Royal Melbourne Institute of Technology

GEOM1044
Spatial Information Science Principles

Project report on

What are the most suitable regions in Victoria for large scale hemp production?

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Contents

Executive Summary

This report aims to identify the most suitable regions in Victoria for large scale industrial hemp production through the analysis of environmental parameters, current land use and economic benefits. This analysis is guided by the compatibility of Victoria's environmental parameters, including mean temperature, average rainfall, soil properties, drought risk and economic benefits against the growing of large-scale industrial hemp.

Suitability was determined using a threshold suitability index value, derived from ideal index values for each of the assessed criteria.

There were 48 local government areas that were identified as having a suitability index value greater than 0, shown in Figure 2. There were 10 with a suitability index value above 80% of the threshold value. Only Glenelg and Moyne achieved a rating of Suitable, having index values greater than the threshold index value, making up 5% of Victorian land. The most profitable LGA analysed was the Southern Grampians with opportunity for $78300 gross profit.

Aims and Introduction

Largescale, industrial hemp production could be a valuable asset to Victoria's agricultural economy, creating environmentally sustainable practises based on environmental, infrastructural and economical constraints. Hemp is strain of the Cannabis sativa plant with low tetrahydrocannabinol (THC), and is most commonly grown for fibre production, however has uses in many different industries (Crawford et al. 2012). The stalk can be used for fibres, paper and housing insulation, the roots, leaves and flowers are used in medicines, and the seeds are used in oils, protein powders and dietary supplements as well as in biofuels (Bouloc et al. 2013).

Hemp is a highly tolerable crop to varying air temperatures, with ideal mean air temperatures ranging from 16-27 °C, however can survive in warmer or cooler conditions and endure frost of up to -5 °C (Adesina et al. 2020). In cooler conditions, the only compromise to the crop is a slower germination of eight to ten days. The crop prefers loose, well drained loam with high organic matter, such as sandy loam, silt loam or clay loam with a pH of 5.8 to 7.5 (Adesina et al. 2020). Industrial hemp crops prefer an average rainfall of 65-67cm per annum, and usually require some degree of irrigation, however, has a relatively low water footprint of 2719 litres per kilogram of fibre, which is less than a third of the water footprint of cotton, a comparable crop also grown in Victoria, at 10,000 litres per kilogram (Averink 2015). The state of Victoria is a suitable candidate state for growing industrial hemp, as it has a cooler climate than most of Australia with regular rainfall, large areas of soils that suit hemp and an already established agricultural industry (Bureau of Meteorology 2020). Due to these qualities, Victoria is the focus of this report.

The density of plants is dependent on the desired use of the crop, for fibre, the plants can be very densely planted with 50 to 750 plants per square meter whilst for seeds and stems it is less dense, with 30 to 120 plants per square meter. For fibre, this produces 10 tonne per hectare, and for seed one tonne per hectare is attainable (Adesina et al. 2020; Cole & Zurbo 2008). The fibre can be sold on the Australian market for approximately $245 per tonne as of 2008, with growing and harvesting costs deducted, this equates to $1250 to $1650 profit per hectare (Cole & Zurbo 2008). The hemp seeds alone can be sold for approximately $3500 per tonne as of 2012, of which approximately $1300 to $1800 is profit for a productive crop after deducting growing costs (Crawford et al. 2012). With hemps global market expected to have doubled between the years of 2016 and 2020 due to an increasing demand, the production of Hemp in Victoria could be a valuable addition to Victoria's agriculture industry and economy(Adesina et al. 2020).

Under Australian conditions, industrial hemp is very resistant to pests and diseases, reducing the need for pesticides (Cole & Zurbo 2008). Although pesticides can be useful for crop yields, they are best avoided, as they can cause ecological disruption, affecting non-target organisms or vegetation and polluting waterways (Aktar, Sengupta & Chowdhury 2009). Due to hemps ability to grow quickly, it has the natural ability to out-compete weeds, which in turn increases crop yield without need for weed control measures (Cole & Zurbo 2008). Hemp is a valuable addition to crop cycling due to its proficiency in phytoremediation, helping to remediate contaminated soils, creating sustainable agricultural practises (Adesina et al. 2020). Through growing crops suited best to the land, the use of irrigation, fertiliser and pesticides can be minimised whilst increasing crop yield and success, establishing and reinforcing agricultural practises that are sustainable and environmentally friendly (Mottet et al. 2006).

This suitability analysis report aims to identify the most appropriate locations in Victoria, Figure 1, on a local government level, to introduce industrial hemp crops. This analysis is guided by the compatibility of Victoria's environmental parameters, including mean temperature, average rainfall, soil properties, drought risk and economic benefits against the growing of large-scale industrial hemp. This report's recommendations can aid local governments and farmers in choosing a crop that is best suited to their land, assist government policy and guide budget allocation. Due to the many products and uses of the crop, the environmentally friendly and sustainable characteristics and its suitability to Victoria, the industrial growing of Hemp could be a valuable addition to Victoria's agricultural industry (Carus et al. 2013).

