GEOM1057

SIS Analytics

Major Project

Thien Phung Tran s3427069

Due date: 09/06/2023

Contents

Spatial Interpolation of Solar Radiation for Solar Farming in Tasmania

Executive Summary

Due to the depletion of fossil fuels and rising environmental consciousness, the use of renewable energy sources has grown in the twenty-first century. Renewable Energy is crucial because of its benefits and the enormous role it will play in the world's future. The goal of this research is to use Kriging as the most effective spatial interpolation method to analyze over a year, the relationship between sun exposure and Rainfall in Tasmania for solar farming 27% of Tasmania is not suited for solar farming, according to the data, while 57% is and 16% is average. This will help advise local governments and farmers in determining whether solar farming would be advantageous, give an idea of the best appropriateness, and support government policies and budget allocations in Renewable Energy.

Introduction & Aim

Energy is vital for a society's ongoing growth and prosperity. Fossil fuels (coal, oil, and natural gas) now account for more than 80% of the world's primary energy needs. Crude oil accounts for 31%, coal for 28%, and natural gas for 22% of global Energy. Even though fossil fuels account for the vast bulk of the world's energy supply, their use significantly negatively impacts the global economy, ecology, and climate. The supply of fossil fuels is limited and will eventually run out and cost more (Kaiser et al., 2013).

The usage of renewable energy sources has increased in the twenty-first century as a result of the depletion of fossil fuels and growing environmental consciousness. Renewable Energy is very important because of its advantages and the significant role it will play in the future of the globe. Renewable energy sources include things like solar Energy, wind energy, biomass energy, geothermal Energy, etc., that can be utilized to create Energy repeatedly (Uyan, 2013). Compared to other energy sources, renewable Energy is clean and has a significantly smaller negative environmental influence, such as reduced carbon footprint, water usage, land use and air pollution ('Are There Any Solar Farms In Australia?', 2023).

Solar power generation is one of the renewable energy sources with the fastest global growth. Solar power generation provides several benefits compared to other energy sources, including flexible locations, government incentives, and environmental benefits(Uyan, 2013). On the other hand, renewable energy sources are limited but not infinite. For the study location, Tasmania was chosen for its food and agricultural sector, as it is highly diversified and includes Vegetables, fruits, viticulture, field crops, dairy and livestock. In Tasmania, renewable energies, such as hydro power, have rapidly expanded in the last decade and has contributed to 80% of homes, business and agriculture (*Tasmania*, n.d.).

This project aims to analyze over 12 months the Solar Exposure and Rainfall in Tasmania for solar farming by selecting the most appropriate spatial interpolation method using ArcGIS Pro. This will help give recommendations to aid local governments, businesses, homeowners and farmers in the best suitability in deciding if solar farming would be beneficial and provide an idea to assist government policies and budget allocations in Renewable Energy.

Methodology

Data

The precipitation maps were created using data from the Bureau of Meteorology. Solar Exposure and Rainfall data are recorded through a network of stations across Australia. The average data of each respectively is based on quality controlled and is spatially analyzed using a technique known as statistical interpolation (*Climate Data Online - Map Search*, n.d.).

Method

There are many ways to interpolate rainfall and sun exposure spatially, but Kriging will be utilized for this research since it enables high-fidelity solar resource modelling at unobserved Locations (Jamaly & Kleissl, 2017). In numerous academic studies, kriging techniques have been proven to be the most effective linear unbiased prediction technique. The Kriging method uses statistical and analytical techniques to anticipate unknown values based on correlations in the Solar data; it is superior in determining interpolation strategies. For geographic interpolation, temporal downscaling, or a forecast of the solar data, the Kriging method can be used with data collected on land and from satellites (Jamaly & Kleissl, 2017).

Determining Kriging Method

The semivariogram/covariance model is used to model irradiance correlations in the Kriging method, and parameters are calculated using the optimized parameter for the output of interpolation Kriging models. It reduces the mean square error and concentrates the optimization process on each model's most crucial parameter(s) (*Parameter Optimization—ArcGIS Pro | Documentation*, n.d.). Table 1 & 2 shows the favourable Optimization Parameters set for Kriging Universal and Kriging Ordinary. To note, kriging universal was set to first order and then optimized for the cross-validation between Kriging Universal and Ordinary for solar Exposure and Rainfall.

Between universal and ordinary Kriging, the cross-validation method found that Kriging is Ordinary is the best in comparison to the universal for both Solar Ezxpsure and Rainfall data. When comparing values having a smaller Mean, Root Mean Square (RMS), and Mean Standardized (MS). The Average Standard error (ASE) is much superior, and the Root Mean Square Standardisation (RMSS) being closer to '1' is more favourable (Bagheri, 2016). As indicated in Table (1), the solar exposure da shows more favourable criteria for Mean, RMS, MS and RMSS, but not in the ASE. In Table (2), the rainfall cross-validation similarly shows more favourable criteria with Ordinary Kriging, and the best interpolation method is determined.

Table 1. Solar Exposure Cross-Validation results

Ordinary Kriging (optimized values)		Universal Kriging (optimized values)	
Count	493	Count	493
Mean	-0.0042538	Mean	0.007373
Root-Mean-Square (RMS)	0.30123494	Root-Mean-Square (RMS)	0.320311
Mean Standardized (MS)	-0.0051484	Mean Standardized	0.02149
Root-Mean-Square Standardized	0.96237209	Root-Mean-Square Standardized	1.046968
Average Standard Error (ASE)	0.3238689	Average Standard Error (ASE)	0.311587

Table 2. Rainfall Cross-Validation results

Ordinary Kriging (optimized values)		Universal Kriging (optimized values)	
Count	338	Count	338
Mean	0.151367	Mean	-0.08254
Root-Mean-Square	11.65934	Root-Mean-Square	11.69784
Mean Standardized	-0.00515	Mean Standardized	-0.00983
Root-Mean-Square Standardized	1.057715	Root-Mean-Square Standardized	1.054107
Average Standard Error	10.66335	Average Standard Error	10.81492

Classifying Solar

The formula from Figure 1 is used to standardize the data for Solar Exposure by obtaining the Maximum value and the Minimum in the Solar Exposure dataset against the monthly Minimum and maximum and then reclassified in the appropriate classes shown in Figure 2.

$$y = \frac{X - X_{\text{min}}}{X_{\text{max}} - X_{\text{min}}}$$

Figure 1. Standardized Formula (H. Zhang et al., 2017)

	L	L-M	M	M-H	H
Range	≤0.3	0.3-0.5	0.5-0.7	0.7-0.9	≥0.9
% of area	0.57	30.50	36.47	30.33	2.14

Figure 2. Classification of solar energy utilization potential reference (H. Zhang et al., 2017)

Classifying Rainfall

The Standardised Precipitation Index (SPI) is one of many indicators that have been developed to examine drought and mapping. It is an efficient and straightforward way to comprehend the foundation of the precipitation index (Bagheri, 2016) by finding each month's Mean and Standard Deviation and using the SPI to gather the values for classification. It is then reclassified into the nine different drought categories and inversed the class to develop the precipitation map.

Annual Standardized Precipitation Index (SPI) $\text{SPI} = p_i - \bar{p}/\text{sd}$ Classification

*; pi : Annual precipitation in each station $\bar{p}$: Average precipitation in each station
sd : Standard deviation of precipitation in each station

Figure 3. Standardized Precipitation Index Formula (Bagheri, 2016)

SPI value	Drought Category
≥ 2	Extremely Humid
1.5 to 1.99	Very Humid
1.0 to 1.49	Moderately Humid
0.5 to 0.99	Lightly Humid
-0.49 to 0.49	Normal
-0.99 to -0.5	Lightly drought
-1.0 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
≤ -2	Extreme drought

Figure 4. Classification of Drought Category (Bagheri, 2016)

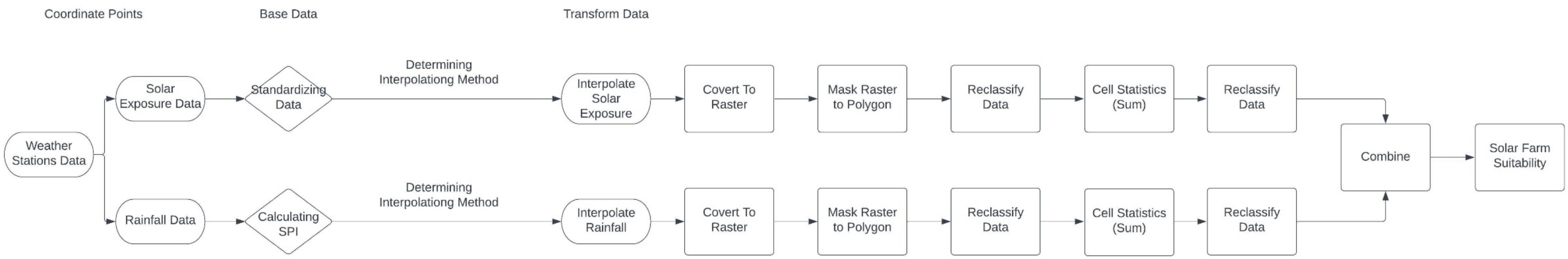
Cell Statistics

For the Cell statistics tool, the value of each position on the output raster is determined as a function of the cell values from all of the inputs at that location. Each statistic. Identifies, cell by cell, the total value of the inputs. In this case, all the inputs are the 12 months of Solar Exposure and Rainfall, respectively, to obtain the overall output over the 12 months.

