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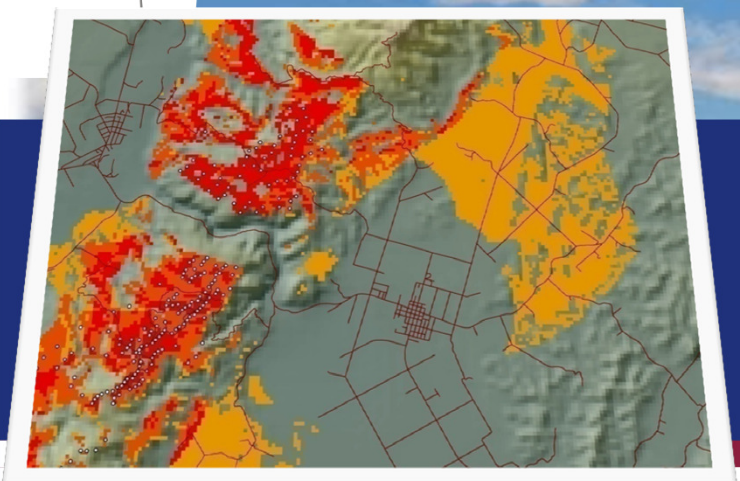

Predicting the wind:

Wind farm prospecting using GIS

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Background

- With global energy trends moving towards sustainable solutions, energy explorers are continuously seeking new ways to effectively search for potential wind farm sites.
- In the past three years, Kenex and Aurecon have developed advanced spatial modelling techniques that combine:
  - Mesoscale modelling of the wind resource to assess the potential of an area
  - Advanced terrain analysis, land use and social acceptability parameters to define the extent of possible wind farms at regional and country-wide scales.
  - Grid connection variables to select sites with the best available connections to the grid, and subsequently more preferable project economics.
- Our modelling has been successfully used by Genesis NZ to evaluate new sites for wind farm development and determine possible turbine sites at current projects.

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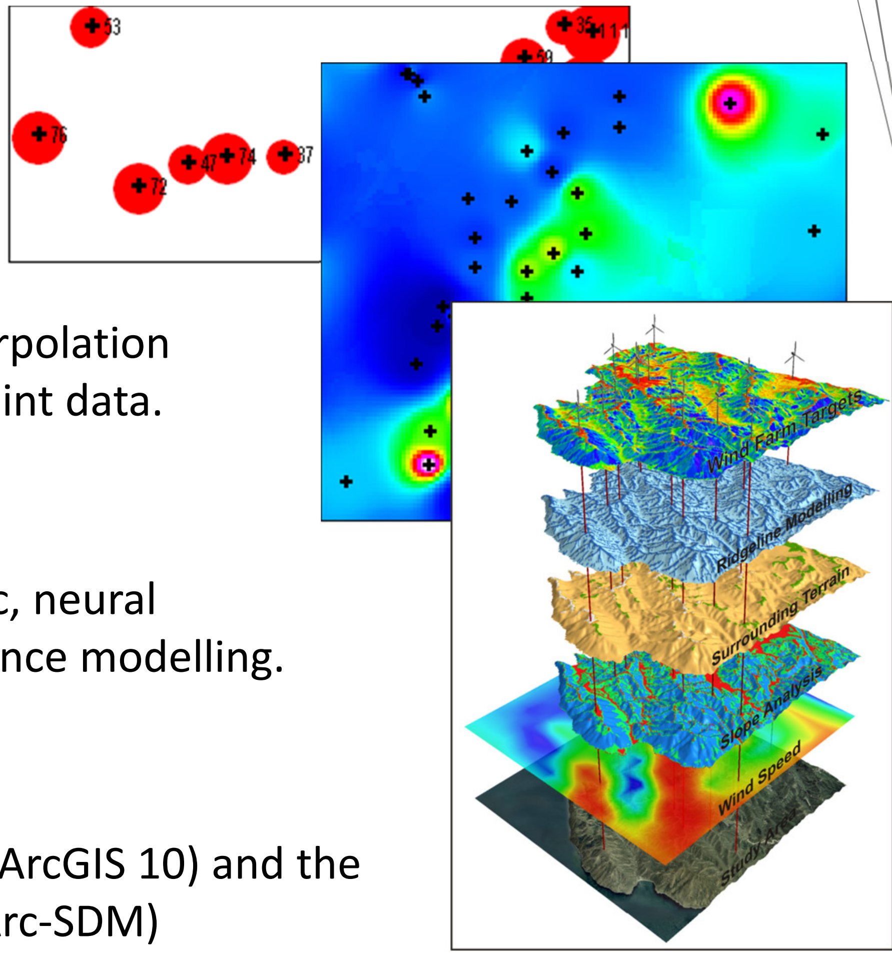
Spatial modelling with ArcGIS and Arc-SDM

Type of Spatial modelling:

Illustrated maps that highlight important features or values.



Basic single layer modelling using interpolation to estimate values between known point data.

Multi-variable models: Fuzzy logic, neural networking, and weights of evidence modelling.

Tools used: Spatial Analyst Fuzzy Overlay (ArcGIS 10) and the Spatial Data Modeller toolbar (Arc-SDM)

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Modelling Successes

- Mineral Exploration
  - Canadian Geological Survey
  - New Zealand Ministry of Economic Development
  - Numerous private companies in New Zealand, Australia, Asia, Africa, the Middle East, Europe and the Pacific.

- Agricultural and Environmental
  - New Zealand wide & Hawke's Bay region grape growth potential
  - Rare *Powelliphanta* land snail habitats (New Zealand)
  - South Island Alpine Gecko habitat modelling for New Zealand Department of Conservation

- Energy
  - Geothermal modelling in the Northern Territory of Australia
  - **Wind Energy Potential in New Zealand, Australia and Argentina.**