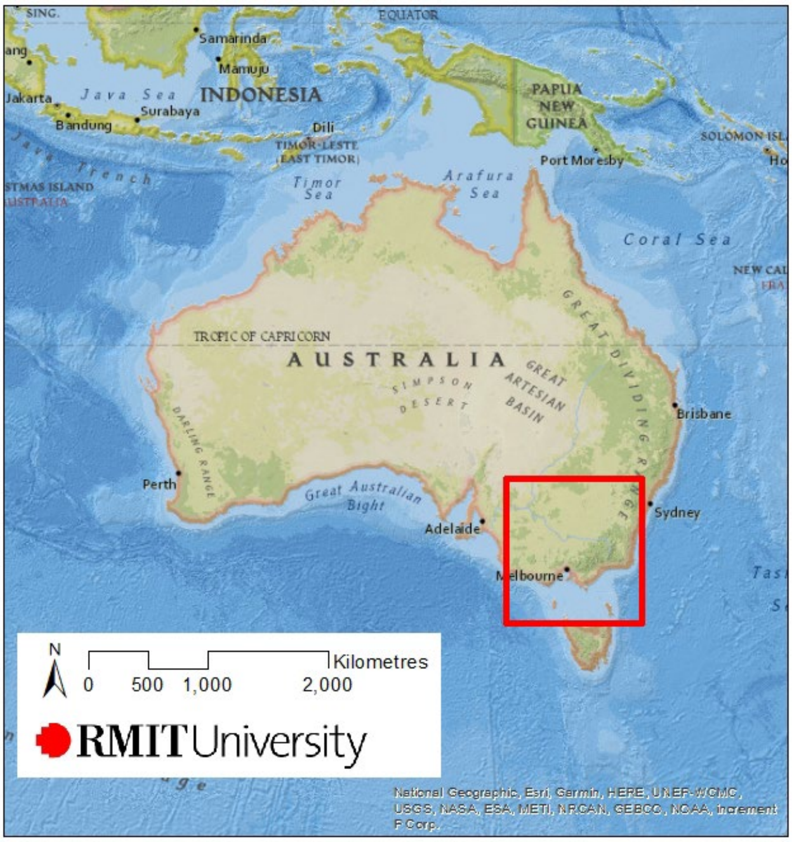


Figure 1. Study Area Extent of Victoria

Methodology

Land Condition

A layer was produced to identified suitable properties for industrial hemp production in Victoria by extracting properties with appropriate land use descriptions and size out of Victorian Land Use Information System 2016-2017. The land use descriptions selected as appropriate were: Mixed farming and grazing; Domestic Livestock Grazing; General Cropping; Livestock Production (Dairy Cattle, Beef Cattle and Sheep); Softwood Plantations; Vineyards; Orchards, Groves and Plantations; Forestry (Commercial Timber Production); Hardwood Plantations; Poultry; Piggeries; Plant / Tree Nurseries; Glasshouse Plant / Vegetable Production; Commercial Flower and Plant Growing. Out of these land use descriptions, only properties greater than 1ha were selected as appropriate.

A suitable soil type layer was created by extracting the most suitable soil types out the Victorian Soil Type Mapping dataset. The only suitable soil type in Victoria that was identified was any suborder of Chromosol (Adesina et al. 2020; Isbell 2016).

Another extraction was then performed by identifying all suitable properties in Victoria that intersected with suitable soil types. This generated a layer that identified all suitable properties for this study; those that were greater than 1 ha, having appropriate land use descriptions and intersecting with suitable soil types.

By comparing the calculated geometry of the suitable properties to the calculated geometry of each Local Government Area (LGA), a percentage of area of each LGA made up by suitable properties could be calculated and then standardised using the linear transformation method. The result of this calculation was used as the values for the land condition criteria.

Climate Characterisation

Temperature
The 30-year mean temperature (1961-1990) for the growing months, October through to April, was used to characterise the study area's temperature.

Maps of the temperature were created using data obtained from the Bureau of Meteorology. The average temperate maps are based on daily temperature data from approximately 600 weather stations around Australia (Bureau of Meteorology n.d.-b).

Data was downloaded as a Grid ASCII file and converted to a raster through ArcMap's conversion tool 'ASCII to Raster'. The resulting raster output was resampled from the original resolution of 2.5km to 2km using a bilinear technique which was selected due to its ability to handle continuous data and is based on a weighted distance average of the four nearest input cell centres (ESRI n.d.) The resample was conducted in order for the zonal statistic calculation of small area LGA's, where without resampling gaping in data for these small area LGA's was observed.

A zonal statistic operation was applied to the resulting resampled raster in order to assign the mean rainfall to each LGA.

Rainfall

The 30-year mean annual precipitation was used to characterise the study area's precipitation due to the growing season precipitation requirements specific to hemp were generally not available.

Maps of the precipitation were created using data obtained from the Bureau of Meteorology (Australia Climate Averages - Rainfall, BoM, n.d.). Rainfall data is recorded through a network of stations across Australia. The average rainfall data is based on quality controlled monthly rainfall data sourced by BoM and spatially analysed using a technique known as statistical interpolation (Australia Climate Averages, BoM, n.d.). The resulting analysed monthly rainfall data was downloaded as a Grid ASCII file and converted to a raster through ArcMap's conversion tool 'ASCII to Raster'. The resulting raster output was resampled from the original resolution of 5km to 2km using a bilinear technique which was selected due to its ability to handle continuous data and is based on a weighted distance average of the four nearest input cell centres (ESRI n.d.) The resample was conducted in order for the zonal statistic calculation of small area LGA's, where without resampling gaping in data for these small area LGA's was observed.

A zonal statistic operation was applied to the resulting resampled raster in order to assign the mean rainfall to each LGA.

Drought Risk

Drought risk was identified as a limiting factor for the growth and production of hemp. A member of the group is a part of a parallel project in conjunction with the Bureau of Meteorology in creation of a Drought Risk Index. The following criteria was defined and decided on by industry experts and the student cohort of this project.

Hazard

<u>Vegetation Health Index</u>

The Vegetation Health index (VHI) is based on a combination of products extracted from vegetation signals, specifically the Normalized Difference Vegetation Index (NDVI) and from the brightness temperatures, both derived from the NOAA Advanced Very High-Resolution Radiometer (AVHRR) sensor.

The VHI index data was downloaded from the National Ocean and Atmospheric Administration (NOAA) through their File Transfer Protocol (FTP) site. The data then joined to each LGA and standardised through the linear transformation method.

<u>Standard Precipitation Index</u>

The Standard Precipitation Index (SPI) is a probability index that considers only precipitation. The SPI is an index dependent on the likelihood of a given amount of precipitation being observed and the probabilities are standardised such that the median amount of precipitation is indicated by the index of zero, where half of the historical quantities of precipitation are below the median and half are above the median (National Centers for Environmental Information n.d.).

The SPI index data was downloaded from the National Ocean and Atmospheric Administration (NOAA) through their File Transfer Protocol (FTP) site. The data was then joined to each LGA and standardised through the linear transformation method.

Soil Moisture

Soil Moisture product is a NESDIS product created by blending soil moisture retrievals from multiple satellites.

The Soil Moisture index data was downloaded from the National Ocean and Atmospheric Administration (NOAA) through their File Transfer Protocol (FTP) site. The data was then joined to each LGA and standardised through the linear transformation method.

Hazard Index Formula

$$\boldsymbol{H_{index}} = \frac{\sum \boldsymbol{x}}{\boldsymbol{n}}$$

Where H_{index} represent the hazard index, x is the criteria, and n is total criteria.

Exposure

Exposure was calculated through three indices: Land Use, Aspect, and elevation.

Land Use

Victorian Land Use Information System (VLUIS) 2016 dataset has been created by the Spatial Sciences Group of the Agriculture Victoria Research Division in the Department of Economic Development, Jobs, Transport, and Resources. It covers the entire landmass of Victoria and separately describes the land tenure, land use and land cover across the state at the cadastral parcel level.

The land use descriptions selected as appropriate were: Mixed farming and grazing; Domestic Livestock Grazing; General Cropping; Livestock Production (Dairy Cattle, Beef Cattle and Sheep); Softwood Plantations; Vineyards; Orchards, Groves and Plantations; Forestry (Commercial Timber Production); Hardwood Plantations; Poultry; Piggeries; Plant / Tree Nurseries; Glasshouse Plant / Vegetable Production; Commercial Flower and Plant Growing.