Combine Cell Statistics

The Combine tool combines several rasters to assign a distinct output value to each distinct combination of input values. For the final results, it was used to add the classified classes of Solar Exposure and Rainfall over the 12 months to get the final output of the Suitability index for Solar farming.

Workflow



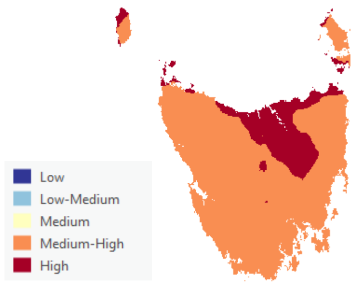
Coordinate Points
Base Data
Transform Data
Weather Stations Data
Solar Exposure Data
Rainfall Data
Standardizing Data
Calculating SPI
Determining Interpolationg Method
Determining Interpolationg Method
Interpolate Solar Exposure
Interpolate Rainfall
Covert To Raster
Covert To Raster
Mask Raster to Polygon
Mask Raster to Polygon
Reclassify Data
Reclassify Data
Cell Statistics (Sum)
Cell Statistics (Sum)
Reclassify Data
Reclassify Data
Combine
Solar Farm Suitability

Results

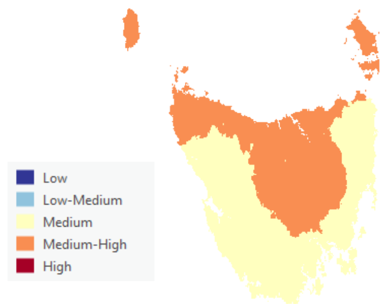
Results - Solar Exposure

Table 3. Overview of Solar Exposure over 12 Months

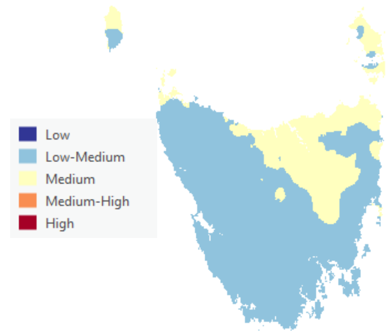
January



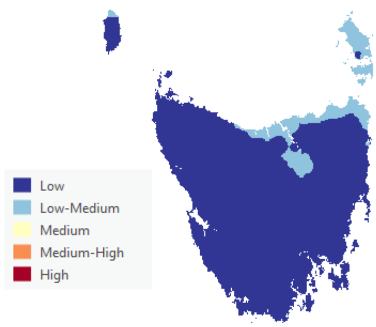
February



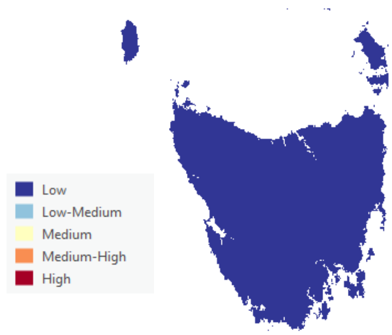
March



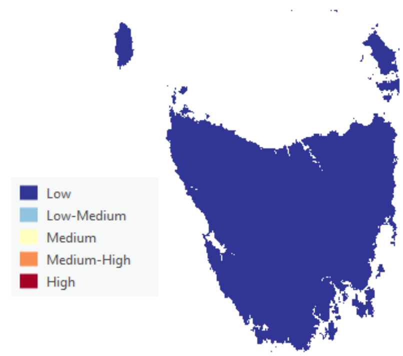
April



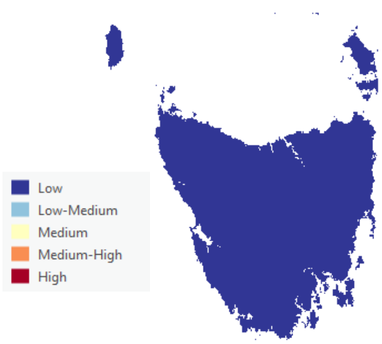
May



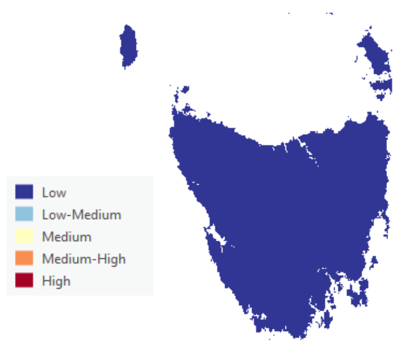
June



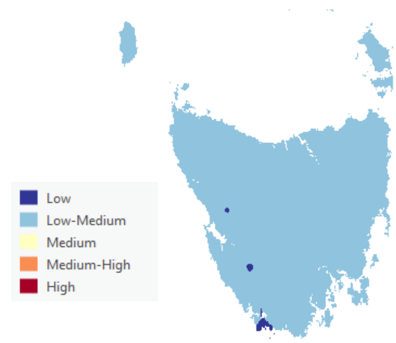
July



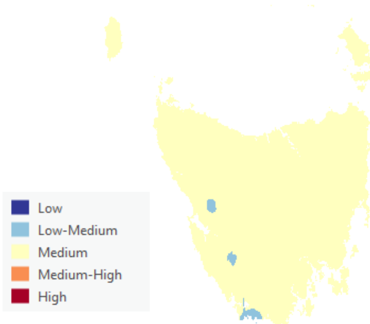
August



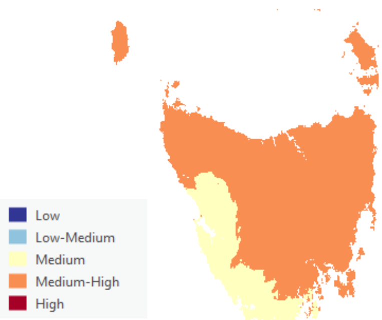
September



October



November



December

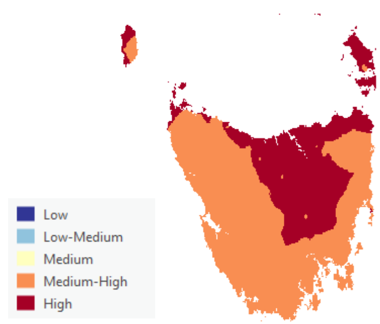


Table 3 shows over the 12 months, and solar radiation follows the seasonal trend in Australia. December to February is summer; March to May is autumn; June to August is winter; and September to November is spring. December and January show the highest amount of solar Exposure covering Tasmania's northern and central parts, with the medium-high covering the rest. Five out of 12 months from April to August show the lowest solar Exposure. In March and June, the majority had low-medium Exposure and in October, with mostly Medium Solar Exposure.

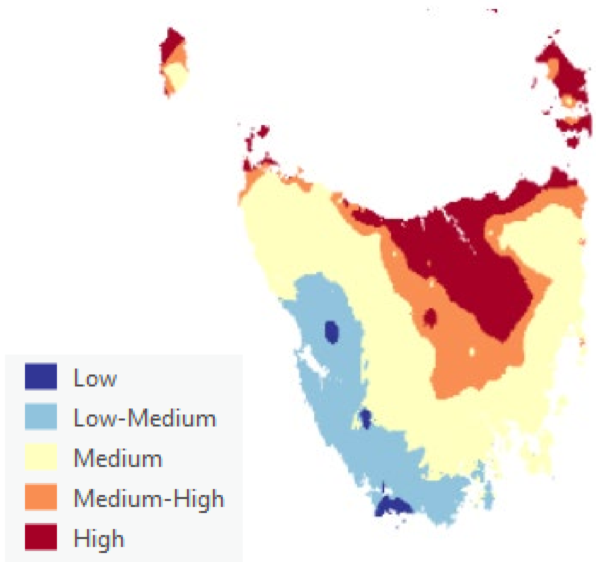


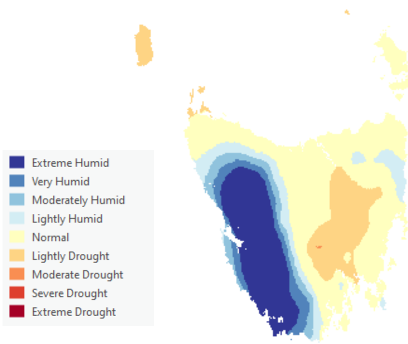
Figure 5. 12 Months Sum Cell Statistics of Solar Exposure

Figure 5. was created using ArcGIS Pro cell statistics with the 12 months' results inputted. There is more Solar Exposure North Of Tasmania and the central north from this. Only along the South-West coast shows low-Medium Exposure in some very small areas with low Exposure. The majority of the map is Normal.

