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Siting a wind farm in Victoria

Introduction

The wind energy sector in Victoria has grown rapidly in recent decades. It now supplies more than 12% of the state's energy requirements (DELWP 2020a) and the Victorian government aims to increase this to 50% by 2050 (DELWP 2020b). This will substantially reduce Victoria's current reliance on fossil fuels (DELWP 2020a) but will require constructing many new wind farms. The aim of this report is to identify which sites in Victoria have the best potential to become wind farms.

Figure 1 Location of existing wind farms in Victoria

To site a wind farm requires considering human, environmental and economic factors simultaneously. In Australia, 75% of people support wind farms when surveyed (Lothian 2020) and a significant majority believe that their benefits outweigh their effects on the visual landscape (ibid). Unfortunately, Wind farms pose a risk to local bird and bat species who can be injured by the turbine blades (DELWP 2020b). While this risk should of course be avoided, the problem is relatively small compared to other factors such as the risk posed to birds by domestic cats (Woinarski et al., 2017). Finally, for a wind farm site to be sensible it must have sufficient wind velocity as well as be accessible by road and existing electricity infrastructure (Baseer et al. 2017).

Methods

To consider all relevant criteria and to weight their importance appropriately, a GIS based multi-criteria decision analysis (MCDA) was used (Malczewski & Rinner, 2015). The MCDA process began by modelling the preferences of a 'development company' with regards to four objectives (table 1). These preferences corresponded to ratings out of 100 which were then normalised to generate relative weightings. These objectives were reified through the criteria in table 2 and the weighting of each objective was divided equally amongst its criteria.

Objectives	Criteria	Criteria Scores					Rating	Weighting	Weight
		1 Very Poor	2 Poor	3 Moderate	4 Good	5 Very Good			
Productive Location	Wind speed at 50m above surface	< 5.5m/s	5.5 – 6m/s	6-6.5m/s	6.5-7m/s	> 7m/s	100	100	0.307692
Accessible	Distance to electricity network	> 5000m	3000-5000m	2000-3000m	1000-2000m	<1000m	85	28.333	0.087179
	Distance to roads	>10,000m	5,000-10,000m	2,500-5,000m	1,000m-2,500m	<1,000m		28.333	0.087179
	Slope	>10º	7.5-10º	5º-7.5º	2.5º-5º	< 2,5º		28.333	0.087179
Least Human disturbance	Distance to residential areas	<1,000m	1,000 – 2,500m	2,500 – 5,000m	5,000 – 10,000	>10,000m	70	70	0.215385
Least ecological disturbance	Distance to Protected Areas	<1,000m	1,000 – 2,000m	2,000 – 3,500m	3,500 – 5,000	>5,000m	70	35	0.107692
	Strategic Biodiversity Value	81-100	61-80	41-60	21-40	1-20		35	0.107692

Table 1 Development company objectives and criteria scores

A set of value ranges was created for each criterion to judge the suitability of each location in Victoria. The value ranges for wind speed were chosen based on 6ms^{-1} at 50 metres being approximately the minimum required for reasonable wind turbine performance (Blakers 2000). Other criteria ranges were modelled on those used in similar studies (Baseer et al. 2017; Saraswat et al. 2021) or to create a linear distribution in the case of the strategic biodiversity value.

Before the scores could be mapped, an exclusion layer was created (figure 2) which combined exclusion layers for each of the exclusion criteria in table 2.

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Suitability scores were then mapped by scoring all of Victoria with regards to each criterion. The scores were then combined by taking their weight-adjusted sum. The resulting map was reclassified once more using a natural breaks algorithm. The same process was performed for each of the other stakeholder groups: environmentalists, anti-wind farm lobbyists and the Victorian State Government (see appendix for ratings).
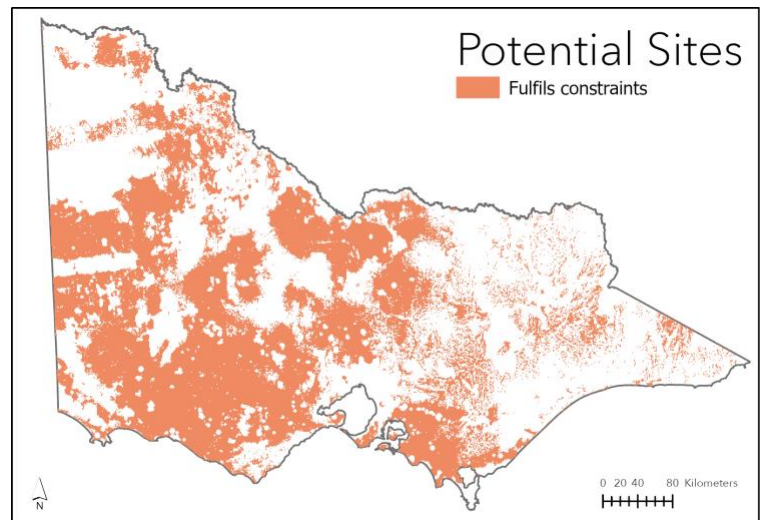