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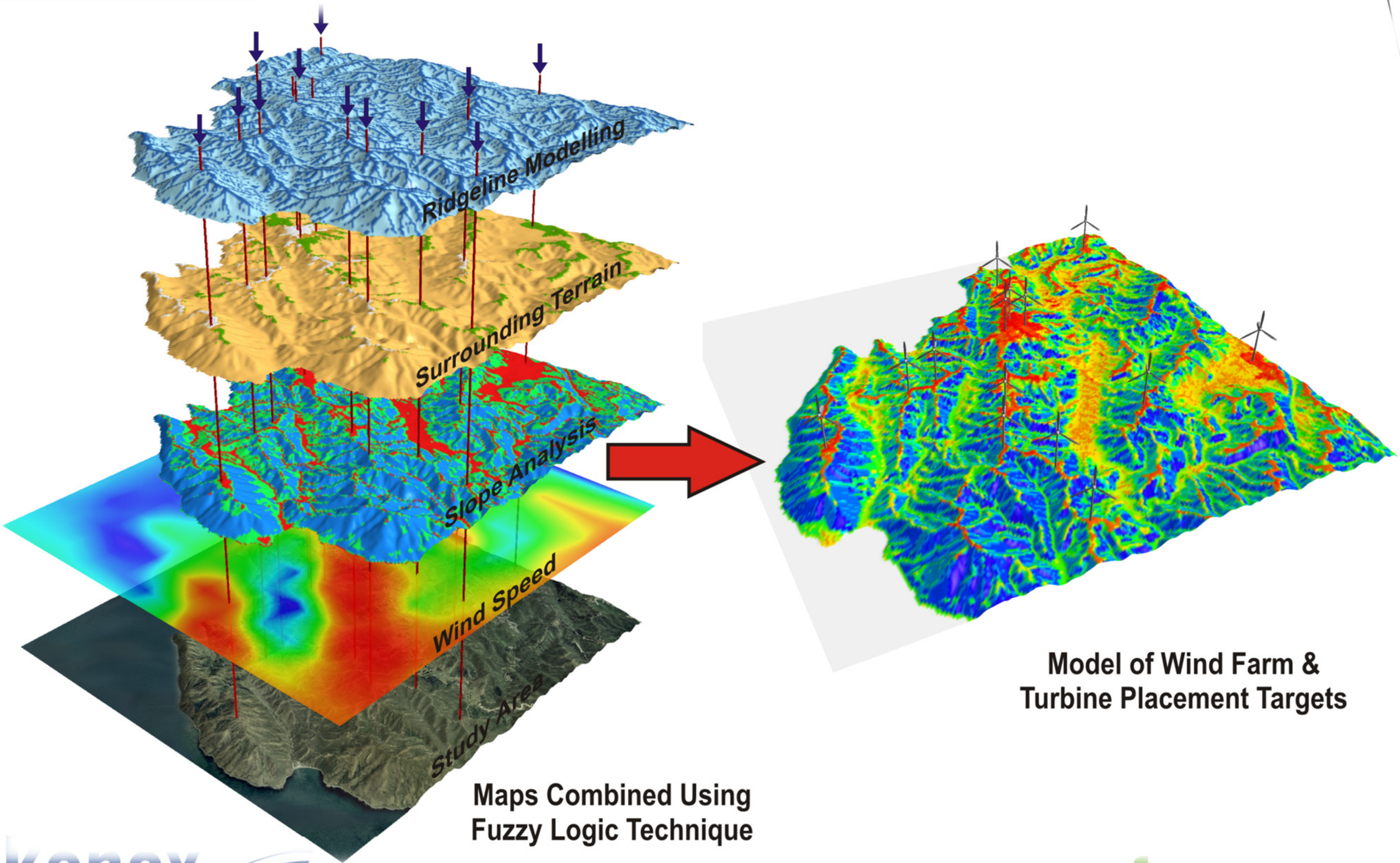
Fuzzy Logic approach to Wind farm prospecting

- The Fuzzy Logic model is knowledge-driven: it utilises expert inputs from wind turbine engineers and relevant spatial data to investigate unexplored areas
- We take this information and create a series of binary or multiclass predictive maps in a GIS that represent the suitability of each theme identified
- These maps are weighted based on their relative importance and statistically combined to create a predictive model of suitable wind farm sites
- Transparent modelling process – at any stage you can see what is going into the model and how the inputs are affecting the final result
- Being the method data-based, we can prospect over large areas (country's/states) to give a comprehensive understanding of the wind farm potential
- We then focus in on smaller regional areas to do more detailed modelling that will help to define the extent of the wind farm and turbine layout
- This process will save time and money often spent investigating unsuitable sites

Fuzzy Logic approach to Wind farm prospecting



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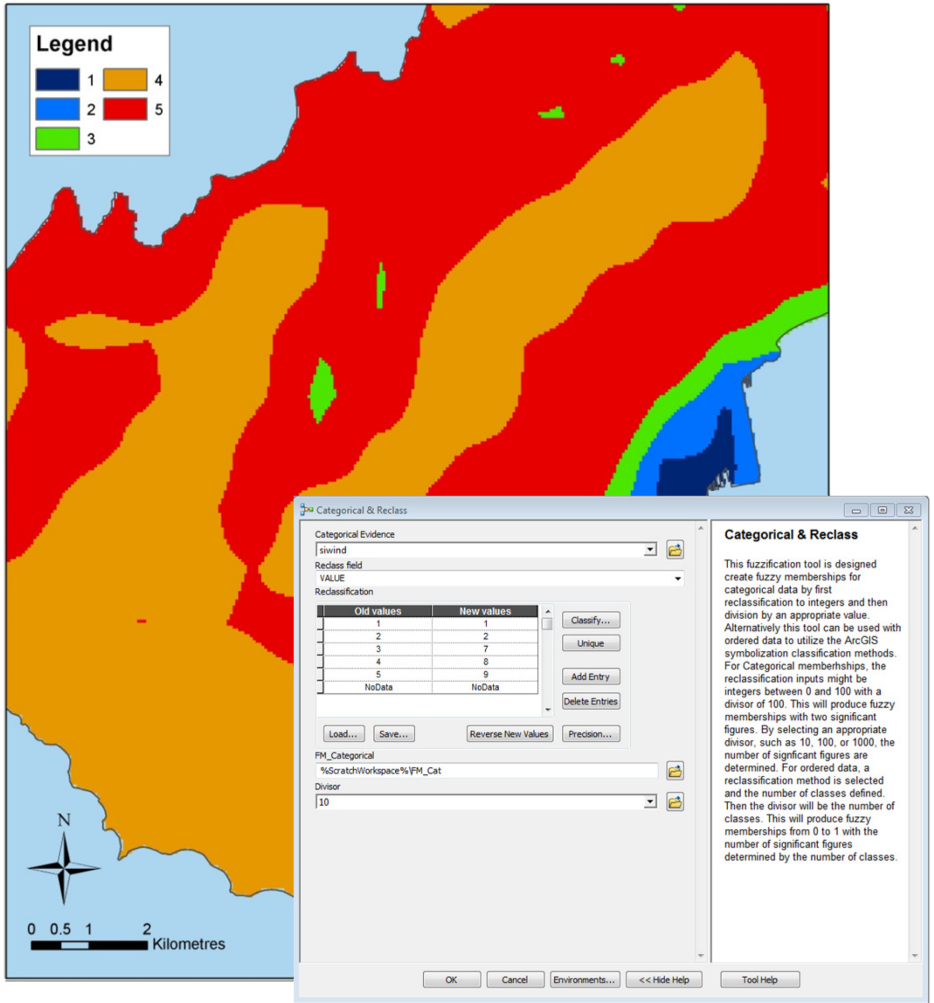
Data Analysis Example: Wind Speed