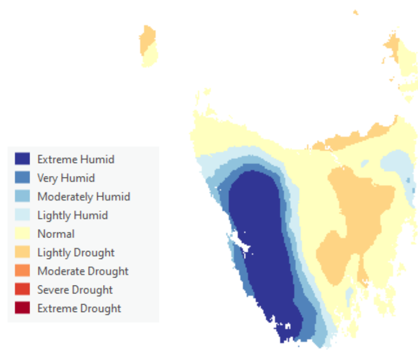
Results – Rainfall

Table 4. Overview of Rainfall over 12 Months

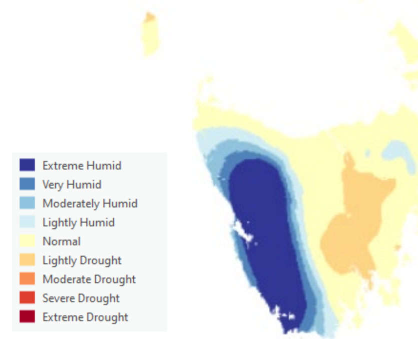
January



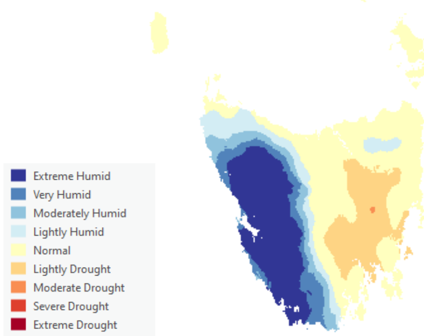
February



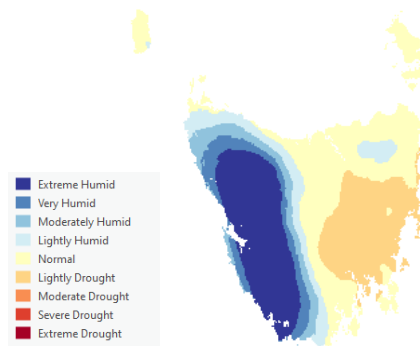
March



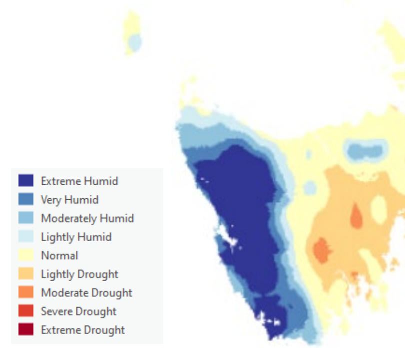
April



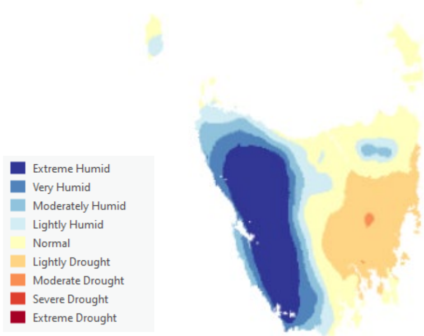
May



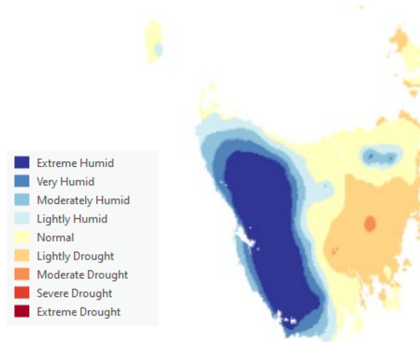
June



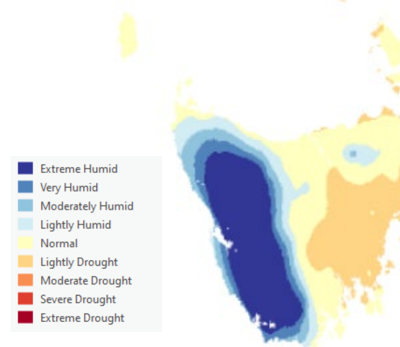
July



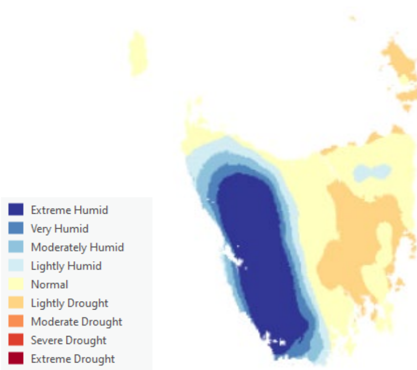
August



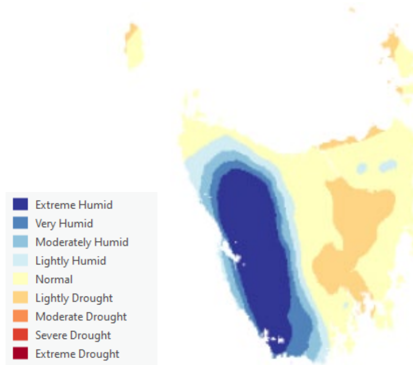
September



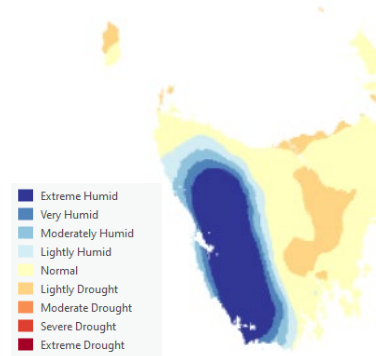
October



November



December



The Rainfall over 12 months is quite consistent. Table 4. above shows that most of the left side of Tasmania constantly has High Humidity, indicating high precipitation levels. Small areas also have High Humidity towards the top right. Central East of Tasmania shows an area of light drought (light precipitation) as well, as the north coast from August to February and from June to August shows a small area of moderate drought and the rest of Tasmania is quite normal.

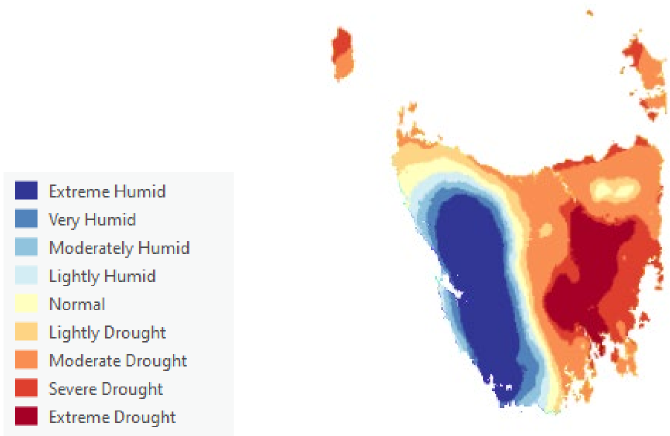


Figure 6. 12 Months Sum Cell Statistics of Rainfall

The cell statistics for Rainfall show the west of Tasmania has a high concentration of Rainfall, whereas the East has extreme-severe drought. The image above depicts that most of Tasmania doesn't have much Rainfall.