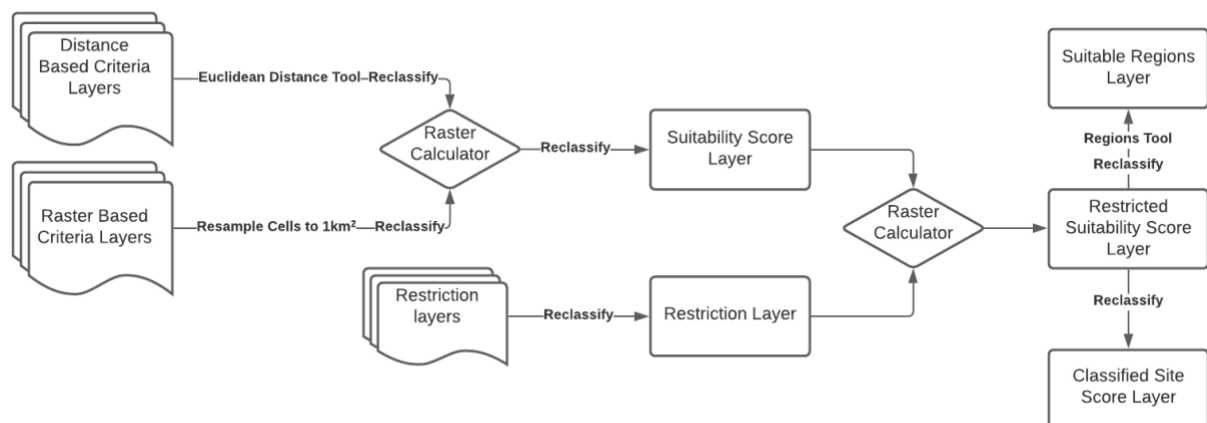*Figure 2 Map of regions not excluded*

Figure 3 Overview of ArcGIS Workflow

To identify the three most promising potential wind farms sites, another suitability layer was created using ten classes to generate smaller, more discrete regions. The 'regions' tool was then utilised to find the three largest contiguous regions which were in the

highest suitability class.

Factor	Exclusion Criteria	Source
Developed area (100ppl/km^2)	Within area	(CIESIN 2018)
Distance to airports	Within 3000m	(DELWP 2021a)
Distance to current wind turbines	Within 1000m	(DELWP 2021c)
Distance to residential areas	Within 1000m	(CIESIN 2018)
Protected area	Within area	(DELWP 2021b)
Coastal bird habitat	Within habitat area	(Department of Transport 2021)
Water body	Within body	(DELWP 2017)
Wind speed	Less than 5ms^{-1}	(Global Wind Atlas 2021)

xResults

Table 2 Exclusion Criteria Information

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Using the development company stakeholder preferences, the largest areas of Victoria classified as 'Very Good' were in the South-West. This is predominantly due to the high wind-speeds in this region compared to the rest of Victoria. Windy coastal and alpine regions were generally not considered due to environmental and access constraints.

As can be seen in figure 5, the spatial distribution of suitability between the Environmentalist and