- Creating predictive maps from wind speed dataset created by Aurecon Mesoscale modelling
- Reclassifying the raster based on its wind speed values
- Assigning weights to the predictive map classes (SDM Categorical & Reclass tool)

Class	Description
1	Not Windy
2	Slightly Windy
3	Moderately Windy
4	Extremely Windy
5	Very Windy

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Wind and Terrain parameters

- Key parameters for energy capture and turbine loads:
  - Wind speed distribution
  - Turbulence
  - Inflow angle
- Wind resource can be assessed with mesoscale modelling
- Turbulence and inflow angle influenced by local and surrounding terrain:
  - Slope near turbine:
    - Influences inflow angle
    - Extreme slope can cause flow separation
    - Construction difficulties
  - Complexity of surrounding terrain:
    - Influences inflow angle
    - Infulences turbulence
  - Terrain effects:
    - Ambient turbulence from upwind terrain features
    - No higher ground in main wind direction and no more than 1/10 height to distance ratio
  - Alignment:
    - Slope at turbine location facing main wind direction
    - Local terrain perpendicular to main wind direction

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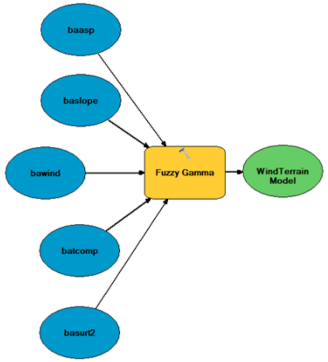
Terrain Layers

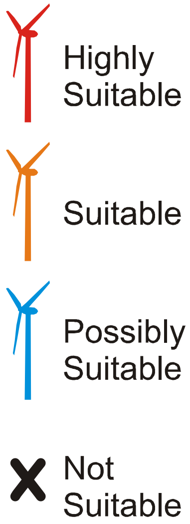
- Slope at site of turbine
- Maximum rate of change from one cell to the next

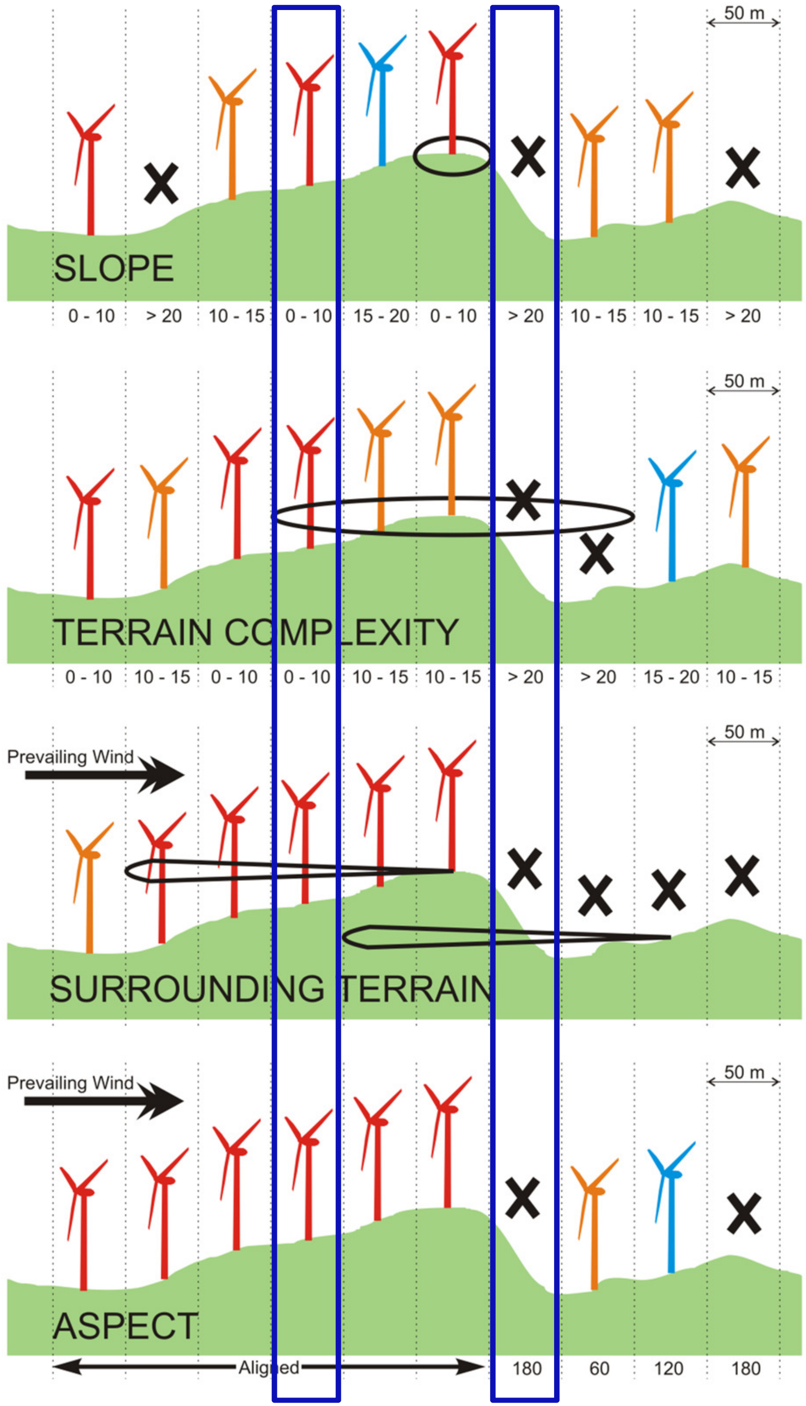
- Average of slope over a wider area
- Defines areas of smooth and rough terrain