Results – Final Suitability

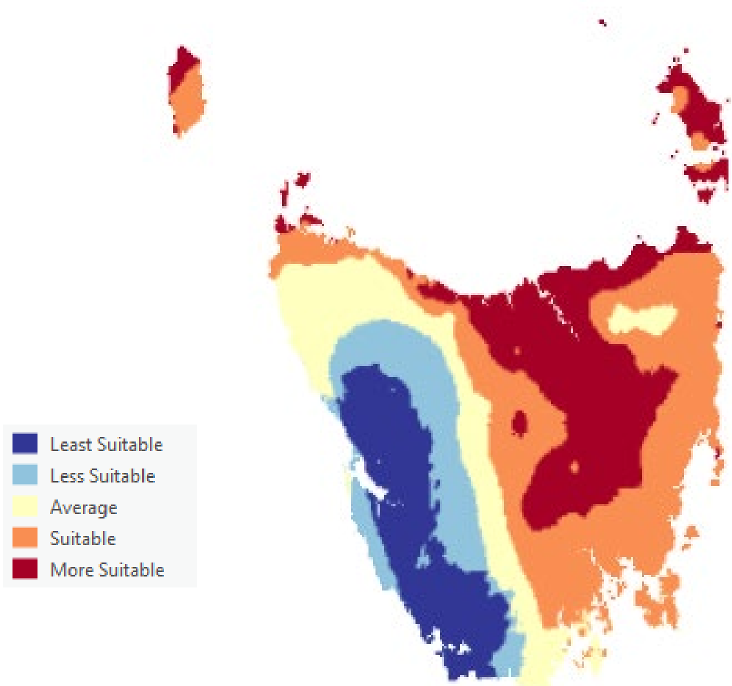


Figure 7. Final Suitability Map for Solar Farming

The Combine cell statistics of Solar Exposure and Rainfall produced the image above, which determines the area from least suitable to more suitable. The combined results have been inputted to add raster values of the classified cell statistics of Solar Exposure and Rainfall. The two areas are least and less suitable due to either Low Solar Exposure or a high chance of Rain. The areas that are Suitable and more suitable are due to the High-Medium chance of Solar and light-moderate drought. This means from Table 5. that 57% of Tasmania is Suitable for solar farming and 27% isn't, and 16% is average.

Table 5. Overview of Suitability Area coverage in percentage

	Count	%Suitable Area
Least Suitable	3445	**15%**
Less Suitable	2744	**12%**
Average	3804	**16%**
Suitable	7638	**33%**
More Suitable	5476	**24%**

Discussion & Recommendation

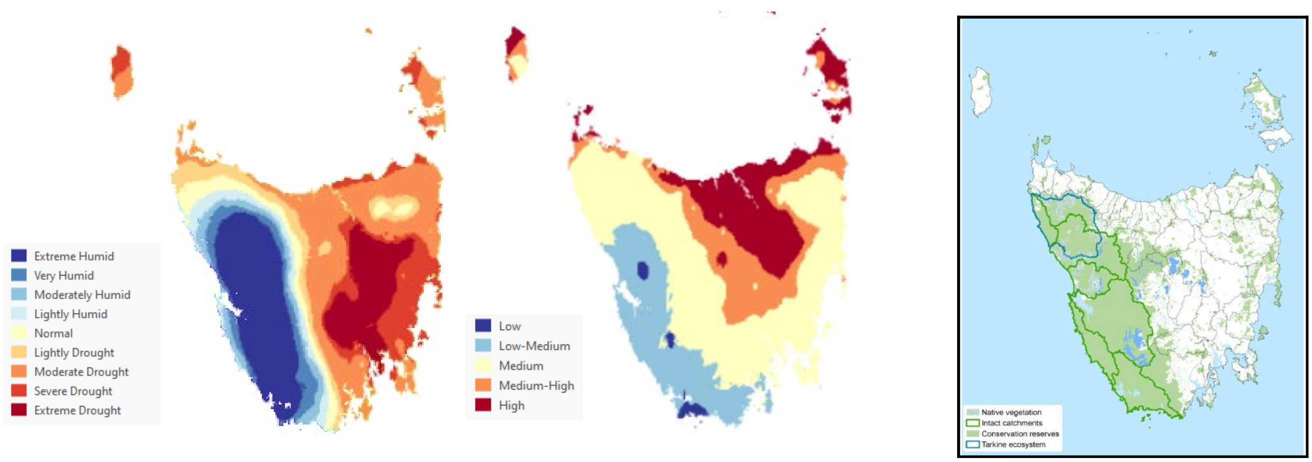


Figure 8. 12 Months Sum Cell Statistics of Rainfall (Left), 12 Months Sum Cell Statistics of Rainfall (Middle), Tracts of large, natural and near-natural terrestrial ecosystems contiguous or near-contiguous in western Tasmania (Right) (Williams, 2012).

Looking into more detail in the geographical area of Tasmania, the western area shows the Temperate Rainforest, implying that the west of Tasmania is least suitable for solar farming. This is because Rainforests frequently partially water themselves. Where transpiration is the process through which plants release water into the atmosphere. The humidity contributes to the heavy cloud cover covering most rainforests. These clouds maintain the rainforest's warmth and humidity even when it is not raining and therefore expect low Solar Exposure (*Rainforests, Explained | National Geographic*, n.d.). Based on the results, the affected area to the west shows Extreme Humidity in relation to Solar Exposure, making it Low in that area, which shows the correlation and the relationship between Solar Exposure and Rainfall, which will determine Solar farming suitability.

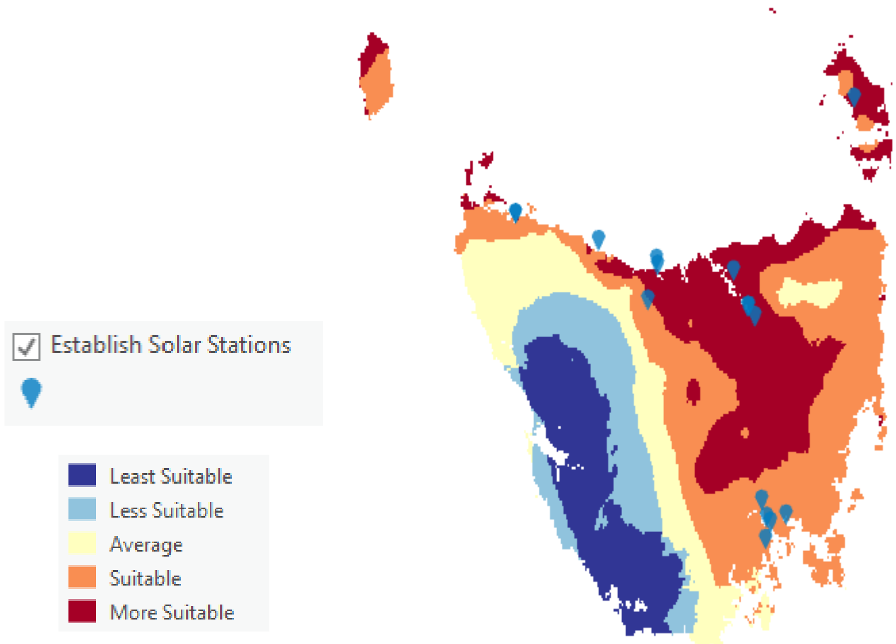


Figure 9. Final Suitability Map with Established Solar Farms

Note: The data in this list is sourced from the Clean Energy Regulator and is up to date as of March 31 2023. This is a list of PV systems with a capacity of more than 100 kilowatts, as recorded in the Clean Energy Regulator's Large Scale Renewable Energy Target (LRET) database. This includes a number of large rooftop and ground-mounted PV systems (hundreds of kW), as well as utility (MW) scale PV systems (Australian Photovoltaic Institute • Large-Scale PV Systems, n.d.).

The Tasmanian Government has created new policies and incentives to encourage investment in Renewable Energy. Figure 11 shows the already-established Solar Farms, where most are located on the north along the coast and a small cluster South. Tasmania is 57% suitable for Solar Farming from its solar Exposure, which makes it valid to support solar farming, even though Tasmania is known for its maritime climate (*Rainforests, Explained | National Geographic*, n.d.). This has been proven as the government has established to fund 2.5 million dollars for the Energy for the Farm Solar Project, which will build solar arrays at up to 13 irrigation pump station locations throughout the State, as the solar panels will improve these pumping stations' energy efficiency (*Energy on Farms Solar Project*, n.d.). The investment in solar infrastructure at these locations will help lower annual on-farm costs and provide irrigation systems with more affordable water on projects where solar arrays are built. The solar panels will reduce electricity consumption and provide extra Energy that will be put back into the grid. The Energy on Farms Solar Project will improve Tasmania's agricultural industry's reputation for sustainability (*Energy on Farms Solar Project*, n.d.).

Some recommendations to encourage the development of new policies for solar farms is to Introduce appealing feed-in tariffs or PPAs to incentivize solar farm development. This method guarantees a fixed price or premium rate for solar Energy generated, providing long-term revenue certainty for project developers—Foster community engagement and support for solar farms through education and awareness programs. Allocate funding for research and development initiatives related to solar Energy, including technological advancements, energy storage solutions, and grid integration. This will encourage collaboration between academia, industry, and government agencies to drive innovation and improve the efficiency of solar farm operations. To develop comprehensive solar farm policies, Foster partnerships between government agencies, energy companies, and other stakeholders. The collaboration can lead to shared expertise, resources, and the development of robust frameworks that support the growth of the solar energy sector. It's important specific policy recommendations may vary depending on the region and its unique circumstances. These suggestions provide a starting point for policymakers to consider when developing policies to incentivize solar farm development.

