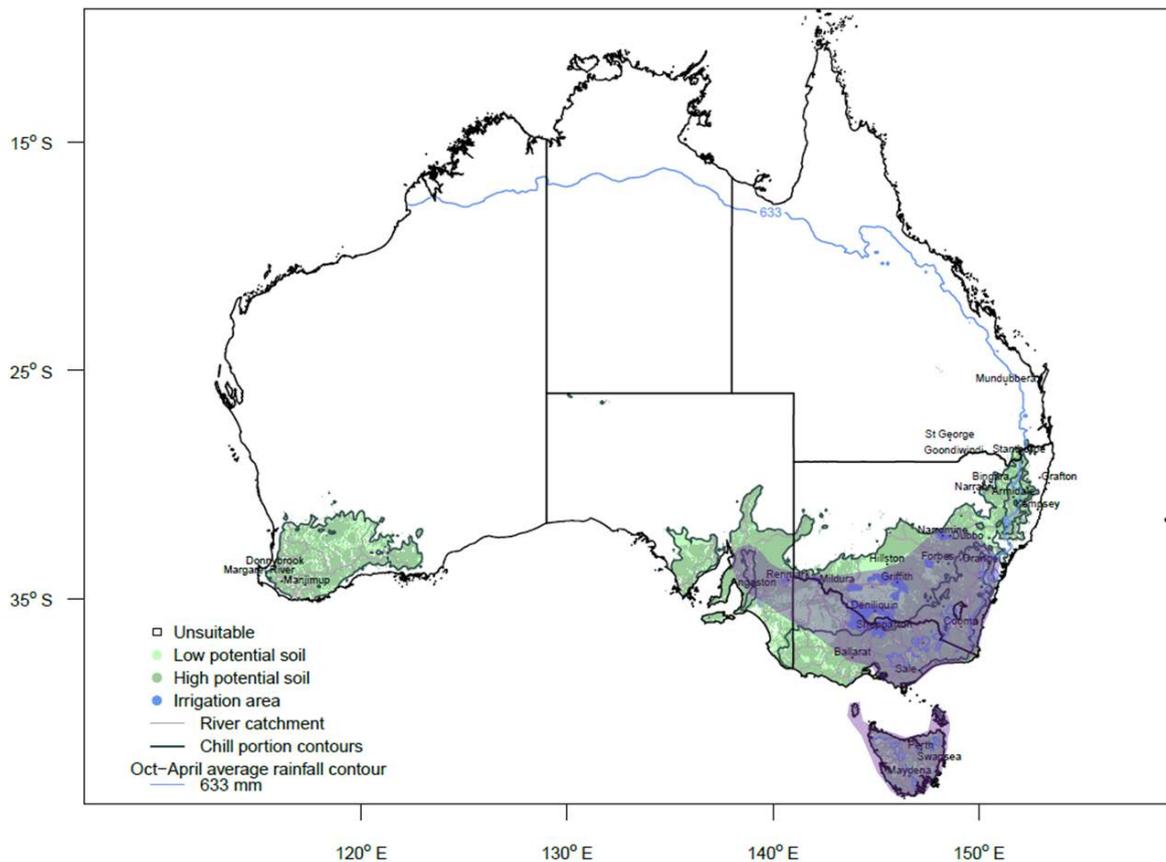


Figure 12. Chestnut industry bioclimatology model. Purple shading indicates areas recommended as potentially suitable for productive chestnut production.

Hazelnuts

Hazelnuts or filberts (*Corylus avellana* L.) are native to Europe and Asia Minor. Hazelnuts have a long history in the human diet, dating back to 8000 BC. Today, hazelnuts are primarily produced in Turkey (70% of global production) and in the United States (U.S.) (~15%). Hazelnuts are self-incompatible trees with small pistillate flowers and staminate male catkins. Flowering and pollination occurs during the winter months and the trees are wind pollinated (Snare, 2010). After pollination, the pollen remains on the flower pistile for 40–60 days when fertilisation occurs during spring. There are many hazelnut cultivars, of which approximately 10 are being grown in Australia. The phenology of cultivars continues to be investigated and will require further research to determine the best cultivar for production and compatibility under Australian conditions.

Commercially, hazelnut trees are grown with a central trunk to approximately 600 mm from ground level, after which branches are trained into a vase form. This tree structure has been shown to be the most productive form of canopy management and trees are maintained up to 6 m tall (Snare, 2010). Mother plants are used to propagate new plants, which are planted bare rooted and without using root stock. This planting methodology makes hazelnuts susceptible to changes in nutritional status and the effects of herbicide and insecticide use.

Historically the Australian hazelnut industry has been relatively small, approximately 144 ha in 2011. The industry size is disproportionately small (producing approximately 60 tonnes per annum) compared with the local demand (importing 2000 tonnes/annum (HGA, 2015)). The Australian hazelnut industry has primarily operated in south-eastern Australia where the climate is cooler. The main production regions have been the NSW Central Tablelands and north-eastern Victoria. There is also some production occurring in Tasmania and other regions of Victoria. More recently, large scale hazelnut production has commenced in the Riverina, within the Murrumbidgee Irrigation Area (MIA).