- Elevation of terrain in the main wind direction
- Identifies sites with no obstructive upwind topographic features

- Alignment of site with the main wind direction







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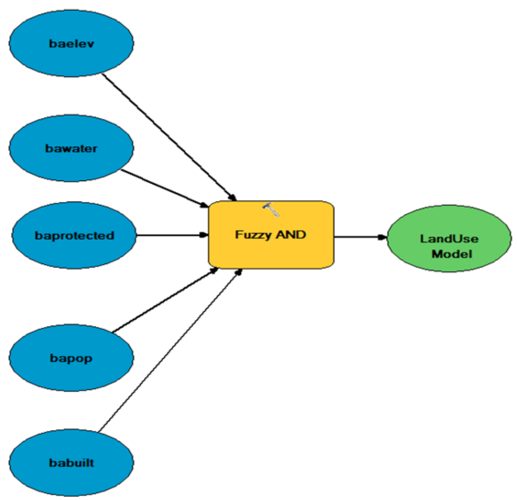
Social Acceptability Parameters

- Other non-technical parameters related to infrastructure, social, land use and environment need to be considered for showing currently suitable areas for wind farm development.

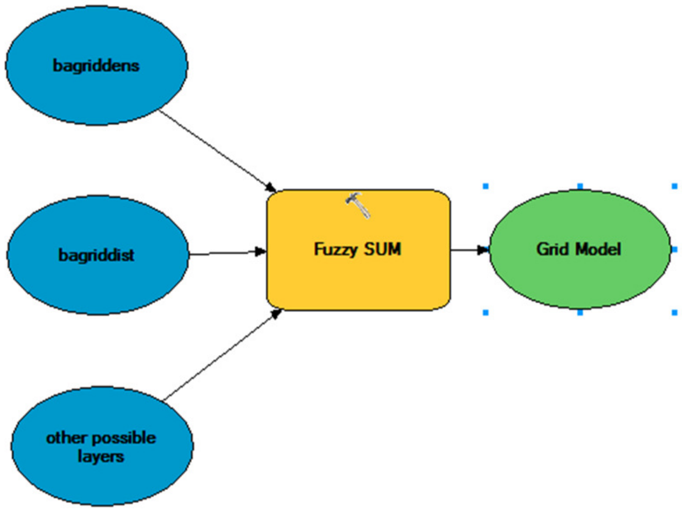
- The layers analysed depend on the data availability, model scale and the area studied. Some of the themes used in our models are:
  - Land use and protected areas
  - Distance from built-up areas
  - Population density
  - Distance from waterways
  - Elevation
  - Proximity to roads



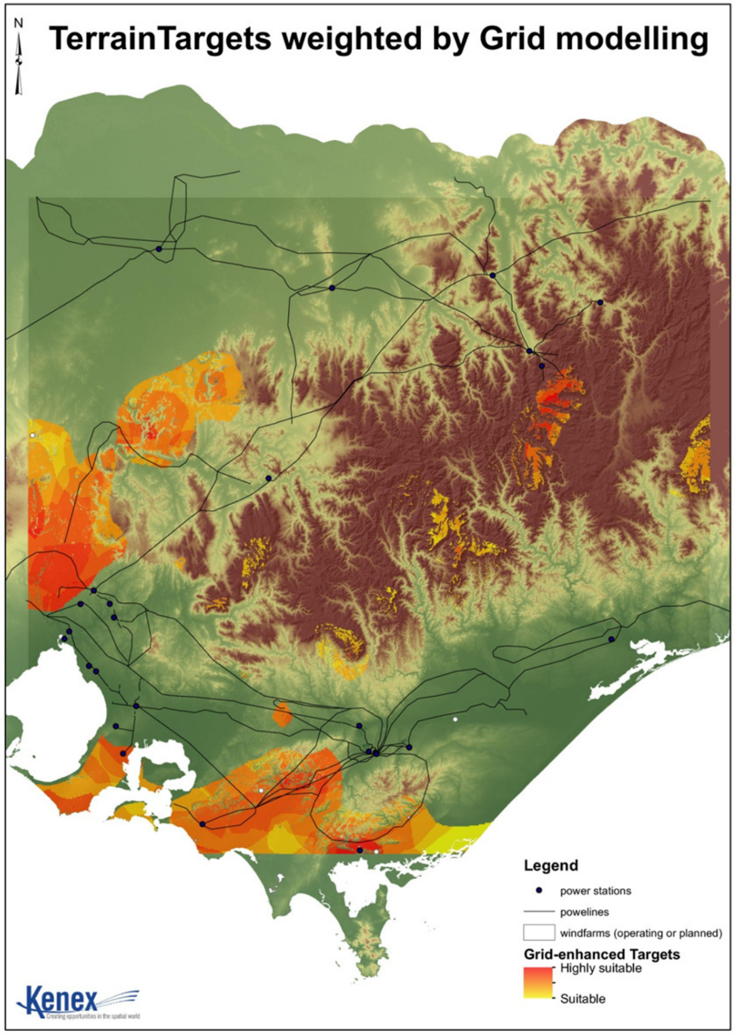
Transmission grid modelling

- Accessing a suitable transmission grid is becoming a key factor in wind farm development, especially in areas where the topography is not a constraint
- Availability of data can strongly influence the model:
  - Obtain, create and verify power line and terminal stations datasets
  - Find information and attributes (i.e. voltage, capacity, marginal loss factor etc…)
  - Create predictive layers based on the information gained
- Basic layers used are:
  - Distance from lines and terminal stations
  - Density of lines and terminal stations
- We can add other layers to the model depending on the information obtained for the area.
- The layers are weighted and combined with the Fuzzy operator SUM

Transmission grid modelling



- The aim of this preliminary grid model is to rank existing wind and terrain targets in order of probability of gaining a good connection to the grid.