Reference

Are There Any Solar Farms In Australia? - Solar Flow. (2023, March 5). *Solar Flow - Specialist Rainwater and Solar Solutions Company in Melbourne Australia*. https://www.solarflow.com.au/are-there-any-solar-farms-in-australia/

Australian Photovoltaic Institute • Large-Scale PV Systems. (n.d.). Retrieved June 11 2023, from https://pv-map.apvi.org.au

Bagheri, F. (2016). Mapping Drought Hazard Using SPI index And GIS (A Case study: Fars province, Iran). *International Journal of Environment and Geoinformatics*, *3*, 22–28. https://doi.org/10.30897/ijegeo.304419

Climate Data Online—Map search. (n.d.). Retrieved June 11 2023, from http://www.bom.gov.au/climate/data/?fbclid=IwAR2x4GdH1klpY1w--8nduO8tb_7Ook1VadVw0yhpeI2xHOkOA5YbxKwebXA

Energy on Farms Solar Project. (n.d.). Tasmanian Irrigation. Retrieved June 11 2023, from https://www.tasmanianirrigation.com.au/energy-on-farms-solar-project

H. Zhang, B. He, Y. Guan, M. Ma, Y. Li, & S. Song. (2017). Assessing the potential for global solar energy utilization. *2017 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, 1618–1621. https://doi.org/10.1109/IGARSS.2017.8127283

Jamaly, M., & Kleissl, J. (2017). Spatiotemporal interpolation and forecast of irradiance data using Kriging. *Solar Energy*, *158*, 407–423. https://doi.org/10.1016/j.solener.2017.09.057

Kaiser, P., Unde, R. B., Kern, C., & Jess, A. (2013). Production of Liquid Hydrocarbons with CO2 as Carbon Source based on Reverse Water-Gas Shift and Fischer-Tropsch Synthesis. *Chemie Ingenieur Technik*, *85*(4), 489–499. https://doi.org/10.1002/cite.201200179

Parameter optimization—ArcGIS Pro | Documentation. (n.d.). Retrieved June 11 2023, from https://pro.arcgis.com/en/pro-app/latest/help/analysis/geostatistical-analyst/parameter-optimization.htm

Rainforests, explained | National Geographic. (n.d.). Retrieved June 11 2023, from https://www.nationalgeographic.co.uk/environment/2019/05/rainforests-explained

Tasmania. (n.d.). AEMC. Retrieved June 11 2023, from https://www.aemc.gov.au/energy-system/electricity/changing-generation-mix/tasmania

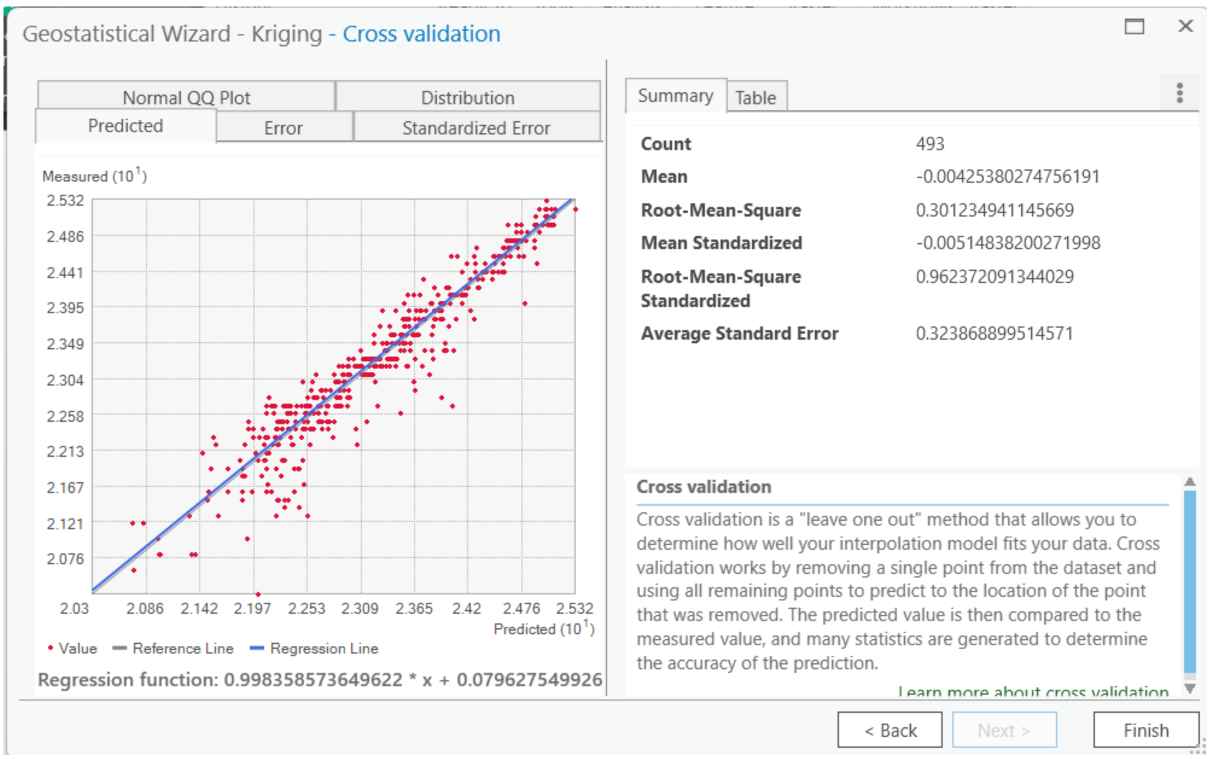
Uyan, M. (2013). GIS-based solar farms site selection using analytic hierarchy process (AHP) in Karapinar region, Konya/Turkey. *Renewable and Sustainable Energy Reviews*, *28*, 11–17. https://doi.org/10.1016/j.rser.2013.07.042

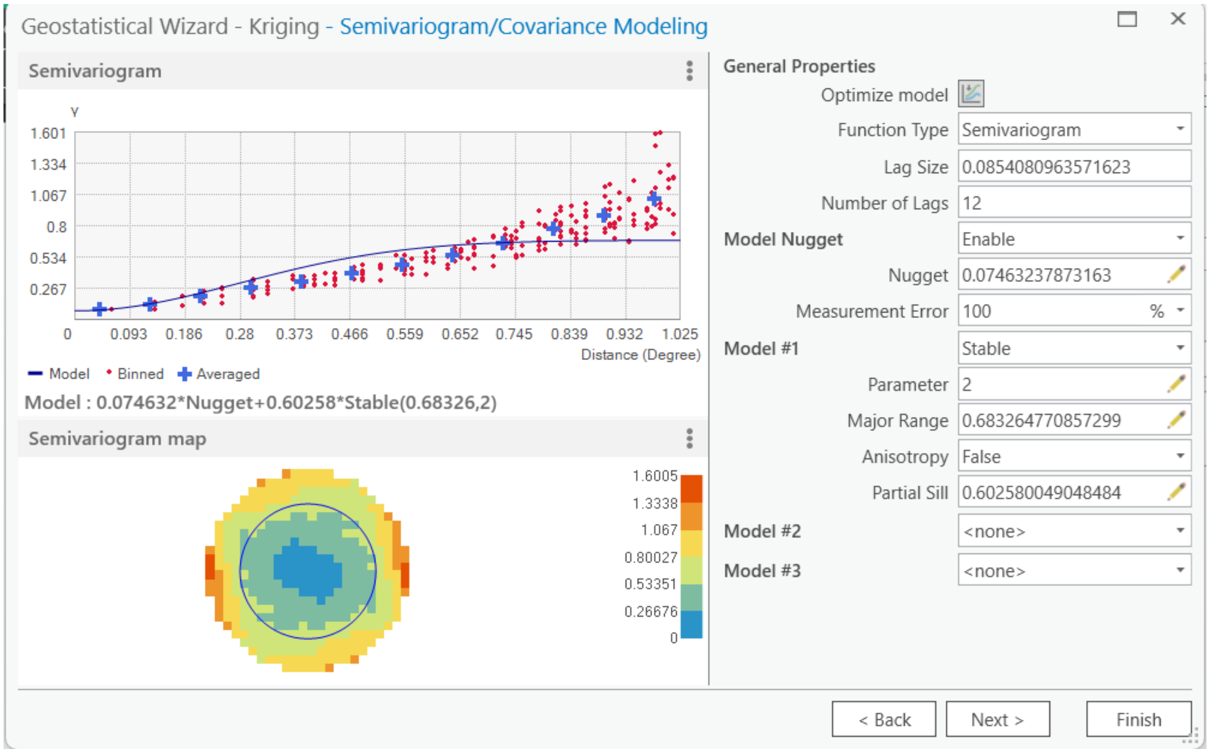
Williams, J. (2012). *The evolutionary significance of Tasmania's rainforests and associated vegetation types FINAL REPORT - IVG 5C*. https://doi.org/10.13140/RG.2.2.34327.80801