Parameters of hazelnut bioclimatology model

Hazelnuts, like other nut trees, require a minimum chill accumulation throughout dormancy (May–October) for phenological processes, including budbreak and flowering. Successful hazelnut plantings combine sufficient chill with the compatible cultivars. The quantity of chill portions required varies between cultivars, and ranges from 48–60 (Table 4).

Hazelnuts require regular water, and do not perform well when water-logged. Scientific literature and industry publications suggest a minimum a water requirement of 366 mm throughout the growing season. This is likely to be an underestimate of water requirements for maximising crop yield and quality. Regions capable of supplying more water are recommended, for example within irrigation schemes.

Hazelnuts prefer deep, well drained, fertile soils. Heavy clays should be avoided, with preference given to loam or sandy loam soils.

Table 4. Chill portions (low from the cultivar Hall's Giant, high from cultivar Ennis) and water (summer mm) requirements of hazelnut trees

	Requirement
Chill	48–60
Water	366

Pecans

Pecans (*Carya illinoensis*) are an alternate-bearing, wind pollinated and self-incompatible tree. A variety of cultivars are required within a pecan farm to ensure cross pollination. Wind pollination occurs during September and nuts mature until May when they are harvested. Pecan trees can grow 20–40 m tall with trunks up to 2 m in diameter; however, the average 10-year-old tree is only 5 m tall. As pecan trees age, pruning is critical to maximising light interception (amount of sunlight which penetrates tree canopy) and yields. The large alternate leaves of the pecan tree consist of up to 15 small pinnate leaflets and are deciduous.

The majority of the Australian pecan industry is located in northern NSW and south-eastern QLD. Stahmann Farms Trawalla property near Moree in northern NSW is the largest pecan operation in the Southern Hemisphere. There are over 100 pecan growers in Australia with more than 180,000 trees planted. Growers belonging to the Australian Pecan Growers Association (APGA) produce approximately 95% of nuts in Australia (APGA, 2011). Australian pecan production has plateaued at around 3,000 tonnes (in shell) since 2006 (ANIC, 2015). There is strong interest in industry expansion, and production is expected to increase to approximately 9500 tonnes in shell by 2025. Identifying regions suitable for pecan production is a key factor for expanding the industry.

Parameters of pecan bioclimatology model

Pecan trees are best grown in regions with hot, humid summers. The quantity of chill portions and heat units required varies between cultivars, with chill portions ranging from 38.8–44 (Table 5). Pecan trees require 750 heat hours to accumulate throughout the growing season. Pecans prefer deep, well-drained, fertile soils

Pecans are native to regions with humid summers and reviewing the literature revealed that pecans require at least 7 ML water during the growing season (October to May). Research from the University of Georgia reports pecans can use as much as 13–20 ML water annually.

Table 5. Chill portions (low from Schley, high from Wichita), heat units (degree days) and water (October–May mm) requirements of pecan trees

	Requirement
Chill	38.8–44
Heat	750
Water	1,058

Recommendations

Suitable regions for expansion of Australian Pecan industry could be within the MIA or areas of central NSW (Figure 14, dark blue shading)

There are potentially suitable regions on the NSW–Victorian border near Mildura and on the QLD–NSW border near Moree and Stanthorpe (where farms are already established).