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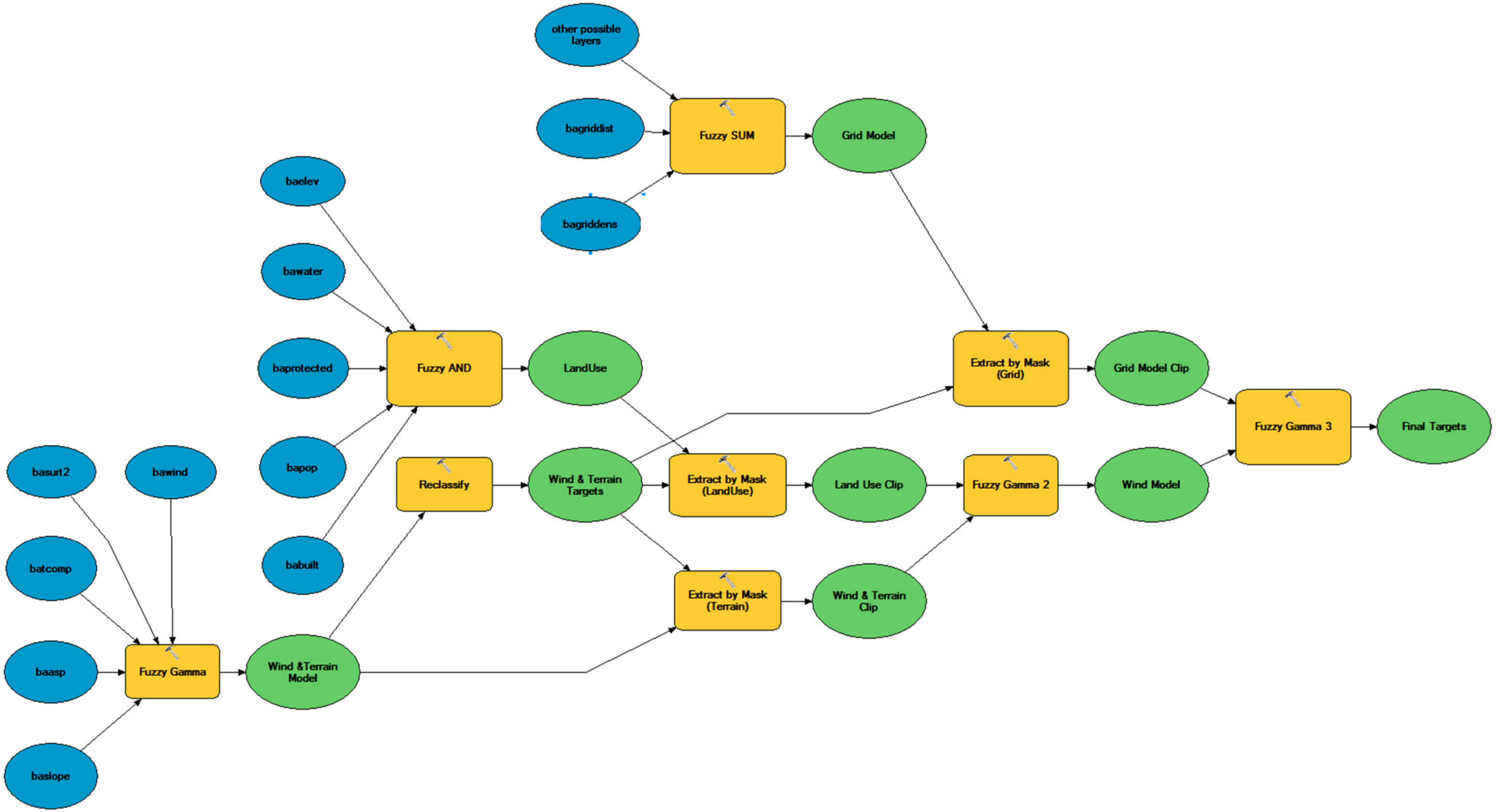
Wind Prospecting model scheme



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Target Generation and Ranking

- The model results can be reclassified to produce specific target areas that are ideal for the development of a wind farm.
- Using the modelling statistics the targets can be ranked in order of suitability for wind farm development.
- This allows for the development of a pipeline of projects where the highest ranked targets are worked on first because they have the best chance of success based on the parameters used for the modelling.

Target Name	NZ Ranking	Wind Class	Post Probability
Kini Creek	1	1	0.9987
Manuherikia River	2	1	0.9875
Mount Haszard	3	1	0.9865
Simpson Creek	4	1	0.9712
Cave Hill	5	1	0.9701
Logans Mistake	6	1	0.9525
Collins Creek	7	1	0.9417
Poplars Fan Stream	8	1	0.9408
Camden	9	1	0.9289
Grandview Mountain	10	1	0.9114
Malrick	11	1	0.8852

An Example from New Zealand

Model Stage 1

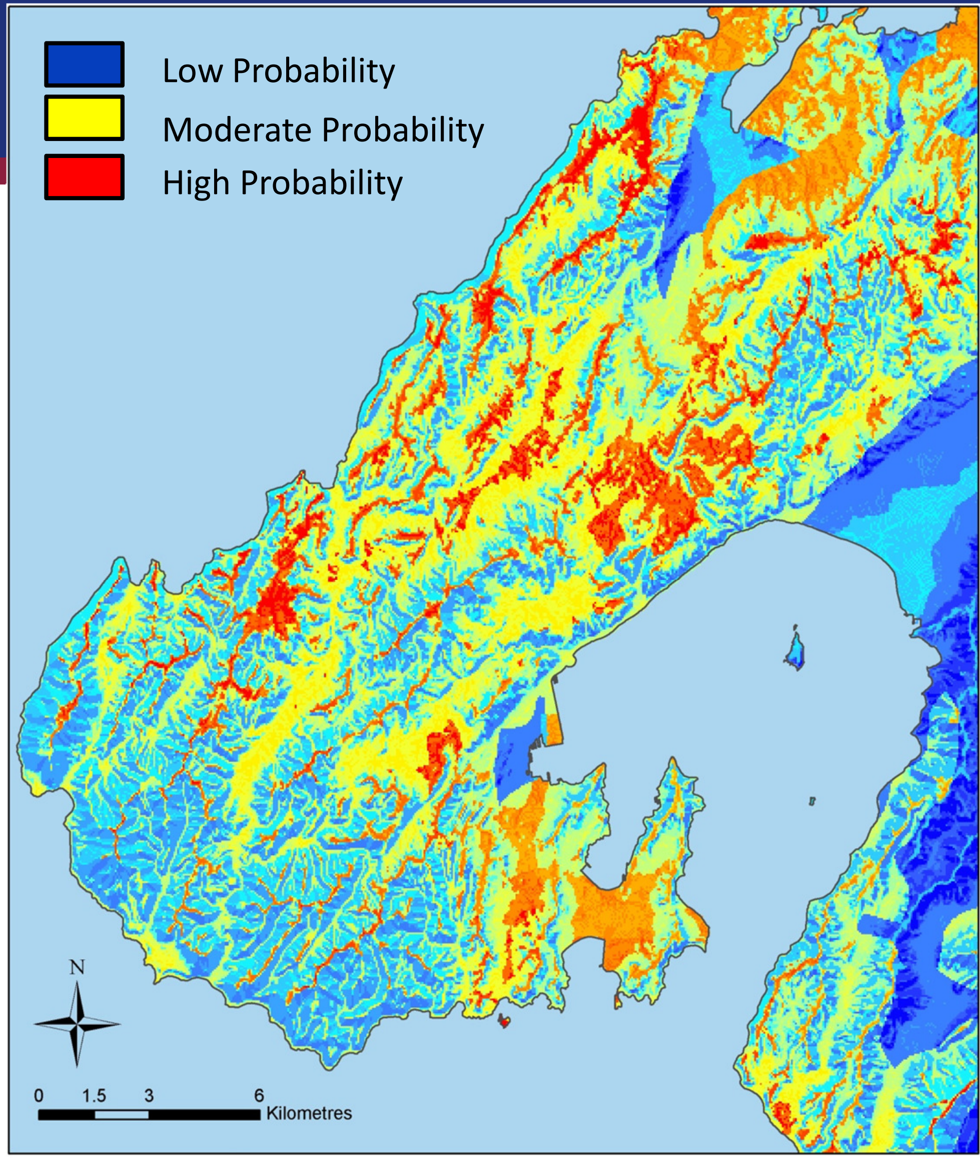
- Model in 2 phases
  - Stage 1a - Wind speed with simple country wide terrain analysis to show areas that are technically feasible for wind farm development
  - Stage 1b - Include environmental, social, land use and infrastructure layers to show areas that are currently suitable for wind farm development
- Produce a list of ranked targets based on modelling statistics