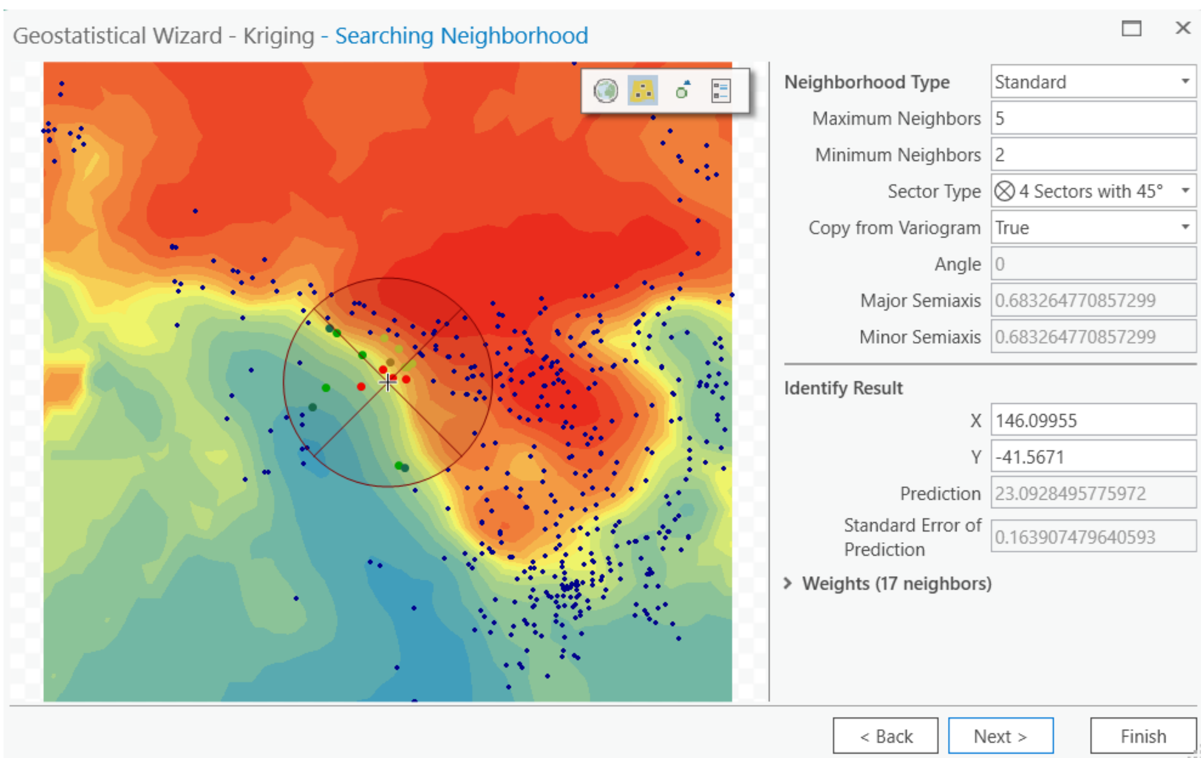
Appendix

Solar

Kriging Ordinary



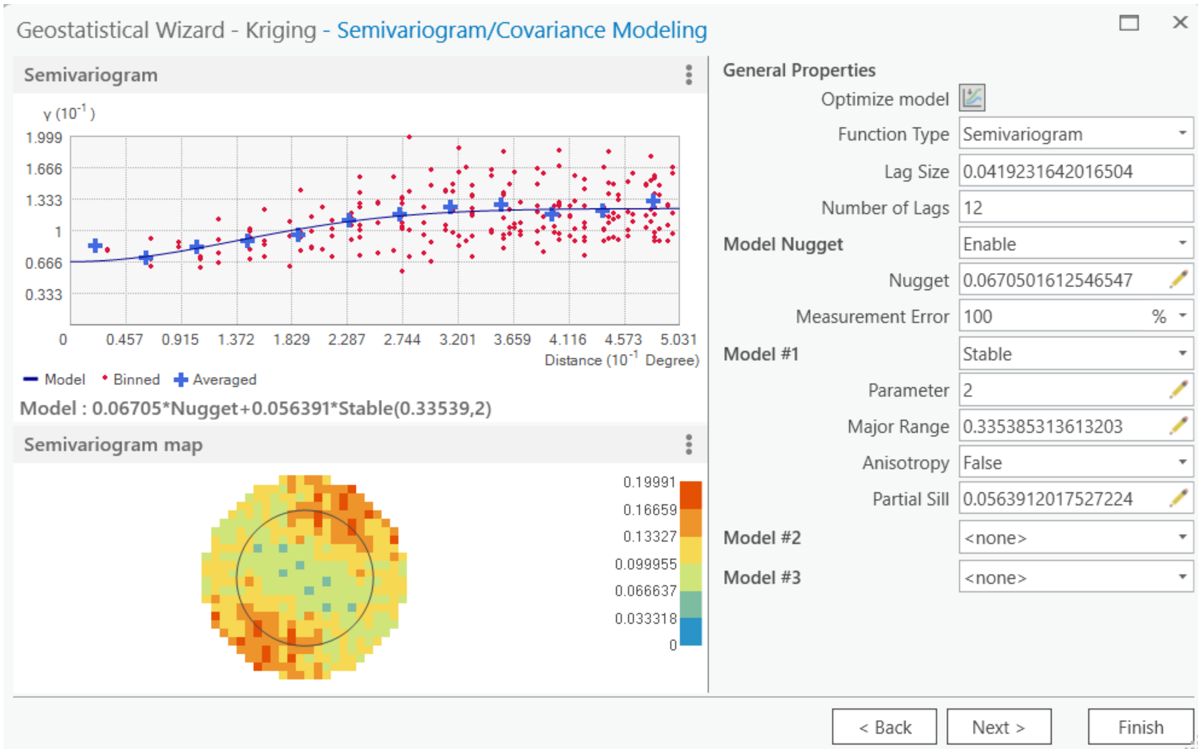


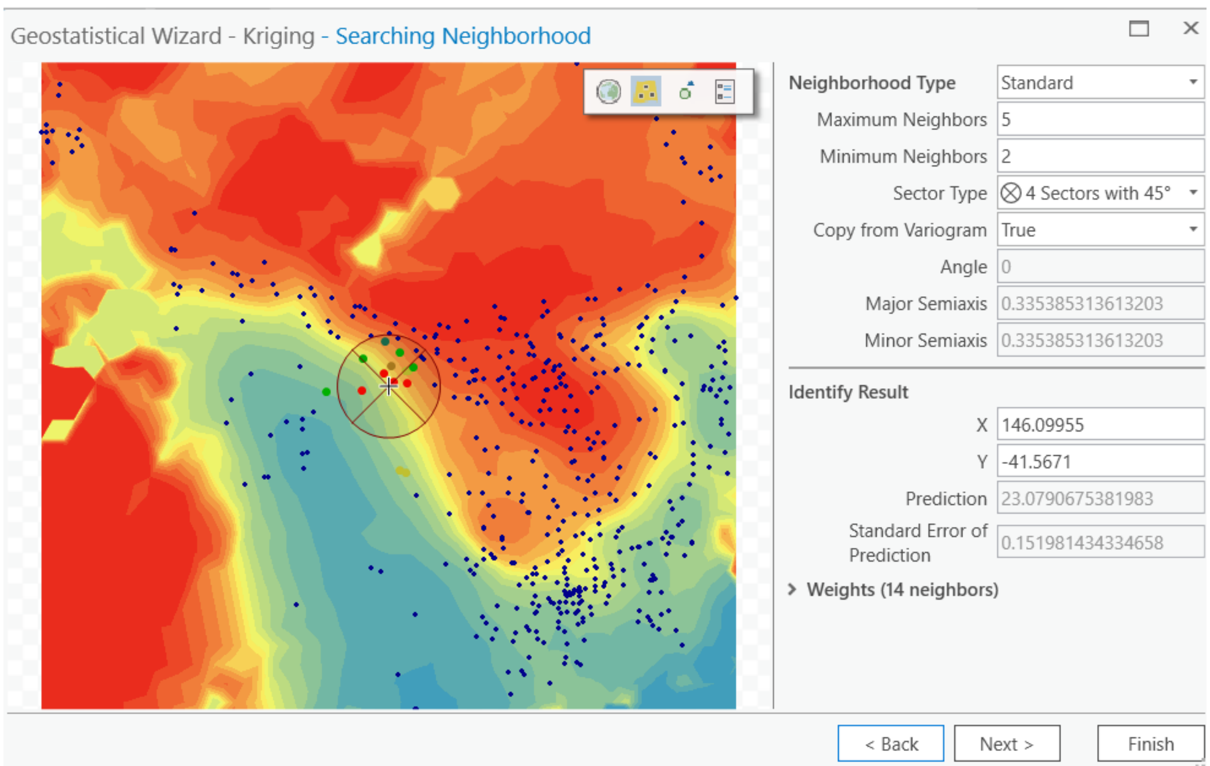


Kriging Universal

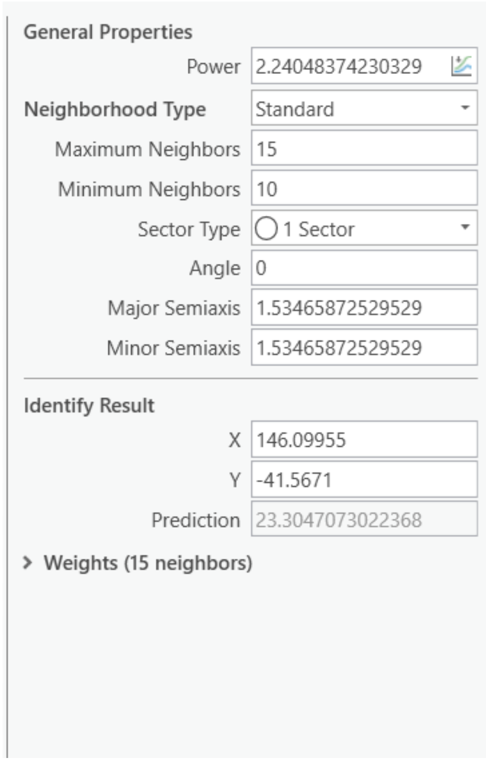
First Order

Optimized model


Geostatistical Wizard - Kriging - Semivariogram/Covariance Modeling
Semivariogram
Model : 0.06705*Nugget+0.056391*Stable(0.33539,2)
Semivariogram map
General Properties
Optimize model
Function Type Semivariogram
Lag Size 0.0419231642016504
Number of Lags 12
Model Nugget Enable
Nugget 0.0670501612546547
Measurement Error 100 %
Model #1 Stable