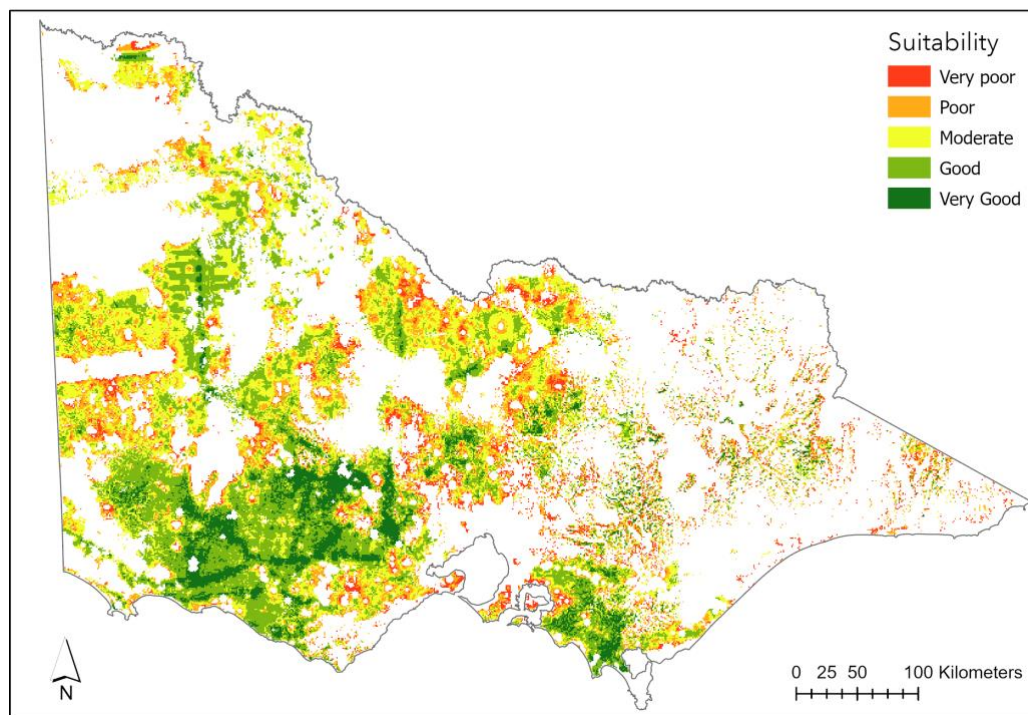Suitability of sites for the development company stakeholder

Figure 4 Suitability map for development company stakeholder

Development Company stakeholders was quite similar. In contrast, the Victorian Government and Anti-Wind Farm lobby stakeholder groups had high suitability levels for most locations sufficiently far away from populated areas.
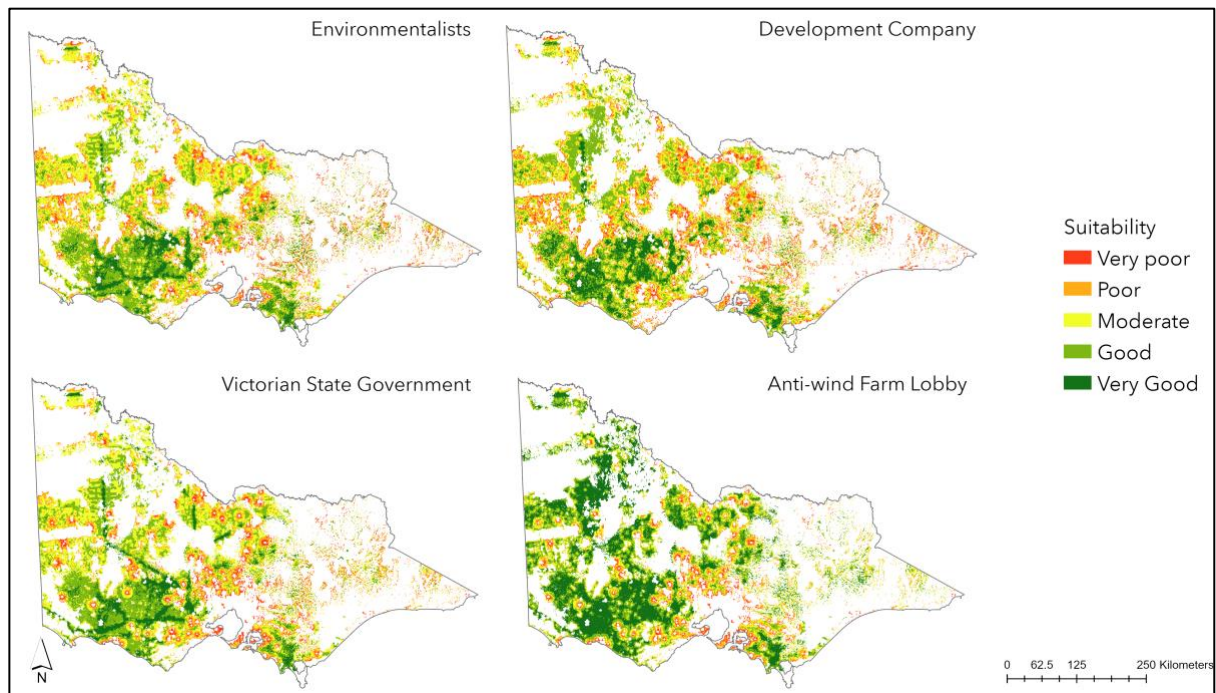
Figure 5 Map of all stakeholder suitability levels