Model Stage 2

- Advanced prospect scale modelling can be completed over targets identified by the New Zealand scale models
- Detailed wind speed and terrain layers (1km wind speed resolution, 50m terrain resolution, ridgelines etc.)

Stage 2 Results – Wellington Class 1

Model Output



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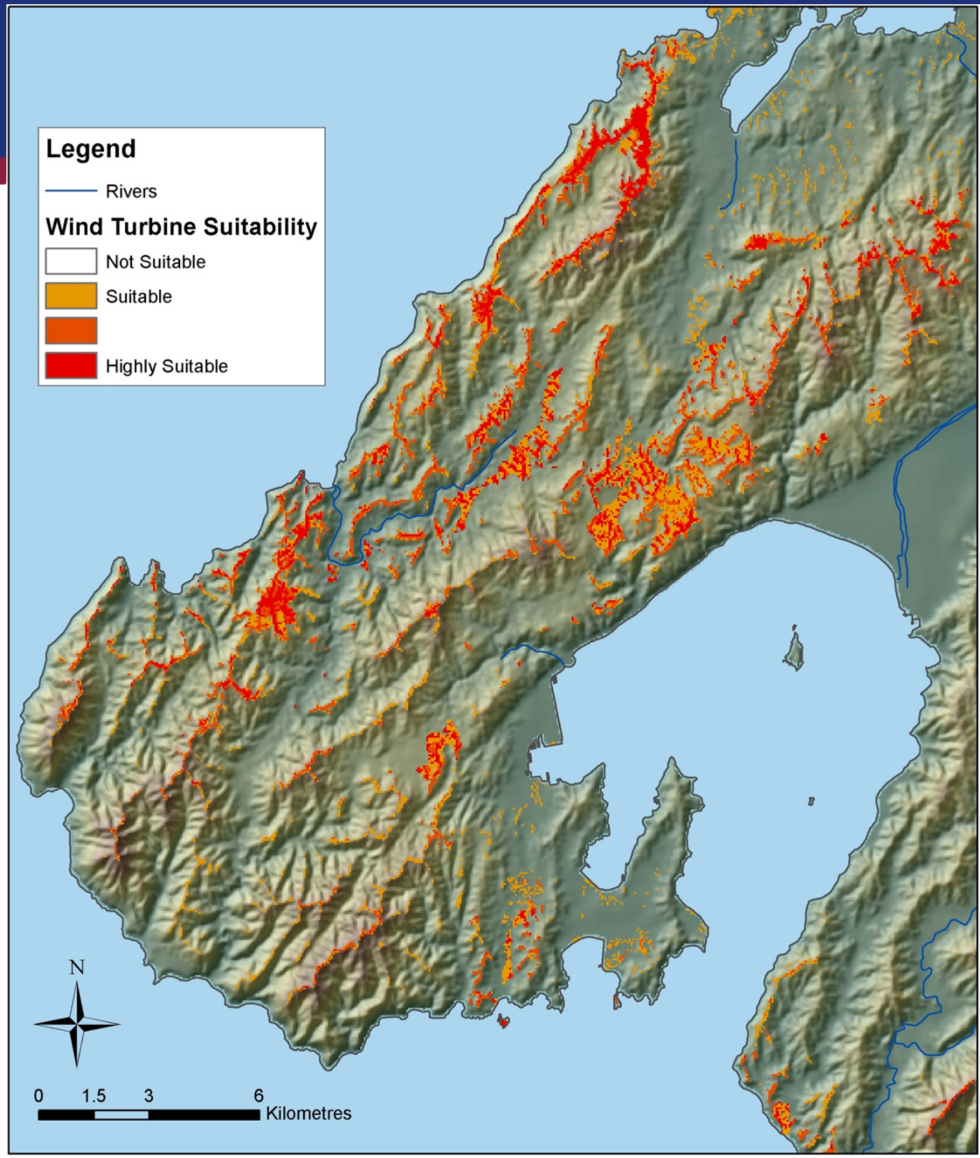
Stage 2 Results – Wellington Class 1