From the selected parcels with the above land use descriptions the count was calculated for each LGA and a ratio of agricultural parcels to total parcels was calculated and standardised through the linear transformation method.

Aspect and Elevation

The SRTM Digital Elevation Models (Australia, 2010) dataset was used to derive the average elevation, slope, and percentage of north-facing aspect for each LGA.

The DEM represents ground surface topography and excludes vegetation features.

Both the aspect and elevation data were standardised through the linear transformation method.

Exposure Index Formula

$$\boldsymbol{E_{index}} = \frac{\sum \boldsymbol{x}}{\boldsymbol{n}}$$

Where E_{index} represent the exposure index, x is the criteria, and n is total criteria.

Vulnerability

Vulnerability has been calculated through three indices. Economic resources, education and occupation, and social dependency.

Economic Resources

The Index of Economic Resources (IER) focuses on the financial aspects of relative socio-economic advantage and disadvantage, by summarising variables related to income and wealth.

The index excludes education and occupation variables as they are not direct measures of economic resources. It also omits some assets such as savings or equities which, although relevant, could not be included because this information was not collected in the 2016 Census.

A low score indicates a relative lack of access to economic resources in general. For example, an area may have a low score if there are:

- many households with low income, or many households paying low rent, AND
- few households with high income, or few owned homes.

A high score indicates relatively greater access to economic resources in general. For example, an area may have a high score if there are:

- many households with high income, or many owned homes, AND
- few low-income households, or few households paying low rent (Australian Bureau of Statistics 2016).

The SEIFA data cube for 2016 IER was used to calculate Economic Resource Risk. While the data comes standardised, it is standardised for the entirety of Australia. Therefore, the Victorian LGA's were extracted and a linear transformation method was applied.

Education and Occupation

The Index of Education and Occupation (IEO) is designed to reflect the educational and occupational level of communities. The education variables in this index show either the level of qualification achieved or whether further education is being undertaken. The occupation variables classify the workforce into the major groups and skill levels of the Australian and New Zealand Standard Classification of Occupations (ANZSCO) and the unemployed. This index does not include any income variables.

A low score indicates relatively lower education and occupation status of people in the area in general. For example, an area could have a low score if there are:

- many people without qualifications, or many people in low skilled occupations or many people unemployed, AND
- few people with a high level of qualifications or in highly skilled occupations.

A high score indicates relatively higher education and occupation status of people in the area in general. For example, an area could have a high score if there are:

- many people with higher education qualifications or many people in highly skilled occupations, AND
- few people without qualifications or few people in low skilled occupations (Australian Bureau of Statistics 2016).

The SEIFA data cube for 2016 IEO was used for the calculation of the Education and Occupation Risk. While the data comes standardised, it is standardised for the entirety of Australia. Therefore, the Victorian LGA's were extracted and a linear transformation method was applied.

<u>Social Dependency</u>
Social dependency was calculated based on the percentage of the LGA population within the agricultural working age (15-65 years). The higher the percentage of the LGA with this age demographic the increased risk to those people in the LGA from drought.

Data from ABS table builder was acquired at the LGA level and encompassed population totals of those aged 15-65. This ratio was calculated against the LGA's total population.

<u>Vulnerability Index Formula</u>

$$\boldsymbol{V_{index} = \frac{\sum x}{n}}$$

Where V_{index} represent the vulnerability index, x is the criteria, and n is total criteria.

DRI Formula

$$\boldsymbol{DRI_{index} = \frac{\sum x}{n}}$$

Where DRI_{index} represent the Drought Risk Index, x is the criteria, and n is total criteria.

Suitability Map

Hemp suitability maps were created using ArcMap to combine the climate and land conditions in Victoria at a LGA level. The result was the development of a simplified model that does not estimate biomass or yield but a map showing local government areas where hemp production would be most suited based on climate, land, and drought risk factors.

Standardisation of criteria
Each of the criteria was standardised using the linear transformation model with the exception of precipitation which was non-linear. The results of standardisation assign each factor a common numeric range, giving higher values to more suitable attributes and allows for fair comparison of criteria.

Linear normalisation:

$$S_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}$$

Where Si is the standardised value of X_i, X_{min} is the lowest original value, and X_{max} is the highest original value.

Temperature was able to be standardised through linear transformation due to the data for Victoria not exceeding the optimal growing temperature which allowed for this standardisation where this is normally not appropriate for a non-linear criterion.

Precipitation was standardised through the following rating table.

Table 1 - Precipitation Ratings

Annual Rainfall (mm)	Rating
> 1500	0.125
950 - 1500	0.250
850 – 950	0.500
750 – 850	0.750
650 – 750 (Optimal)	1.000
550 – 650	0.750
450 - 550	0.500
350 - 450	0.250
< 450	0.125

Establishing Weights

This stage was completed to establish a set of weights for each of the criteria. The importance or preference of each criterion relative to the rest of the criteria for suitable hemp production selection was expressed by assigning weights and was based on related review literatures, and on group judgment through the use of weighted linear combination method which was used by Lein and Stump (2009) in their wildfire risk model.

Table 2 - Criteria Weighting

Criteria	Weighting
DRI	2
Land Condition	2
Temperature	3
Precipitation	3

Suitability Formula

IF(Land Condition <1%,"Not Suitable", MEAN(SUM(3*Temperature + 3*Rainfall + 2*Land Condition – 2*DRI))

Threshold value

A threshold value was derived in order to identify LGAs that surpassed ideal index values for each of the criteria. This threshold value was calculated as using the mean drought index value of 0.526, the ideal rainfall index value of 1, the minimum ideal temperature of 16 C (Adesina et al. 2020), with an index value of 0.876 and the mean land suitability index for values greater than 0, with an index value of 0.258. The resulting threshold suitability index value was 1.272.

The results of the LGA index values were subsequently categorised by percentage brackets in relation to this threshold index value. LGAs were described using the following percentages of the threshold value: Suitable ≥100%, Mostly suitable >80%, Moderately suitable >70%, Marginally suitable >60%, Low suitability >50%, Very low suitability >0%, Not suitable ≤0%.

Model Assumptions

Simplifying assumptions are seen in all models and it is necessary to know the assumptions in order to understand their importance and impact on the results of the model and to recognise the limitations of the model.

Temperature

Temperatures exceeding the absolute maximum or those falling below the absolute minimum tolerated by a crop do not kill the plant, but rather stop or significantly reduce cell division or elongation. When temperatures return to optimal range cell division and growth resume at the same rate that occurred prior to the unfavourable temperatures.