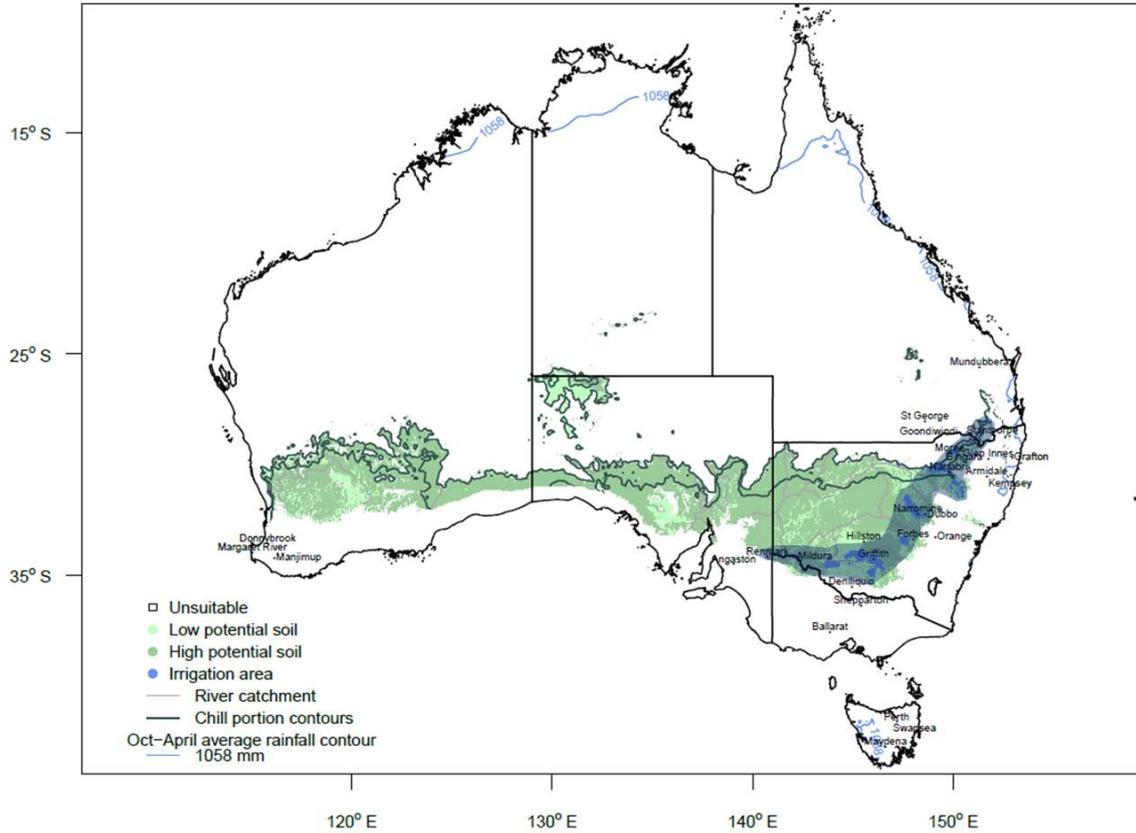


Figure 14. Pecan industry bioclimatology model. Dark blue shading indicates areas recommended as potentially suitable for productive pecan production.

Pistachios

The pistachio (*Pistacia vera* L.) is native to the dessert regions of western Asia and Asia Minor and has a high tolerance to salinity and drought stress. Favourable climatic conditions for pistachio trees are hot, dry summers and cold winters. Multiple cultivars are required in order to have productive plantings as pistachios are wind pollinated, dioecious (separate male and female trees). Pistachio trees are full bearing by 10–12 years of age, with the first year of productive bearing seven years after planting (Ferguson, 2005).

Pistachios are a biennial crop with alternating years of productivity, known as the 'on/off cycle'. In 'on' years the Australian pistachio industry has produced up to 5300 kg/ ha yields of in shell nuts (PGAI, 2011). There is proven potential for increases in the productivity of these, with Californian growers capable of producing more than 6000 kg/ ha of in shell nuts during 'on' years. The pistachio industry is dominated by production in Iran and California. Research into the productivity of pistachios has focused on the crops in these locations and the climatic and biological conditions present.

The Australian pistachio industry primarily operates along the River Murray from Swan Hill in Victoria and up into South Australia. Production also occurs in Western Australia and New South Wales. The Australian Pioneer Pistachio Company process the majority of nuts produced in Australia in Robinvale, Victoria. In 2014 there were 950 ha of pistachio plantings (ANIC, 2014) in Australia with an average production of 3000 kg/ha over the on/off cycle (PGAI, 2011).

The popularity of nuts and nut products is growing, not only in Australia, but around the world. The demand for pistachios in Australia is greater than the current supply, indicating the potential to expand the Australian pistachio industry's share of the local, and global, pistachio markets. The farm gate value of Australian pistachios is presently \$9 million. This is expected to rise to \$30 million by 2025 (ANIC, 2014).

Parameters of pistachio bioclimatology model

Pistachio trees are best grown in regions with cool winters and hot, dry summers in areas with deep, well-drained, fertile soils. Chill requirements were identified as a critical determinant of agronomic success with pistachios requiring a minimum chill accumulation throughout dormancy (May–October) to achieve bud burst. This has been identified as 59 chill portions (Zhang, 2011). During spring, the accumulation of 900 heat units is necessary for flowering and nut maturation.

Pistachios are dessert natives and can tolerate drought, however they are more productive with greater water availability. A scientific literature review revealed that pistachios require dry summers with excessive summer rain negatively affecting the maturing nuts. We used a summer water requirement of 246 mm (Table 6) however; an economically desirable crop will require significantly greater volumes of water than this minimum.

Table 6. Chill portions, heat units (degree days) and water (summer mm) requirements of pistachio trees

	Requirement
Chill	59
Heat	900
Water	246

Recommendations

Suitable regions for expanding the Australian pistachio industry could be within the MIA or Murray–Darling river catchment (Figure 15, pink shading).

There are potentially suitable regions in South Australia such as Renmark, and Western Australia, particularly near Donnybrook and the Margaret River.

