CONSULTANCY REPORT

Term 2 2021

GEOS9016

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Executive Summary

For the expansion of its facilities at Smith's Lake Field Station, The University of New South Wales engaged with Kookaburra Pt. Ltd. for identifying the location for expansion. Following an extensive study conducted by the company for analysing the site in respects to fire hazards, construction costs, impacts on conservation, study of the soil erosion in the area, etc. For the purpose of study, the company developed four comprehensive models such as the Soil Erosion Model, Fire Model, Conservation Model, Building Cost Model. These models describe the respective characteristics of the area independently, hence a combined model has been developed based on the models to analyse the suitability of sites across all parameters from each model. The model development has been made using data sourced from a combination of verified and unverified sources. Assumptions of certain parameters during the construction of various models have been made to successfully identify the locations for construction. This report discusses the results and observations from the study and identifies the different locations suggested for the University to construct its facility. An inspection of the sites prior to finalising the sites from below is highly suggested.

1. Introduction

Smith's Lake Field Station is a University of New South Wales (UNSW) run facility located in Myall Lakes National Park. Established in 2003, existing infrastructure has since provided resources and accommodation for approximately 3000 students plus staff annually (https://www.bees.unsw.edu.au/about-us/facilities/smiths-lake-field-station). To increase the stations capacity to support educational and research outcomes, UNSW is currently exploring options for expansion. Due to natural disaster risks, financial constraints and environmental concerns, careful analysis must first be completed the determine the most suitable locations for any further development.

To achieve this soil erosion modelling was performed to identify areas of high pollution source risk. Erosion was calculated following the Universe Soil Lose Equation (USLE) (Alewell et al. 2019) and areas of low erosion relative to the study area identified as acceptable locations for development.

Furthermore, fire risk modelling was performed to detect suitable, low- risk sites within the Smith Lake area. These are preventative measures that are implemented as a protocol to protect societal, health and environmental impacts (Neale & May, 2020). The suitability of these sites is founded on a fire intensity model which identifies areas which in the case of a bushfire, fire intensity will be low enough that it can be controlled. These models are based on The McArthur Forest Fire Danger Meter which were then turned into an equation by Neal (1980) (CSRIO, 1967).

Finally, building constraints and ecological impact were also considered.

The aim of this report therefore, is to find a suitable location for the development of the Smith's Lake Field Station of University of New South Wales. The expansion facility which will be used for the purpose of accommodation should minimise the construction costs, minimise the impact on conservation, minimise the fire hazards and should ensure that it minimises any impact arising from constructions such as soil erosion, etc. If possible, the location should aim at maximising the solar radiation and should be located around a nice view. The goal of this study is to find locations which fulfil the requirements help in locating the theoretically potential sites for development.

2. Methods

Location

Smith’s Lake Field Station (-32.39983912963695, 152.476820367634) (Image 2.1.) is located in the Hunter Valley region of New South Wales, Australia, which is approximately 270 kilometres north of Sydney. Smith’s Lake Field Station is owned by the University of New South Wales (UNSW) and is in an extension of Myall Lakes National Park.

The area contains Coastal heath, swamps and eucalypt forests, along with fresh and salt-water lakes. The UNSW run field station contains pre-existing buildings used for research and accommodation.

Since 1980, the area has averaged 1454.8mm of precipitation per year (Bureau of Meteorology).

Datasets for Analysis

The study involved the usage of various datasets for the purpose of development of the models. These data have been sourced from multiple locations. Since the data was sourced from multiple locations, the first and foremost task was to set the coordinate system of each dataset into the same type. For the entire study, the coordinate system of all the datasets is GDA 1994 MGA Zone 56. For the datasets which did not have their coordinates predefined, projection tool helped in transforming their coordinates to the coordinate system.

The following table describes the different datasets used in the study along with a brief description.

Dataset	Geometry	Model developed
Endangered_flora	Point	Conservation
Endangered_fauna	Point	Conservation
Wetlands	Polygon	Conservation
Vegetation	Polygon	Soil Erosion
Sealed_roads	Line	Building
Unsealed_roads	Line	Building
Power_Lines	Line	Building
Study_area	Polygon	Conservation, Building,
K Prediction	Raster	Soil Erosion

Prior to the development of the models, the processing extents set as: Top = 6418000, Right = 457000, Left = 447000, Bottom = 6408000. The raster analysis cell size was also set to 10 to maximise raster accuracy (Mori, 2006).

2.1. Erosion Modelling

Predicted erosion (Image 3.1.4.) was modelled using the Universe Soil Lose Equation (USLE) (Alewell et al. 2019):

$$\text{Erosion} = R*K*S*L*C*P$$

Where Erosion = Predicted soil erosion (t ha^{-1} y^{-1})

R = Rainfall Factor (MJ mm h^{-1} ha^{-1} yr^{-1})

K = Soil erodibility factor (t ha^{-1} y^{-1})

S = Slope gradient factor (dimensionless)

L = Slope length factor (dimensionless)

C = Land cover and land management factor (dimensionless)

P = Soil conservation management factor (dimensionless)

The R factor value applied was 3500. This was the middle value of the 3000-4000 R factor value range for the study site region (Rosewell, 1993).

The K value raster was supplied without any measurement of error (Image 2.1.1).