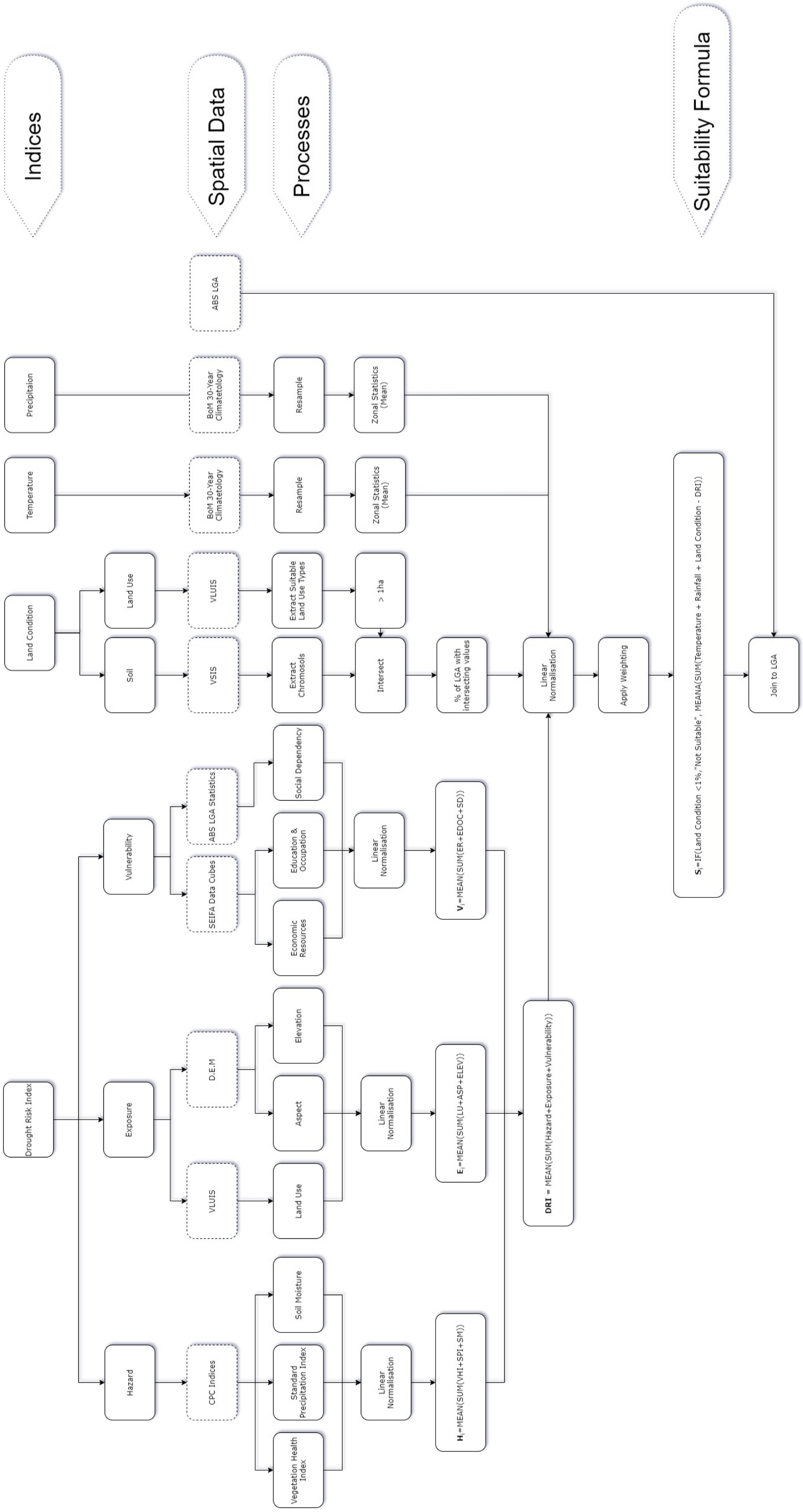
Rainfall

Areas where rainfall is below optimal conditions has the ability and resources to supplement with irrigation. Areas where irrigation exceeds optimal, soil drainage can be modified by land management practices.

GIS

The main assumption to consider is the sharp boundaries of the LGA polygons which assumes that discrete lines between polygons accurately represent the changes in the physical properties of the soil, climate, or both. In the real world, such a scenario never happens. Generally, a transition in soil and or climate properties is gradual and gradient. Therefore, classifications of suitability near the LGA boundaries may be uncertain.

Workflow Diagram



Results

Index Values

There were 48 local government areas (LGAs) that were identified as having a suitability index value greater than 0, shown in Figure 2**.** There were 10 with a suitability index value above 80% of the threshold value of 1.018: Glenelg (1.354), Moyne (1.35), Warrnambool (1.179), Ararat (1.177), Southern Grampians (1.17), Northern Grampians (1.124), Corangamite (1.092), Benalla (1.053), Mount Alexander (1.034) and Pyrenees (1.021) (Table 3). Only Glenelg and Moyne achieved a rating of Suitable, having index values greater than the threshold index value of 1.272.

The greater than 80% threshold suitability rated LGAs make up a total geographical area of 18**%** of Victoria (Table 4) and are generally confined to the south western region of Victoria (Figure 5) This correlates to many large agricultural properties on chromosols in the region (Figure 7) as well as close to ideal rainfall frequently observed in the region (Figure 4).

The 2 Suitable rated LGAs, Glenelg and Moyne, were both within the ideal rainfall range of 650 to 750 mm (Adesina et al. 2020), with 728.4mm and 700.2mm respectively. The only LGA with the Mostly Suitable rating within the ideal rainfall range was Corangamite, with a rainfall of 727.6mm. The remaining Mostly Suitable rated LGAs were within 150mm± annual precipitation of the ideal range (Table 3).

There were no >80% Threshold value LGAs within the ideal mean annual temperature range of 16 to 27 C, (Adesina et al. 2020), as seen in Table 3**.** Only 2 LGAs were within the ideal temperature range, both of which had no suitable land identified (Figure 7).There were no >80% Threshold value LGAs within the ideal mean annual temperature range of 16 to 27 C, (Adesina et al. 2020), as seen in Table 3**.** Only 2 LGAs were within the ideal temperature range, both of which had no suitable land identified (Figure 7).

Only 3 >80% Threshold LGAs were above the average Drought Index value of 0.526, they were: Moyne, Southern Grampians, and Mount Alexander with 0.617, 0.631 and 0.528, respectively (Table 3). In contrast to this, Moyne was firmly within the ideal annual rainfall range and had the highest land suitability index value, Southern Grampians had the second highest suitability land index value and Mount Alexander had above average land suitability and rainfall.