Model Target Areas
- Wind speed and terrain parameters



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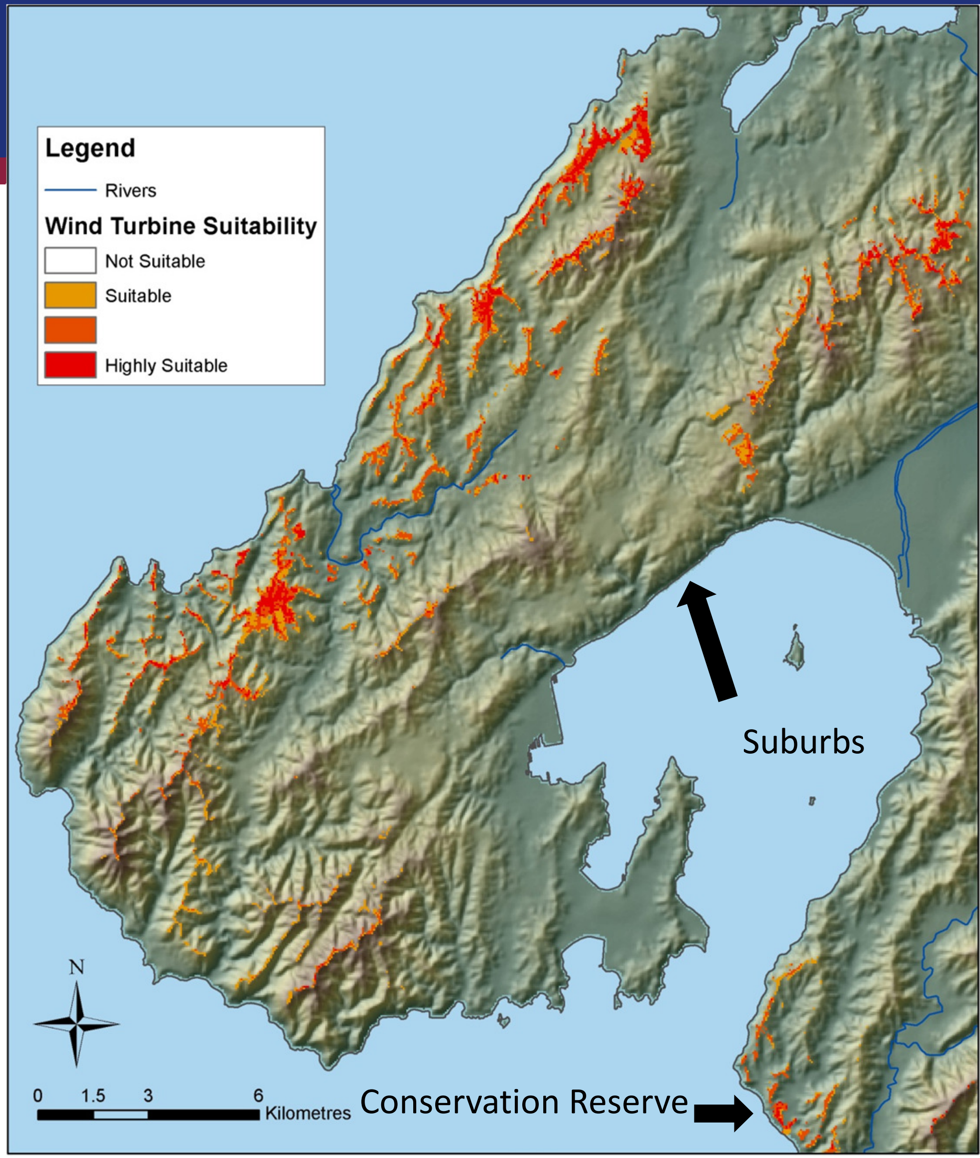
Stage 2 Results – Wellington Class 1

Remodel to exclude built-up areas and unsuitable land use (e.g. ecological areas)



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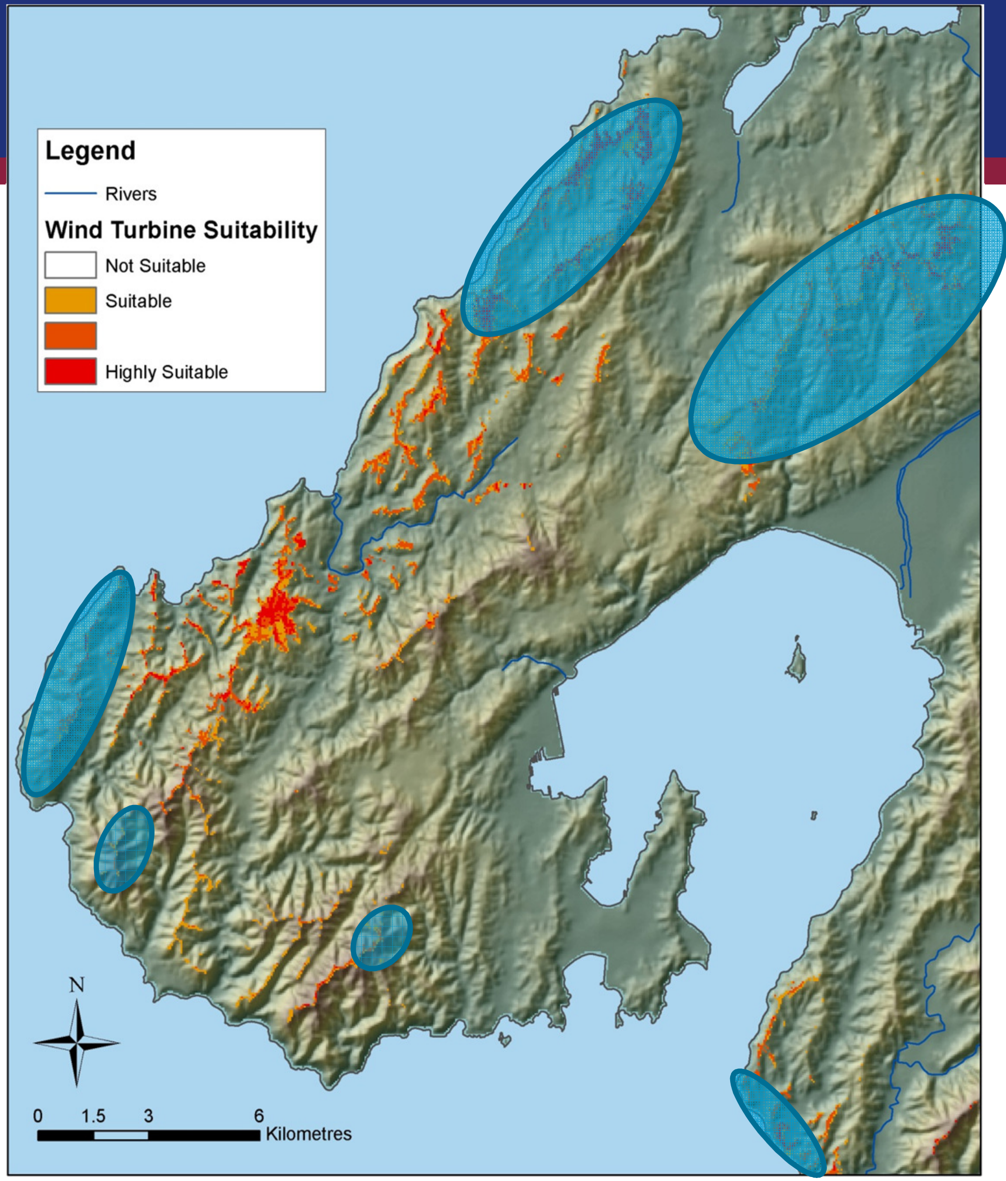
Stage 2 Results – Wellington Class 1