The three potential sites selected can be seen in figure 6, they are located along major roads connected to the City of Ballarat. The selected sites had an average wind speed of 6.33ms^{-1} which is greater than the 6.02ms^{-1} average of existing wind turbine locations.
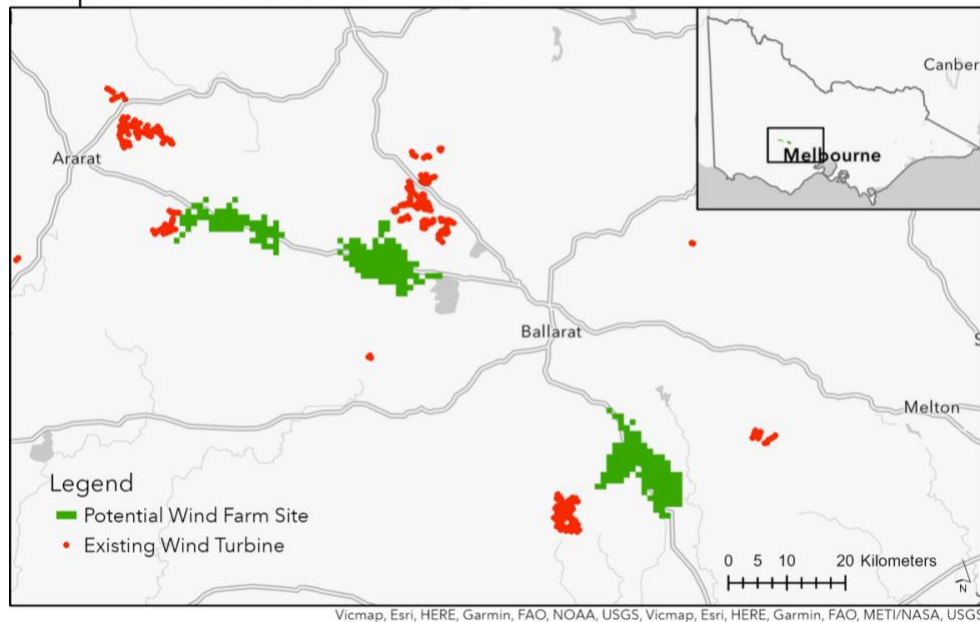

Figure 6 Map of identified potential sites

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Discussion

The three proposed wind farm sites in figure 6 are all located near existing wind turbines. The middle site encompasses an area where a planning permit proposal has already been lodged for a wind farm (DELWP 2021e). This indicates that the study methodology was valid because wind turbines are unlikely to be constructed in these areas if they are truly inappropriate. All three sites appear to be predominantly farmland, hence building wind turbines in these locations would require purchasing or leasing the land from its current owners. Given the high energy productivity potential and accessibility of these sites compared to their low human and environmental impact, they would likely be appropriate additions to the Victorian wind farm system.

The criteria used to score each objective seems to have been appropriate. The areas with the highest suitability scores are far away from cities and wildlife areas. The addition of the strategic biodiversity values meant that important areas for Victorian ecosystems which are not formally protected were still considered in the analysis. However, the accessibility criteria may require internal reweighting as the slope of the terrain is arguably less important than proximity to power lines and roads.

The limitations of the study are most evident in the small number of datasets used and their limited resolution. For example, the use of only mean wind speed may hide considerable variability in wind speeds throughout the year. While seabird habitat data was used to exclude some coastal areas from the analysis, information about inland bird distribution and migratory paths should also have been included (Taoufik and Fekri, 2021). The use of a km^2 cell size meant that potentially suitable shorelines were poorly resolved and that small distance restrictions were at times not accurately represented.

Another issue in this analysis was the subjective nature of the criteria score intervals and the interpretation of suitability scores. Most similar studies used a more objective 'fuzzy set' approach to define their criteria scores (Aydin et al., 2010; Sánchez-Lozano et al., 2016). Another analysis approach such as cost-revenue optimisation (Van Haaren & Fthenakis, 2011) may have provided a more objective threshold for when a site is considered viable.

The practical outcome of this study is to drastically reduce the search area for any party wishing to construct a new wind farm. It demonstrates that there is an abundance of suitable area for wind farms to be constructed in Victoria to expand its wind power capacity.