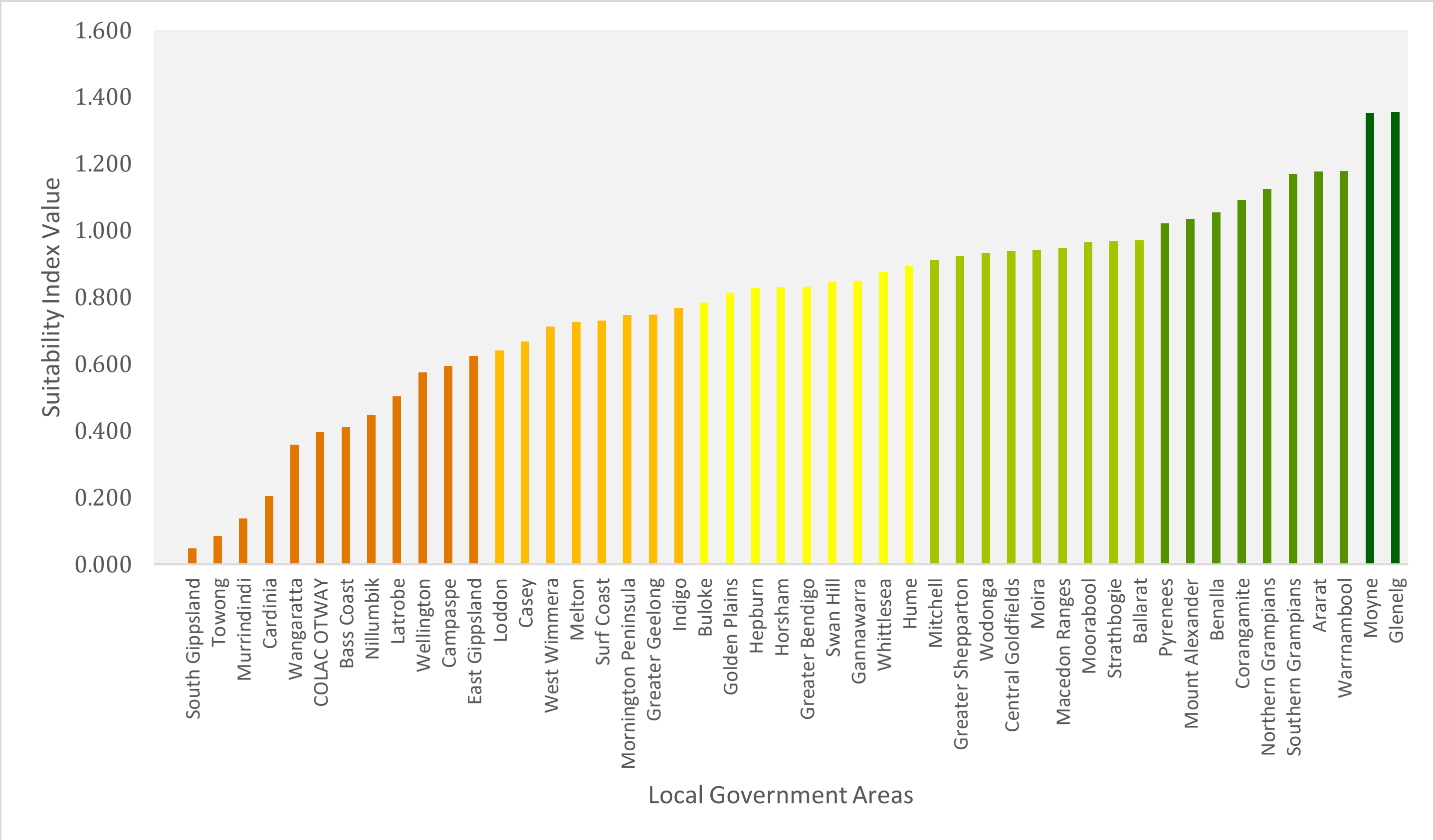


Figure 2: Local Government Areas in Victoria with a Suitability Index Value greater than 0. Colours are associated with the legend in Figure 5.

*Table 3: Index Values of LGAs with a suitability index value >80% of the suitability threshold. * indicates value greater than 100% Suitability threshold*

Mostly Suitable to Suitable LGAs (>80% Threshold)	Normalised Drought Index	Mean Annual Rainfall (mm)	Annual Daytime Temperature Mean (°C)	Normalised land suitability Index	Suitability Index
Pyrenees	0.523	591.9	14.6	0.493	1.021
Mount Alexander	0.528	605.3	14.6	0.531	1.034
Benalla	0.424	753.4	13.6	0.735	1.053
Corangamite	0.431	727.6	14.0	0.327	1.092
Northern Grampians	0.345	522.6	15.0	0.424	1.124
Southern Grampians	0.631	634.5	14.5	0.944	1.170
Ararat	0.347	583.4	14.7	0.597	1.177
Warrnambool	0.066	759.9	13.5	0.657	1.179
Moyne	0.617	700.2	14.1	1.000	1.350 *
Glenelg	0.245	728.4	13.9	0.693	1.354 *