Parameter 2
Major Range 0.335385313613203
Anisotropy False
Partial Sill 0.0563912017527224
Model #2 <none>
Model #3 <none>
< Back
Next >
Finish

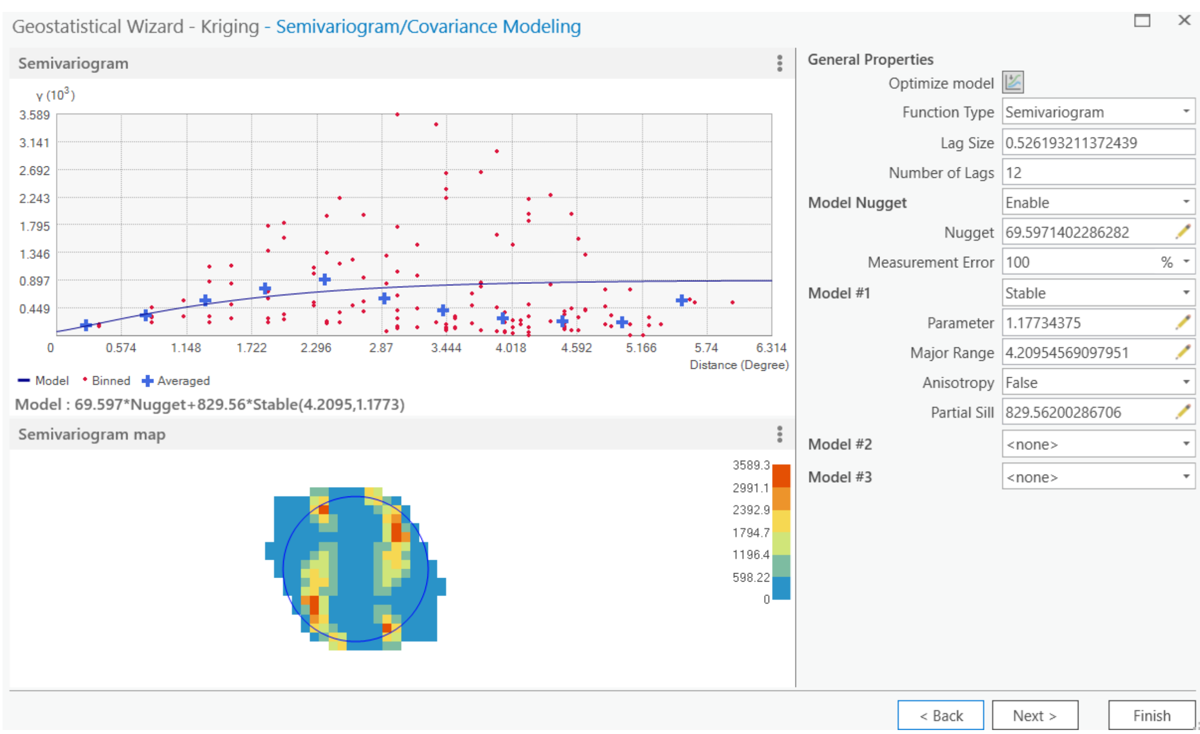

Geostatistical Wizard - Kriging - Searching Neighborhood
Neighborhood Type Standard
Maximum Neighbors 5
Minimum Neighbors 2
Sector Type 4 Sectors with 45°
Copy from Variogram True
Angle 0
Major Semiaxis 0.335385313613203
Minor Semiaxis 0.335385313613203
Identify Result
X 146.09955
Y -41.5671
Prediction 23.0790675381983
Standard Error of Prediction 0.151981434334658
Weights (14 neighbors)
< Back
Next >
Finish