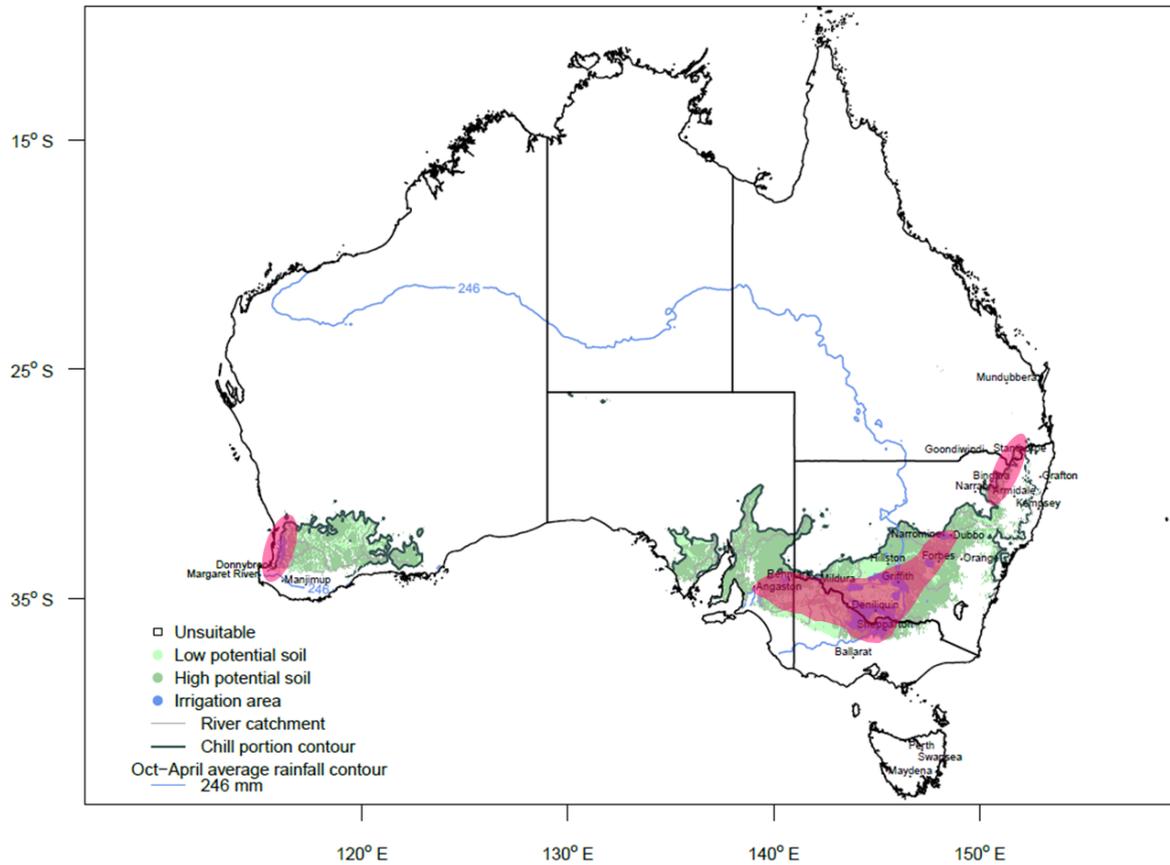


Figure 15. Pistachio industry bioclimatology model. Pink shading indicates areas recommended as potentially suitable for productive pistachio production.

Walnuts

Presently, walnuts are planted from Tasmania to Moree (northern NSW), with small production regions scattered throughout northern Victoria, southern NSW, the Adelaide Hills and Riverland regions of South Australia. Large walnut orchards are located in the Goulburn Valley (Victoria), Riverina (NSW) and Tasmania. There has been strong growth in the Australian walnut industry over the last decade, with projections for continued growth. The Australian Walnut Industry Association (AWIA) is the representative association for small and large walnut orchards, which presently cover approximately 3,000 ha of walnut plantings throughout Australia (ANIC 2015).

Walnuts (*Juglans regia* L.) grow up to 25–30 m tall and can live for hundreds of years. Native to Central Asia, they prefer a Mediterranean climate with cold winters and mild summers. A walnut tree is first harvestable after 4–6 years and reaches full productivity by 11–12 years of age. Trees are wind pollinated over 2–3 weeks; they are self-compatible, but, pollination and flower receptivity often fail to synchronise and pollinators need to be interspersed throughout the orchard (Adem, 2004). Walnut trees produce male catkins and female pistillate flowers.

The Australian industry is relatively disease and pest free (compared with other global industries), which increases the marketability of Australian grown walnuts. Large walnut industries are located in the Northern Hemisphere, for example California, with only 3% of the world's production coming from the Southern Hemisphere in 2008 (ANIC, 2015). The Australian walnut industry has room to expand and provide fresh nuts for six months of the year.