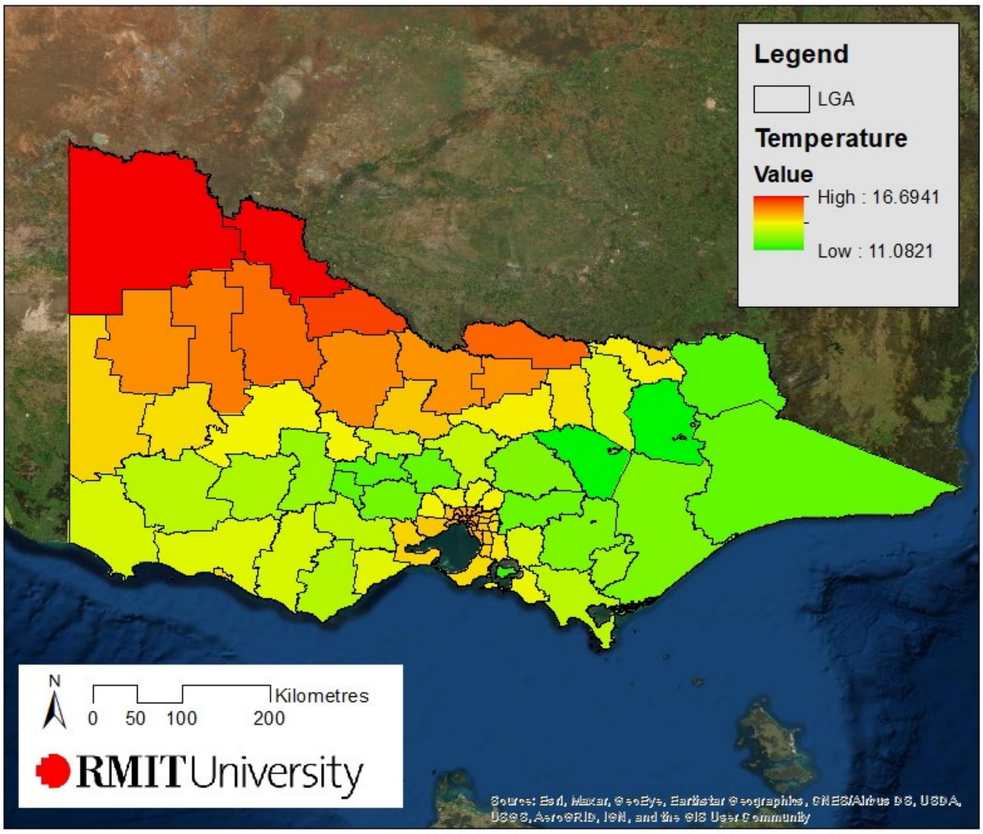


Figure 3. Map of Victorian average daily mean temperature (October to April) (Bureau of Meteorology n.d.-a)

Table 4: The distribution of land suitability classes in Victoria.

Suitability	Land Area (ha)	Percentage (%)
Suitable	1,170,026	5
Mostly Suitable	2,844,028	13
Moderately Suitable	1,919,696	8
Marginally Suitable	3,028,771	13
Low Suitability	2,230,678	10
Very Low Suitability	6,121,636	27
Not Suitable	5,434,728	24
Total	**22,749,563**	**100%**

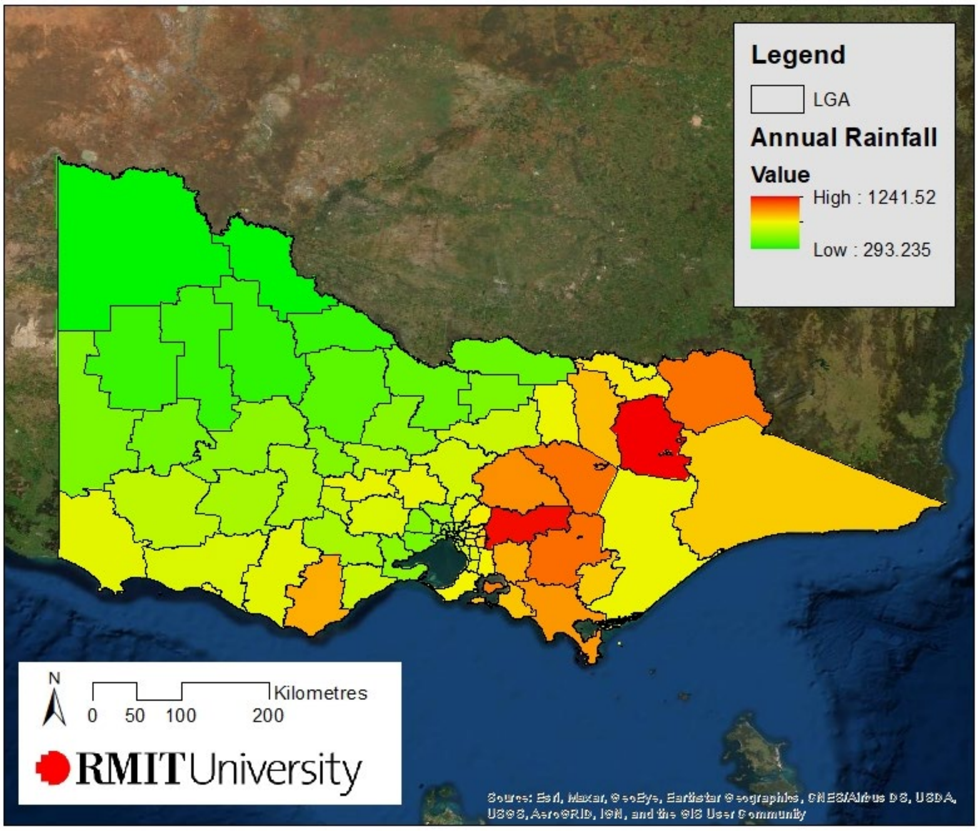


Figure 4. Map of Victorian average annual rainfall (Bureau of Meteorology n.d.-a)