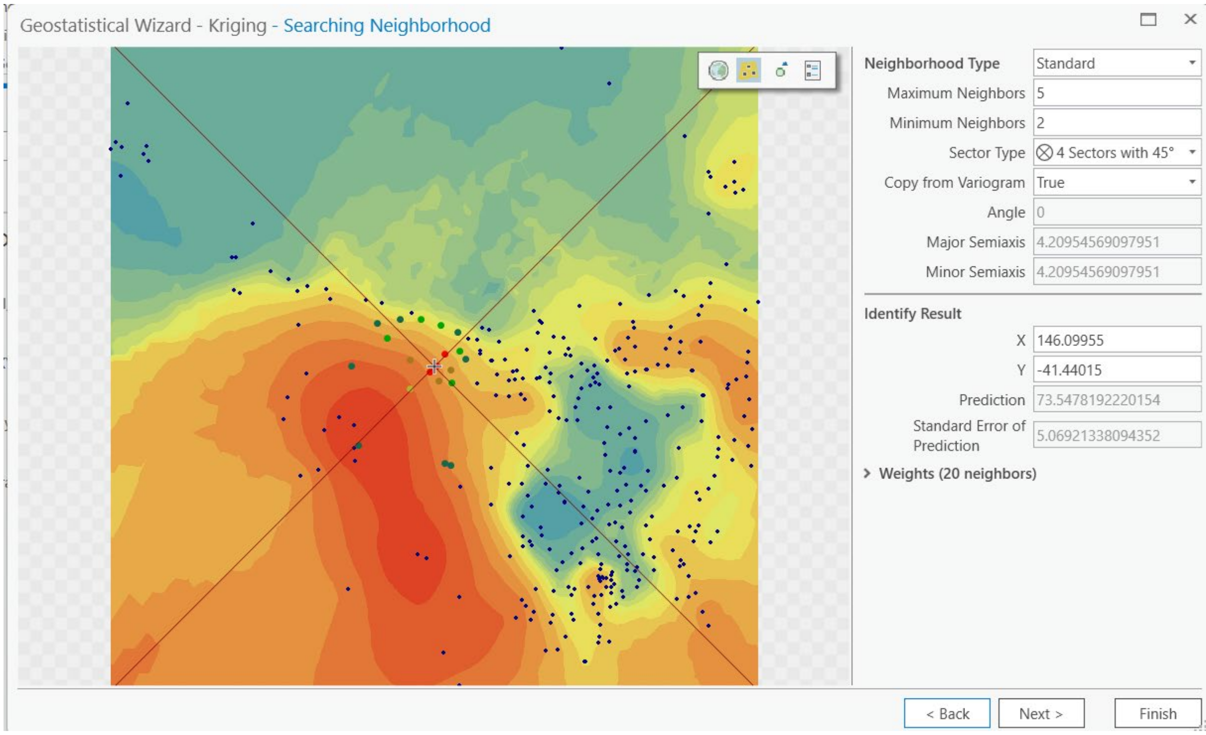
IDW



Rainfall

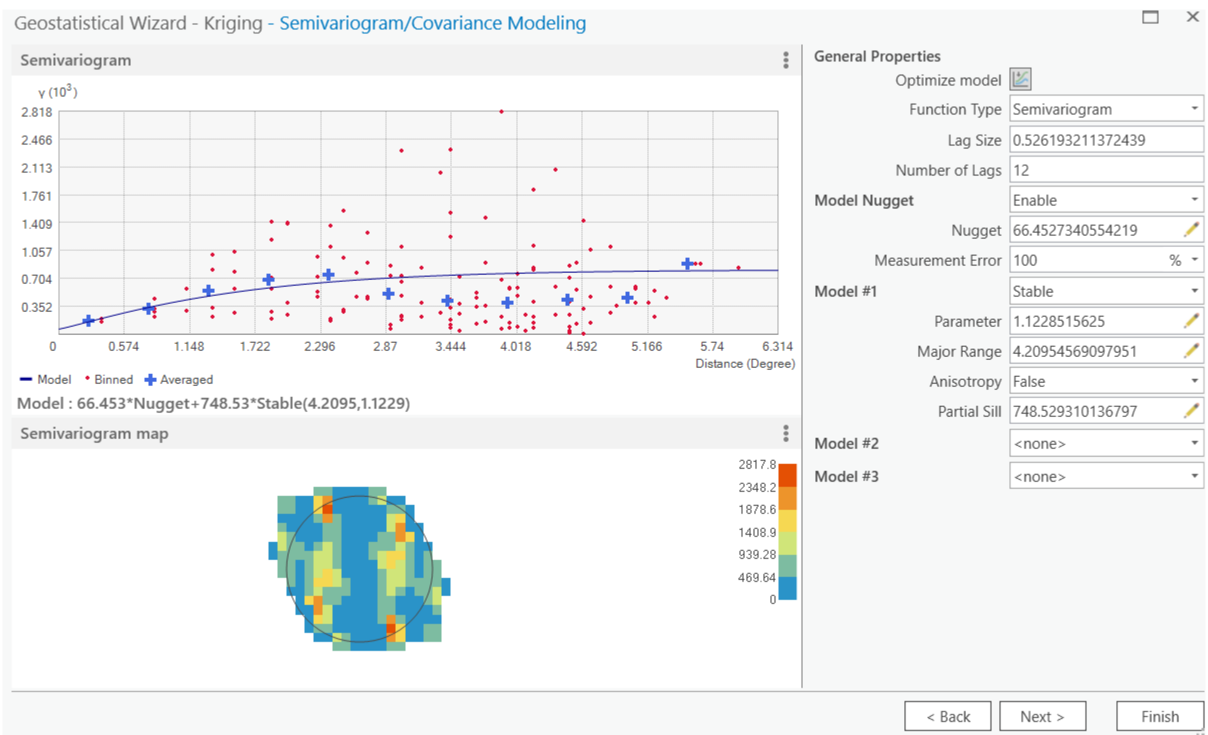
Kriging Ordinary (optimized)

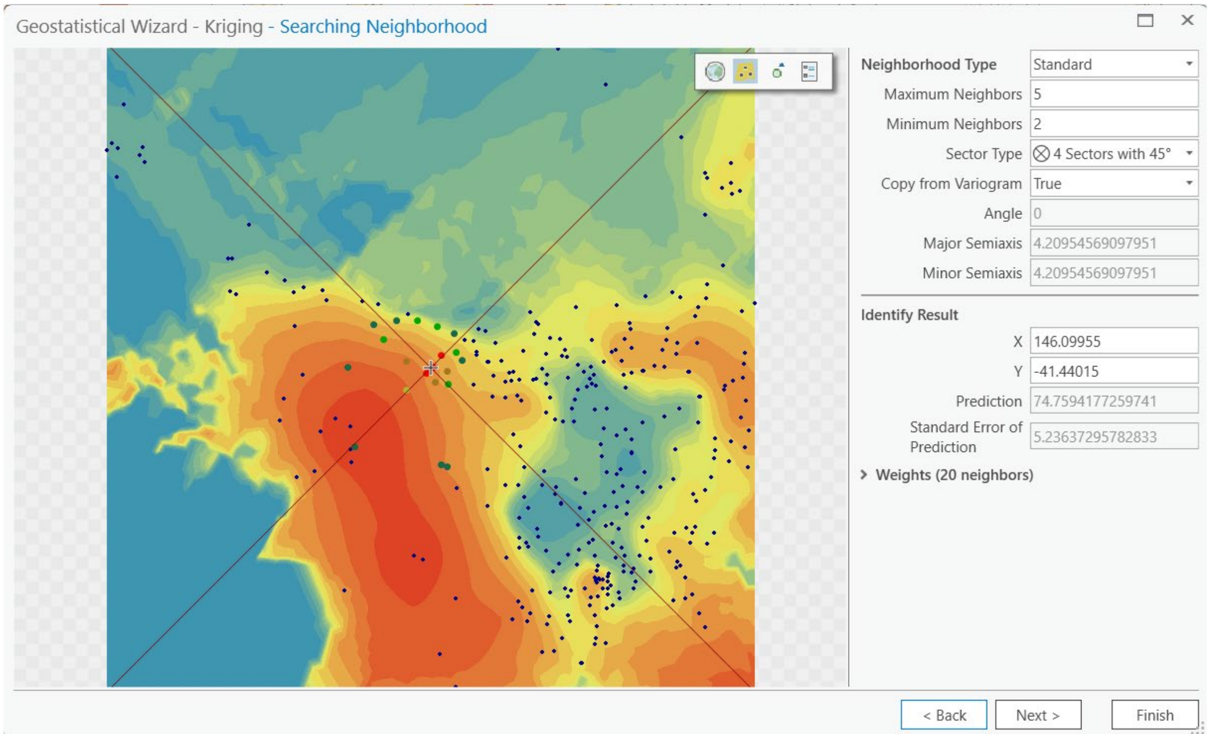




Kriging Universal (optimized)

First Order




Geostatistical Wizard - Kriging - Searching Neighborhood
Neighborhood Type
Standard
Maximum Neighbors
5
Minimum Neighbors
2
Sector Type
4 Sectors with 45°
Copy from Variogram
True
Angle
0
Major Semiaxis
4.20954569097951
Minor Semiaxis
4.20954569097951
Identify Result
X
146.09955
Y
-41.44015
Prediction
74.7594177259741
Standard Error of Prediction
5.23637295782833
Weights (20 neighbors)
< Back
Next >
Finish

Dataset:

Description	Dataset Name	Source Link	Format	Data Accessed	Intended Use
Tasmania LGAs	Tas_polygon	https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026/access-and-downloads/digital-boundary-files	Esri Shape File	03/04/2023	To set LGA boundaries within Tasmania
Tasmania Active Weather stations	Tas_weather_stations_active	https://data.gov.au/data/dataset/5aa692ee-513b-425c-8c9d-b2a858724c25?fbclid=IwAR0BfXoIX6dMtpGpnTVuJgUd60TS33nOWuuLMGsQ2C2pYfBiWQEFz4JCsqg	Esri Shape File	03/04/2023	To identify active weather stations in Tasmania
Solar Exposure data	SolarExpo_data_XY	http://www.bom.gov.au/climate/data/?fbclid=IwAR2x4GdH1klpY1w--8nduO8tb_7Ook1VadVw0yhpeI2xHOkOA5YbxKwebXA	Excel Sheet	03/04/2023	To find the spatial pattern of solar Exposure monthly and annually
Rainfall data	Rainfall_data_XY	http://www.bom.gov.au/climate/data/?fbclid=IwAR2x4GdH1klpY1w--8nduO8tb_7Ook1VadVw0yhpeI2xHOkOA5YbxKwebXA	Excel Sheet	05/04/2023	To find the spatial pattern of Rainfall monthly and annually
Solar_stations	Established Solar Stations	https://pv-map.apvi.org.au/power-stations	Excel Sheet	10/06/2023	To locate existing solar farms

Gantt C

	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Project Journal											
Obtaining Data											
Spatial Correlation Analysis											
Spatial Interpolation of Solar Radiation											
Spatial Interpolation of Rainfall											
Graphs Table and map production											
Develop Presentation											
Present Project											
Develop Report											
Project Submission											