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Data Sources

Airport Layer
Department of Environment, Land, Water & Planning (DELWP), 2021a, *Airport Area - Vicmap Transport*, viewed 28th September 2021, https://discover.data.vic.gov.au/dataset/airport-area-vicmap-transport

Coastal Bird Habitats Layer
Department of Transport, 2021, *Coastal bird habitats on the Victorian coast*, viewed 28th September 2021, https://discover.data.vic.gov.au/dataset/coastal-bird-habitats-on-the-victorian-coast

Conservation Areas Layer
Department of Environment, Land, Water & Planning (DELWP), 2021b, *Parks and Conservation Reserves (PARKRES),* viewed 28th September 2021, *http://services.land.vic.gov.au/SpatialDatamart/viewMetadata.html?anzlicId=ANZVI0803004883*

Current Wind Turbine Layer
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DEM layer
Geoscience Australia, 2010, *Geoscience Australia, 3 second SRTM Digital Elevation Model (DEM) v01,* viewed 28th September 2021, https://data.gov.au/data/dataset/12e0731d-96dd-49cc-aa21-ebfd65a3f67a

Land Cover Layer
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Population density layer
Center for International Earth Science Information Network - CIESIN - Columbia University, 2018, *Gridded Population of the World, Version 4 (GPWv4): Population Density, Revision 11,* viewed 28th September 2021, https://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-rev11/metadata

Sealed Road Layer
Department of Environment, Land, Water & Planning (DELWP), 2021d, *Road Network - Vicmap Transport,* viewed 28th September 2021, https://discover.data.vic.gov.au/dataset/road-network-vicmap-transport

Transmission Line Layer
Orr, K., Allan, B., 2015. Electricity Transmission Lines. Geoscience Australia, Canberra. http://dx.doi.org/10.4225/25/553DC89AD105C

Strategic Biodiversity Values Layer
Department of Environment, Land, Water & Planning (DELWP), 2019, *NaturePrint v4.0 Strategic Biodiversity Values*, viewed 28th September 2021, https://discover.data.vic.gov.au/dataset/natureprint-v4-0-strategic-biodiversity-values

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Vic LGA Layer
Department of Industry, Science, Energy and Resources, 2014, *VIC Local Government Areas - Geoscape Administrative Boundaries*, viewed 28th September 2021, https://data.gov.au/dataset/ds-dga-bdf92691-c6fe-42b9-a0e2-a4cd716fa811/details

Wind Speed Layer
Global Wind Atlas, 2021, viewed 28th September 2021, https://globalwindatlas.info/area/Australia/Victoria

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Appendix

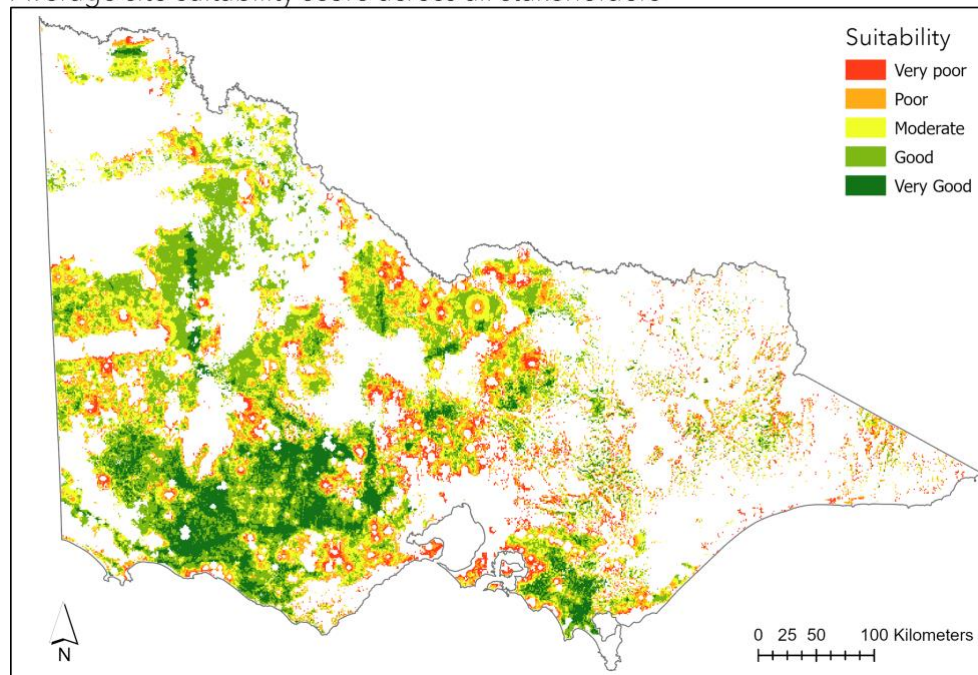| Criteria	Description	Source
Wind speed at 50m above surface	The wind speed at approximately the height at which turbines are expected to be positioned (ms^{-1})	(Global Wind Atlas 2021)
Distance to electricity network	The distance to the nearest high voltage electricity transmission line (m)	(Orr & Allan 2015)
Distance to roads	The distance to the nearest sealed road (m)	(DELWP 2021d)
Slope	The angle of slope at a given position (º)	(Geoscience Australia 2010)
Distance to residential areas	The distance to the nearest area with a population density of greater than 100 people per km^2	(CIESIN 2018)
Distance to Protected Areas	The distance to the nearest conservation area as designated by the Victorian Government	(DELWP 2021b)
Strategic Biodiversity Value	The relative importance of an area to the conservation of biodiversity in Victoria (1-100), lower values indicate areas that major developments should be placed to minimise impact (DELWP 2017)	(DELWP 2019)