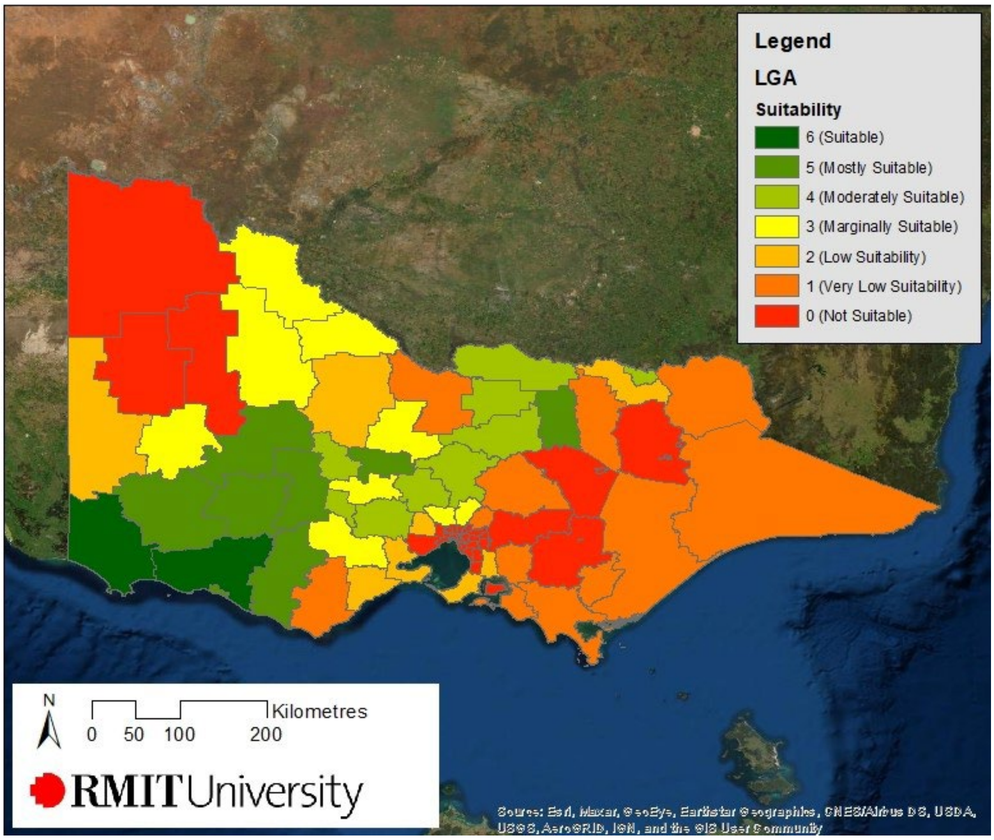


Figure 5. Map of Victorian Hemp Production Suitability

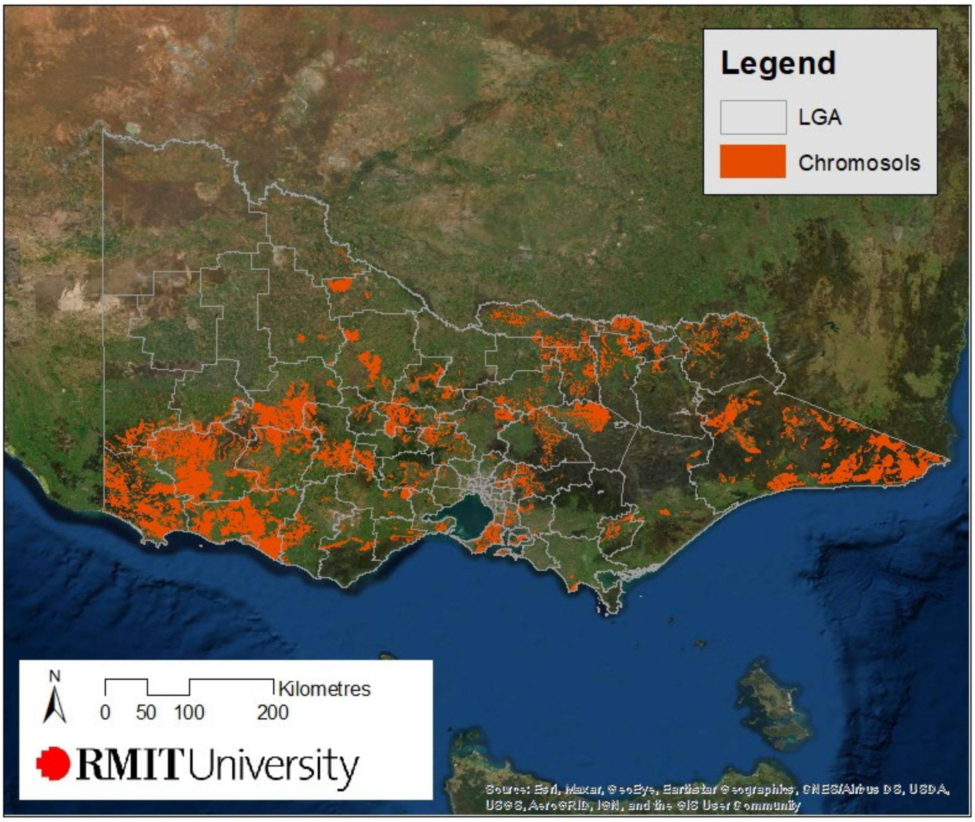


Figure 6. Map of Victoria Chromosols

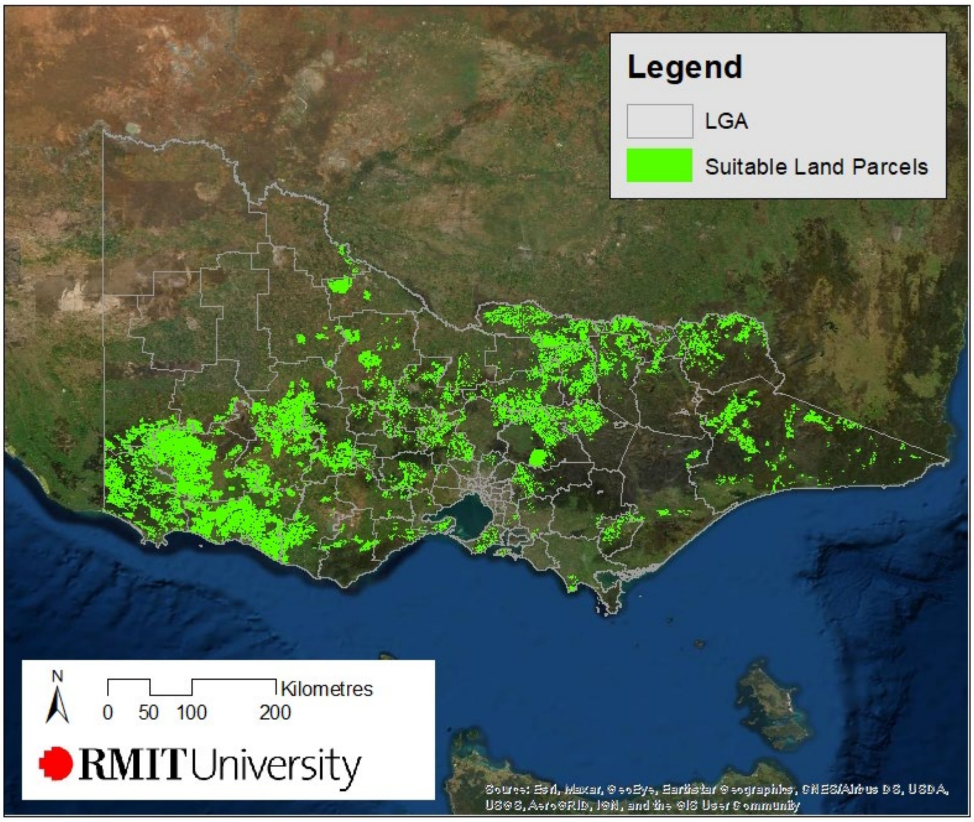


Figure 7. Map of Victorian Suitable Land Parcels intersecting with Chromosols

Profitability

Table 5 Approximate Gross Profit for hemp fibre and seed production for top ten most suitable LGAs with greater than 80% threshold. Mean suitable property size (ha) rounded to closest hectare. Approximate yield for fibre and seed calculated from 10t/ha and 1t/ha and 1t/ha respectively. Gross profit calculated from mean Australian market value for fibre = $245/t, seed = $3500/t, times approximate yield minus mean growing and harvesting costs per ha, fibre = $1000/ha, seed = $1950/ha times property size (ha) (Cole & Zurbo 2008; Crawford et al. 2012)

		Fibre		**Seed**	
Mostly Suitable to Suitable LGAs (>80% Threshold)	Mean Suitable Property Size (ha)	Approximate yield (t/ha)	Gross Profit ($)	Approximate yield (t/ha)	Gross Profit ($)
Mount Alexander	21	210	30450	21	32550
Pyrenees	33	330	47850	33	51150
Corangamite	34	340	49300	34	52700
Ararat	36	360	52200	36	55800
Warrnambool	38	380	55100	38	58900
Moyne	42	240	16800	42	65100
Benalla	43	430	62350	43	66650
Northern Grampians	44	440	63800	44	68200
Glenelg	46	460	66700	46	71300
Southern Grampians	54	540	78300	54	83700

The LGA with the least gross profit for both fibre and seed out of the top ten most suitable LGAs was Mount Alexander with $30450 and $32550 in profit respectively (Table 5). The most profitable LGA analysed was the Southern Grampians, with the largest mean suitable property size from the top 12 suitable LGA's. The Southern Grampians holds the opportunity for $78300 gross profit from growing industrial hemp crops for fibre, and $83700 gross profit for hemp seeds (Cole & Zurbo 2008; Crawford et al. 2012). The average mean suitability property size for the top ten most suitable LGAs for growing industrial hemp was 38.6 ha, the average gross profit for fibre and seed was $52391.67 and $59933.33 respectively (Table 5).