Traditionally, the cultivars planted in Australia were terminal bearing; more recently there has been an increase in cultivation of lateral-bearing varieties, many of which are imported from California. Pollination occurs during spring and nuts are harvested in April–May. The edible nut, or walnut kernel, is contained within a hard wrinkled shell that grows inside a leathery green husk. Nut break occurs late in the growing season and trees are shaken during mechanical harvesting.

Parameters of walnut bioclimatology model

The accumulation of chill heavily influences the location of walnut plantings and the combination of cultivars that are compatible. Walnuts prefer deep, well-drained, fertile soils. Heavy clays should be avoided with preference given to loam or sandy loam soils. Walnuts require regular water, and do not perform well when water logged. Industry publications and a scientific literature review were used to determine an average water requirement of 10 ML per hectare throughout summer.

Table 7. Chill portions (low from Hartley, high from Chandler) and water (summer mm) requirements of walnut trees

	Requirement
Chill	54–72
Water	738

Recommendations

Regions potentially suitable for walnut production (Figure 16, yellow shading) include:

- southern NSW within the MIA
- the Central Tablelands (region around Orange) and Central NSW (Narromine – Dubbo) regions
- some parts of Tasmania are also potentially productive according to the bioclimatology model, however, access may not always be convenient, for example along parts of the western coast
- Both Angaston (Adelaide Hills) and Renmark (Riverlands) in South Australia, which fall within the chill contours, with suitable soils and good water availability
- Western Australia, south-western coast – but there is limited access to perennial river systems
- Victoria – near Shepparton and towards the east coast.

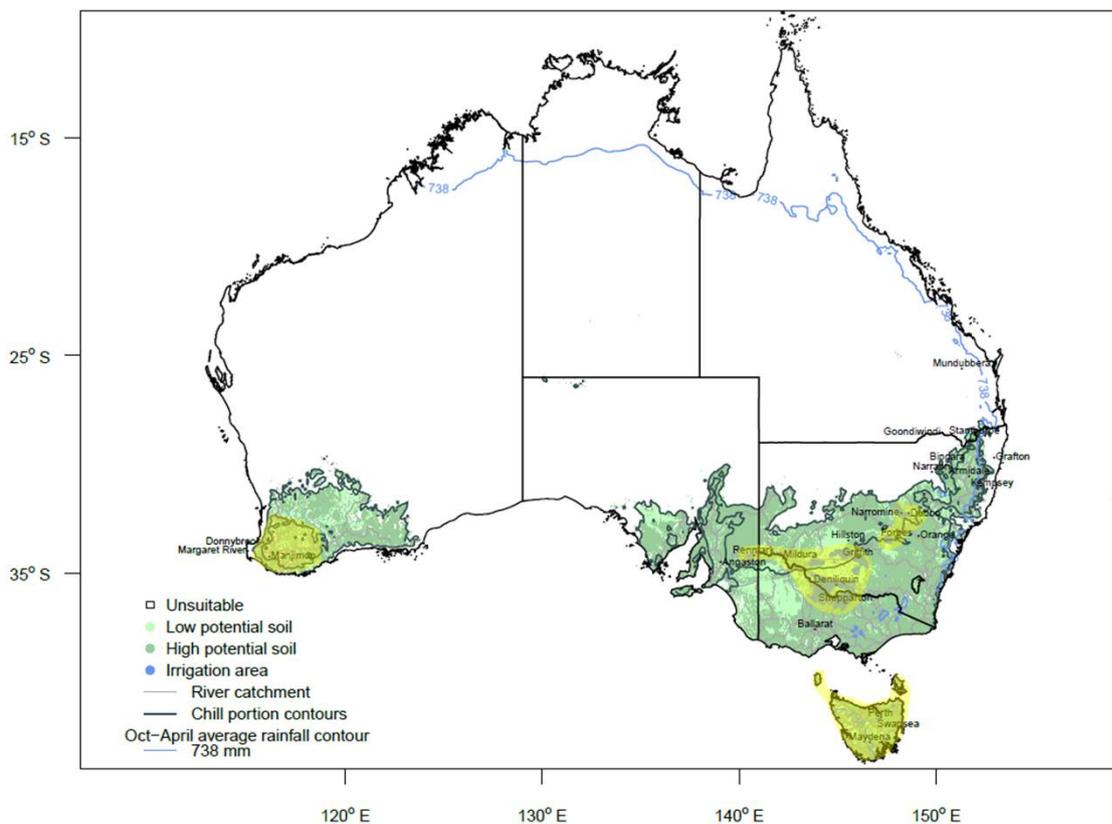


Figure 16. Walnut industry bioclimatology model. Yellow shading indicates areas recommended as potentially suitable for productive walnut production.

Overlap

There are regions suitable for expansion that overlap and multiple nut trees plantings could be established (Figure 17). These generally follow the perennial river systems or fall within irrigation scheme areas.