Descriptions for the criteria used in this report

Objective	Development Company	State Government	Anti-Wind Farm Lobby	Environmentalists
Productive Location	100	50	30	75
Accessible	85	80	30	50
Least human disturbance	70	90	85	40
Least ecological disturbance	70	30	50	100

Map of average suitability score for all stakeholders considered

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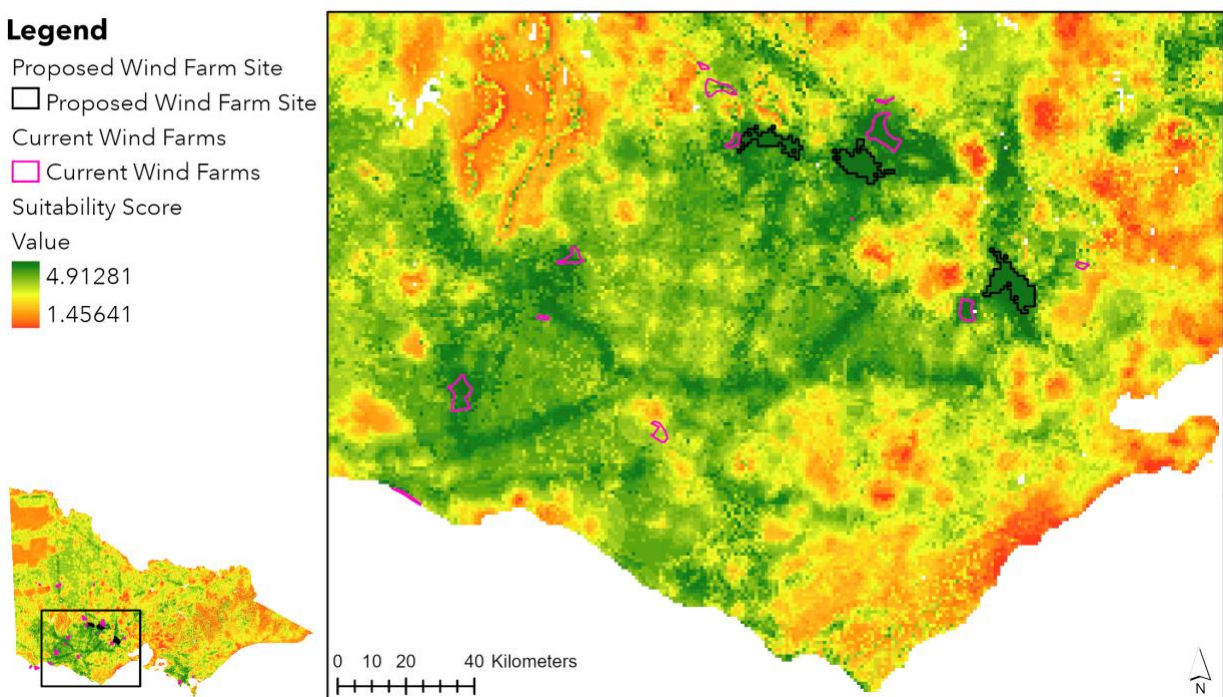Average site suitability score across all stakeholders

Rating of each objective by each stakeholder group

Suitability of Proposed Sites and Existing Sites

Map comparing the unrestricted suitability of proposed and existing sites