Identification of unsuitable areas not excluded by the model

- Alternative land uses
- Weather radar stations
- Environmental or archaeological concerns
- Consent issues

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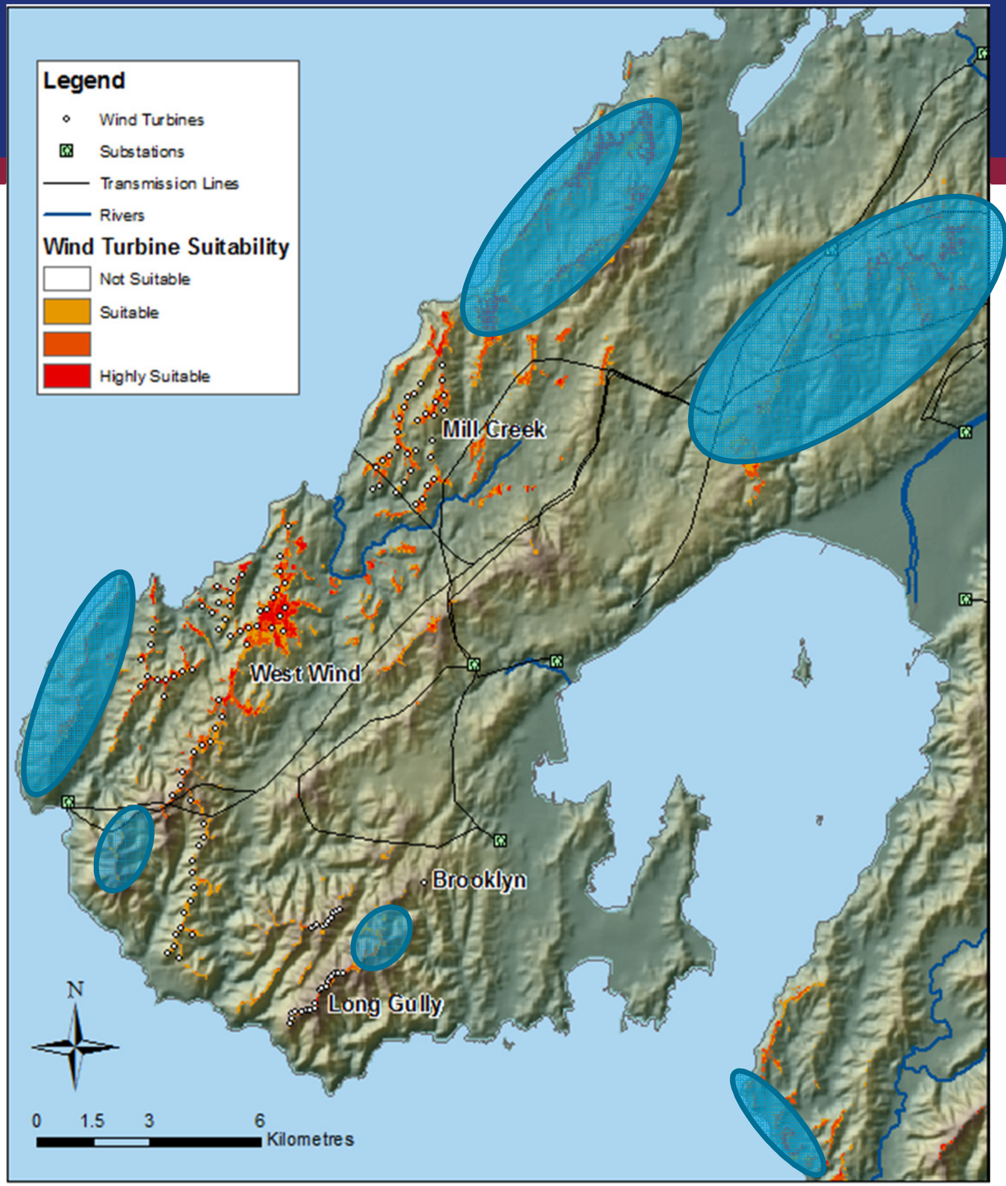
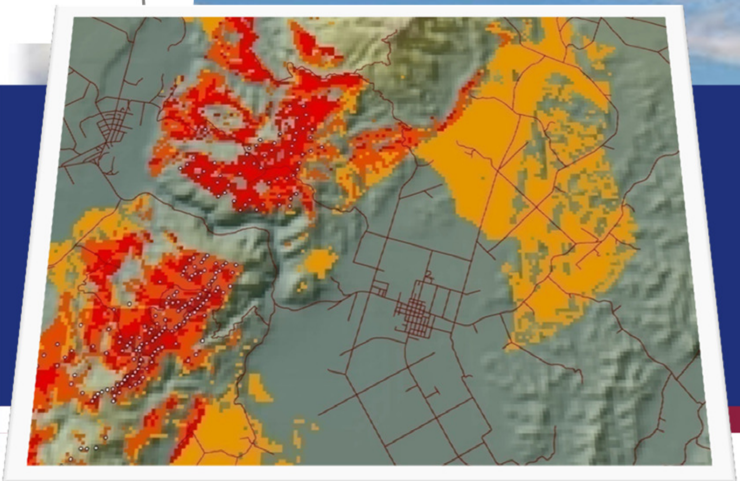
Stage 2 Results – Wellington Class 1



Model validated by existing and planned turbine locations

Benefits of Spatial Data Modelling

- Can quickly and cost effectively define the potential extent of an individual wind farm
- Allows for easy approximation of the number of turbines that the wind farm can hold
- Can easily identify the land owners that need to be approached
- Can potentially be a guide for turbine and monitoring mast placement
- The modelling technique is a tool that can manage and make sense of overwhelming amounts of spatial data during the development of a wind farm



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