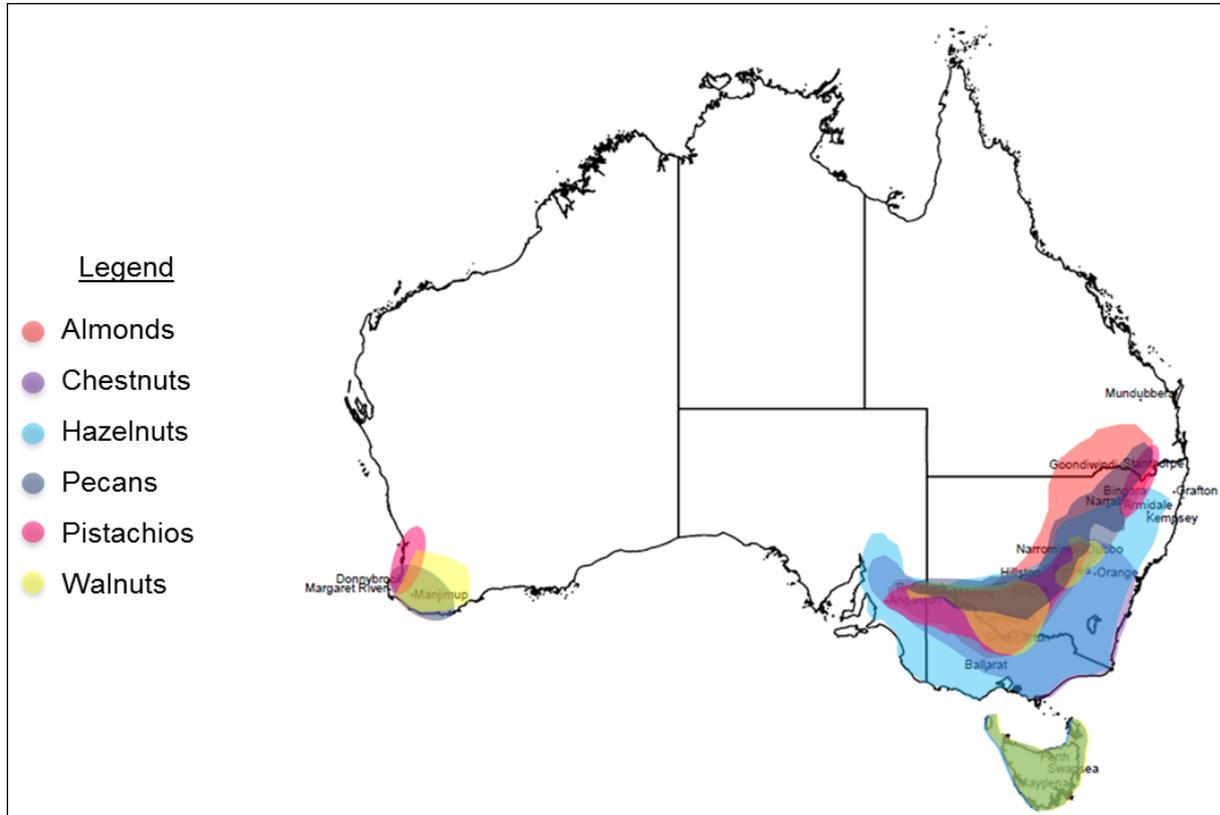


Figure 17. Regional suitability from bioclimatology modelling for Australian temperate nut industries. Shading for each nut crop is based on analysis of bioclimatology models and provided as a guide only.

Future work and possible applications

The majority of available information about establishing farms and orchards, climatic suitability and farm/orchard management is based on international research. As a result, issues were encountered when attempting to determine values for chill, water and soil requirements based on scientific literature and industry publications. The Australian temperate nut industries will benefit greatly from further research into the requirements of nut trees under Australian conditions. Increasing our knowledge on Australian-based nut growth will assist the industries to expand within the areas defined in this publication.

The initial use of this information package would be to guide the establishment of sentinel plantings in some locations that have been highlighted as potentially suitable regions for nut crop production. Full site evaluation and analysis should be undertaken before any site is established, regardless of the bioclimatology modelling.

Economic viability of nut orchard establishment

Each nut grower is unique, with individual business plans and goals. Individuals are strongly encouraged to fully investigate the economic viability of nut orchard establishment according to their own circumstances. The following sections briefly provide some initial information to aid economic analyses – land value, water availability and processing facility details. The information in this section changes regularly and is only an accurate guide as of January 2016.

Individual requirements for processing and market access vary depending on the scale of production of individual nut growers. Market access can refer to large scale distribution and international markets as well as local farmers markets and speciality distribution. We recommend new nut growers thoroughly investigate the sustainability and accessibility of market access most appropriate to their business model.

Land value for some of the recommended regions

The January 2016 real estate market was analysed to determine the median land sale price in some of the regions identified as potentially suitable for nut industry expansion. Rural properties with more than 2.5 hectares of unused land were selected and both currently listed and recently (2015/16 financial year, to date) sold properties were included. A data summary (box plots) of the property values per hectare for each region is shown in Figure 18. We have endeavoured to include a range of properties both with and without infrastructure (for example, dwellings, sheds, irrigation systems and pumps or other significant structures). This data was only accurate in January 2016 and current, local information should be sought and incorporated into individual business plans.