Limitations

There were a number of limitations that may have impacted the reliability of the evaluation made, including the several arbitrary allocations of discrete ratings to indices, reasonable assumptions, and selection of models and weights.

Regarding the land condition index, only the most suitable soil in Victoria was selected for this analysis, Chromosols. Other somewhat suitable soils may have also been included and allocated a weighting as part of this study and could have significantly influenced the results. Furthermore, the land use description data used for this index is from 2016 was the latest available data at the time of reporting, although it could be outdated.

DRI, temperature and rainfall limitations to be considered would be the reliance on historical data. While it can give an indication of what may occur in the future, it cannot be considered an exact prediction of future events.

The Lein and Stump (2009) weighted linear combination method was used in conjunction with MCE (multi-criteria evaluation), however both could be considered a simplification for land suitability. The multi-criteria assessment involves the allocation of land to suit a particular purpose on the basis of a range of characteristics of the selected areas. The manner in which requirements should be standardised and aggregated to make a final judgement on the method of land allocation is unclear and therefore limits the accuracy of the suitability calculation.

The weights allocated for this method (Table 2) were selected based on the extent that policy would not be able to directly impact their values. As a result, mean precipitation and temperature, intrinsic values of the LGAs were weighted higher than Drought index and Land condition as these indices are influenced by administrative decision making. With that being said, the weighted values assigned to these criteria were not derived from literature but were assigned by perceived value based on the objectives of the present study.

Discussion and Recommendations

Suitable Local Government Areas

The 2 Local Government Areas identified as being suitable were Glenelg and Moyne, both located in the South Plains Region of south west Victoria. This is a region that's primary land use is dryland agriculture cropping, grazing, dairy and forestry and is well known for its broad range of rainfalls (Victoria 2020).

Moyne Council has invested significantly in increasing the areas resilience to climate change by investing heavily in renewable energy, high tech industry and innovative sustainability for its agricultural sector, making it an ideal LGA for a future Industrial hemp hub (Council, MS 2019). Moyne is primarily a dairy hub in Victoria, industrial hemp offers an opportunity for this council to diversify its agricultural sector to be more resilient. Furthermore, hemp production by-products are viable as a low-cost cattle feedstock and could work viably in tandem with the existing dairy industry (Australia 2014). Several High Priority agricultural objectives from this council include advance sector wide improvements in agricultural infrastructure. This indicates that this LGA will only improve in its suitability moving forward.

Glenelg council has a much more diverse range of agricultural produce (Statistics 2011) and a large manufacturing sector. This correlates to our findings that Glenelg would be a suitable LGA for an industrial hemp hub as a highly skilled workforce and a suitable infrastructure system is already established. The large export infrastructure development plan in development, designed to improve this regions production and export capacity (Council, GS 2015) further improves the standing of Glenelg as ideal for a future industrial hemp hub for Victoria.

Profitability

Hemp fibre produces higher yields than seed production at a ratio of 10:1, however seed production is consistently higher in gross profit compared to fibre, as shown through Table 2 (Cole & Zurbo 2008; Crawford et al. 2012). Despite the significantly smaller yield and higher growing and harvesting costs, hemp seeds gross profit is approximately 100% higher than the gross profit of fibre, primarily consequent of the seeds higher selling price. The gross profit is primarily dependant on the property size available, of which the Southern Grampians hold the highest gross profit attainability (Table 2).

Hemp is a relatively new crop to the Australian agricultural industry, and with its environmental benefits and a growing consumer base due to its many uses. With Europe increasing hemp cultivation due to a growing demand, Victoria could also benefit in this new worldwide market (Symes, Cupper & Patten 2020).

Recommendations

Recommendation for future iterations of this study would be to consider projected impacts of climate change on the suitability of regions in Victoria to grow hemp, to predict where the most suitable areas in the future may be. In addition, a critical evaluation of weights for each criterion would be recommended by reviewing academic literature to determine more rigorous values. This would produce a more accurate suitability index.

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Appendix

Data Set Sources

Table 6 – Spatial Database and Sources

Data Type	Source
CPC (Climate Prediction Centre)	
Vegetation Health Index	https://ftp.cpc.ncep.noaa.gov/precip/PORT/SEMDP/VEGETATION-INDEX/VHI/DATA/
Standard Precipitation Index	https://ftp.cpc.ncep.noaa.gov/precip/PORT/SEMDP/SPI/DATA/
Soil Moisture	https://ftp.cpc.ncep.noaa.gov/precip/PORT/SEMDP/SOIL-MOISTURE/SMOPS/DATA/
VLUIS (Victorian Land Use Information System)	
Land Use	https://discover.data.vic.gov.au/dataset/victorian-land-use-information-system-2016
SRTM Digital Elevation Models (Australia, 2010)	
Aspect/Elevation	http://www.ga.gov.au/scientific-topics/national-location-information/digital-elevation-data
SEIFA Data Cubes	
Index of Economic Resource	http://stat.data.abs.gov.au/Index.aspx?DataSetCode=ABS_SEIFA_LGA
Index of Education and Occupation	http://stat.data.abs.gov.au/Index.aspx?DataSetCode=ABS_SEIFA_LGA
ABS	
Population Statistics	https://www.abs.gov.au/websitedbs/d3310114.nsf/home/about+tablebuilder
LGA	https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.003July%202016?OpenDocument#Data
VSIS	
Soil Type	https://discover.data.vic.gov.au/dataset/victorian-soil-type-mapping
BoM 30-year Climatology	
Rainfall	http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall/index.jsp
Temperature	http://www.bom.gov.au/jsp/ncc/climate_averages/temperature/index.jsp

Software

Table 7 – Software Packages

Software	Application
ESRI	ArcMap
Microsoft	Excel
Microsoft	Word
Clarivate	EndNote