The data was sourced from realestate.com.au and domainrural, as databases of properties from all regions. Local real estate information is also available from a range of agents, specific to each region.

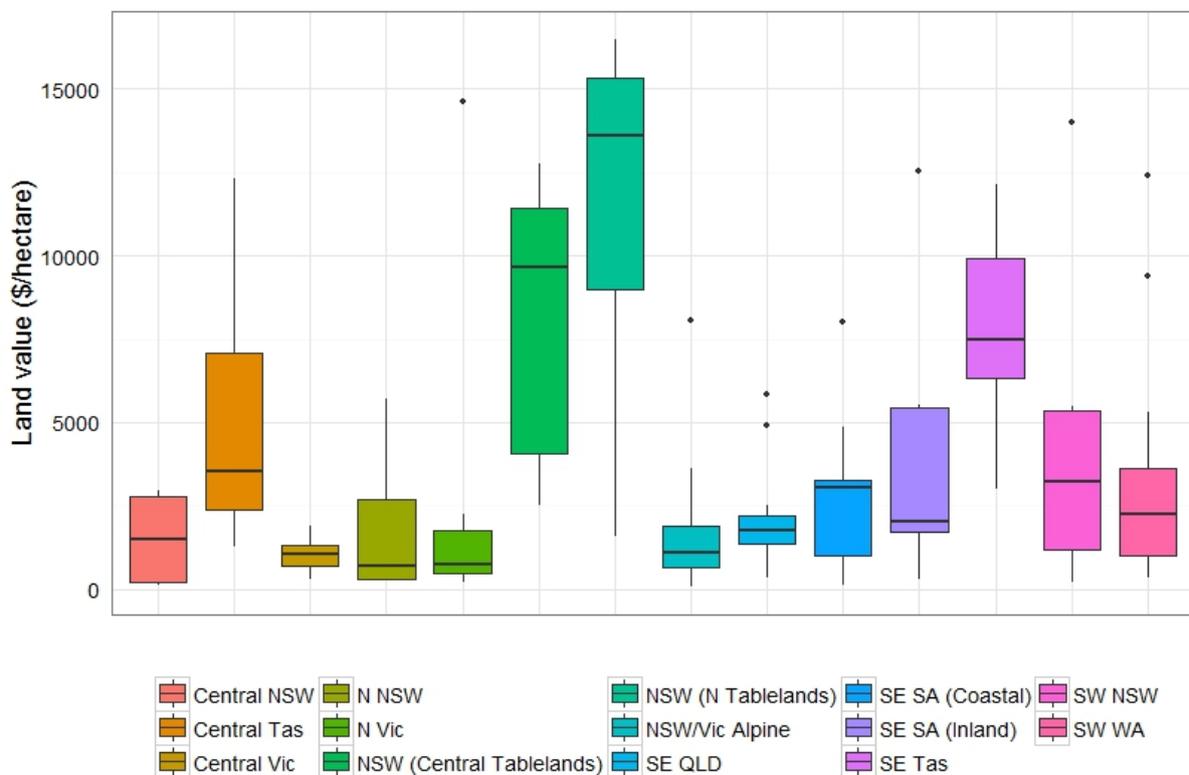


Figure 18. Box plots showing variability in the value of land in some potentially productive regions identified for expansion of Australian nut industries based on bioclimatology modelling. The median land value is the horizontal black line within each box.

Water accessibility

The availability of water throughout Australia heavily relies upon the consistency of rainfall in major catchment and dam areas. There are some regions in Australia that experience higher rainfall, generally implying a greater availability of water, while others experience regular droughts with very minimal available water. Water allocation processes are in place throughout Australia, to ensure water is used in a sustainable manner. Water rights or licenses are available for purchase by landholders that allocate a certain volume to the holder.

Water allocations, as a percentage of the licenced volume, for NSW and northern VIC are shown in Figure 19. Allocation values represented here are accurate as at January 2016 and will vary. Current allocation values and more information regarding NSW water allocations can be found at the [NSW DPI Water](#) allocation summary page, and about northern Victorian allocations on the [NVRM website](#) or [Victorian Water Register](#). Current and relevant information regarding water allocations requires locally focused investigation.

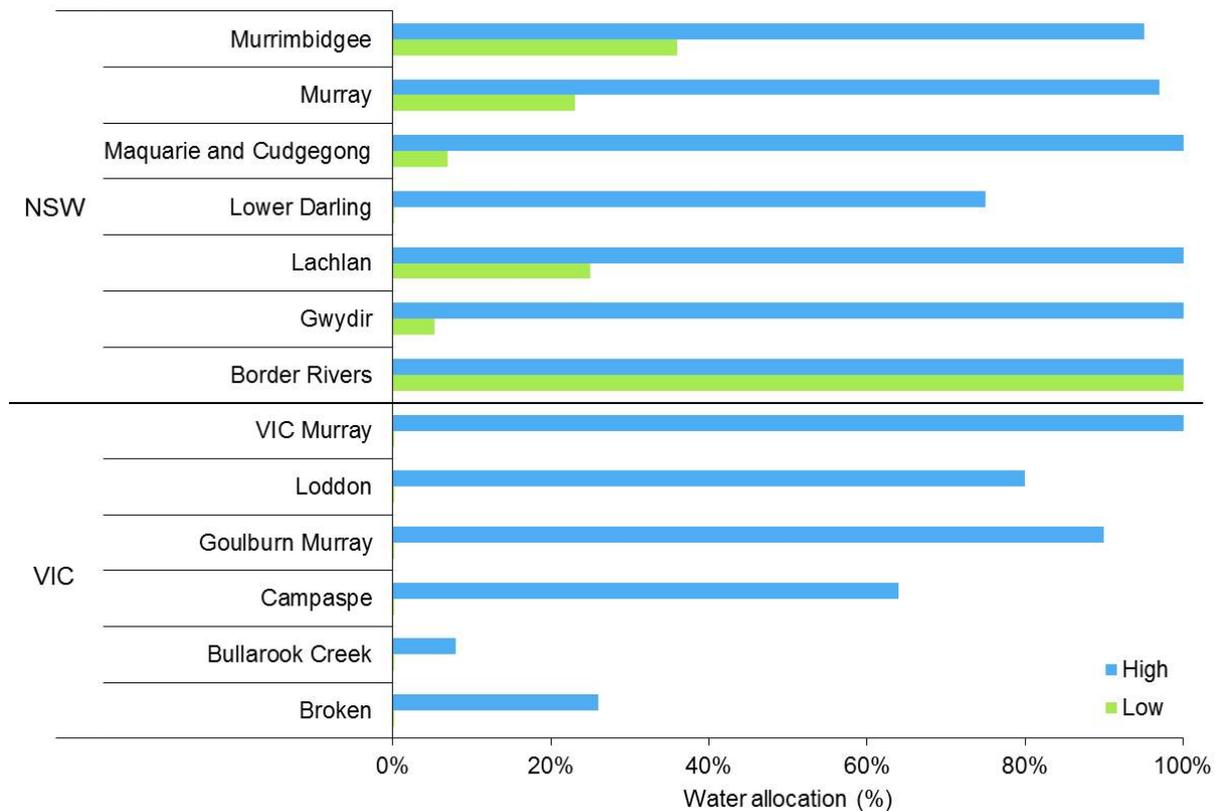


Figure 19. Water allocations for NSW high and general security and Northern Victorian high security water licence/ entitlement holders in January 2016. All Northern Victorian general (also referred to as Low Reliability) water allocations are presently set at 0%.

Processing facilities

All nuts require processing before they can be sent to the appropriate market. The need for on-site processing facilities will depend on the scale and resources of the operation.. It is wise to consider the cost, time, access to and convenience of both on-site processing and outsourcing processing.

We have provided a list (Table 8) of processing facilities to help with an initial step of this assessment. This list includes small processors, co-operatives and large scale processing locations. The access to these facilities and cost involved in processing should be determined on an individual basis as part of business modelling. This information was provided by ANIC and Trevor Ranford (Industry Development Officer, Chestnuts Australia Inc.; Communications Officer, Hazelnut Growers of Australia Inc.; Executive Officer, Pistachio Growers' Association Inc. and Australian Industry Development Officer, Walnut Industry Association Inc.)

Table 8. Existing processing facilities for each nut industry.

Industry	State	Localities	
Almond	NSW	Griffith (future)	
	VIC	Lindsay Point Carwarp	Robinvale
	SA	Virginia Loxton	Lyrup Renmark
Chestnut	NSW	Tumbarumba	Hoskinstown
	VIC	Beechworth Wandiligong Stanley Fumina	Hoddles creek Bright Porepunkah
	SA	Forest range	Heathfield
	TAS	Preolenna	Wynyard
	WA	Manjimup	Carlotta
Hazelnut	NSW	Mudgee Orange	Hoskinstown Peelwood
	TAS	Meander Hagley	Preolenna
	SA	Forest range	
Pecan	QLD	Toowoomba	
	NSW	Lismore	
Pistachio	NSW	Elong Elong	
	VIC	Robinvale	
	SA	Gawler	
Walnut	NSW	Sassafras	Wisemans Creek
	VIC	Violet Town Myrree Dargo	Barooga Leongatha Kalimna West
	WA	Nannup/Manjimup	
	SA	Forreston	
	TAS	Richmond	

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For updates go to www.dpi.nsw.gov.au/factsheets

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