Factors S (Image 3.1.1) and L (Image 3.1.2) were developed using a Digital Elevation Model (DEM) of the study site (Image 2.1.2) that was developed prior to soil erosion modelling (Smith, unpublished). The DEM passed logical consistency tests and returned a root mean square error (RMSE) of 5.08 meters.

The S factor was calculated by the formula (Selby, 1993):

$$S = (\sin(\text{slope}/57.296)/0.0896)^{1.35}$$

The DEM was applied to the *Slope (Spatial Analyst)* tool with subsequent calculations performed within ArcMap via the *Math* toolbox to generate the S factor raster.

L factor was calculated by the formula (Selby, 1993):

$$L = \text{flow length}^{0.4}$$

Flow length was obtained by calculating flow direction and subsequent flow accumulation from the DEM using the d-infinity algorithm and applying the resulting flow accumulation raster to the equation (Moore and Burch, 1986a,b):

$$\text{flow length} = \text{flow accumulation} * (\text{cell size}/22.13)$$

It was assumed that soil erosivity would not increase beyond a flow length of 150m so cells greater than 150m were clipped to return a value of 150m.

the C factor raster (Image 3.1.3) was created by assigning a value of 0.042 for areas of cleared vegetation and 0.004 where vegetation is intact (Rosewell, 1993). Areas of cleared and intact vegetation were identified by a supplied polygon data set of vegetation types across the study site.

The P factor was assigned a constant value of 1 as no soil conservation management actions had taken place at the study site.

Image 2.1. Satellite imagery of the Smith's Lake Area.

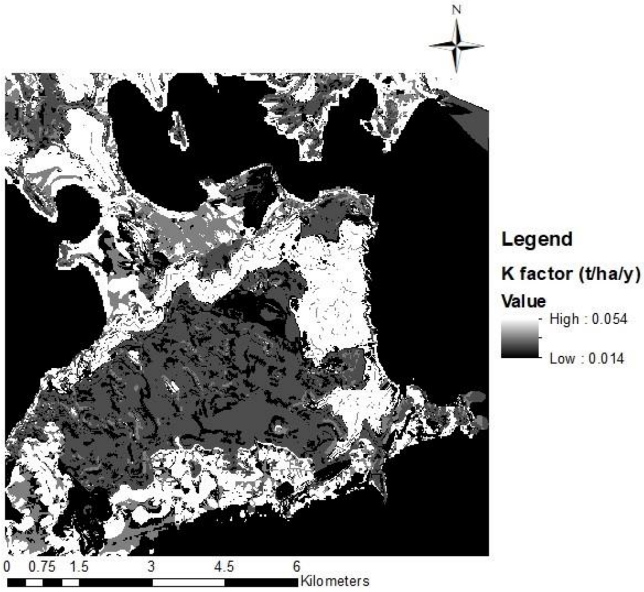

Image 2.1.1. K factor raster.

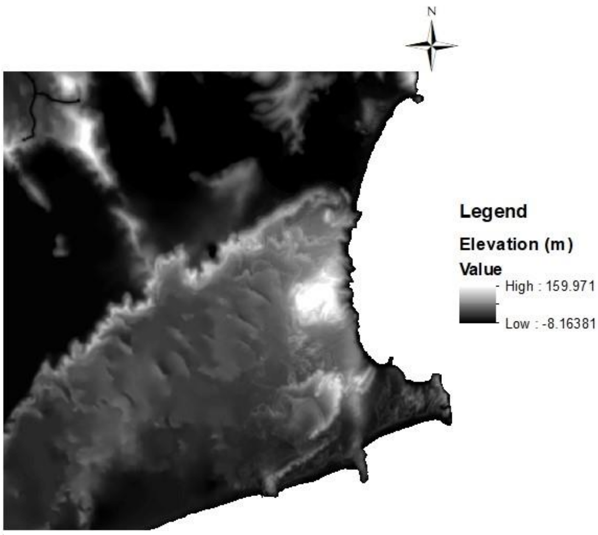

Image 2.1.2. ANUDEM developed for Smiths Lake study area (Smith, unpublished)

2.2. Fire Risk Modelling

All modelling was performed in ArcGIS pro. The processing extent was set to Top=6418000, Right= 457000, Left= 447000 and Bottom= 6408000. The raster cell size was set to 10cm^2. McArthur Forest Fire Danger Meter Mk5 was used to determine the rate of spread of the grass and forest. Swamps and wetlands were determined by halving the result of the forest rate of spread. The results were used in the fire intensity equation supplied by (Noble et al., 1980)
The following equations were applied to scenario 1. The values in scenario 1 were supplied by an external party but used the same equations as below.
The McArthur Forest Fire Danger Meter Mk5 equation is as followed:

<u>Equation:</u>

$$M= \frac{97.7+4.06\,x\,H}{T+6.0} -0.00854 \times H + \frac{3000}{C} - 30$$

Therefore, the Fuel Moisture content in the grassland is: 15.677%
Danger Index Model equation is as followed:
The Fuel moisture content in the forested areas is calculated as a function in the Danger Index Model.

Where
Grassland Fire Danger Meter Mk5:
M= Fuel moisture content in %
H= Relative Humidity
T= Air Temperature
C= Degree of curing
Environmental conditions:

M= Fuel moisture content

H=75%
T=41.9%
C= 80%

$$M= -\frac{97.7+4.06\,x\,75}{41.9+6.0} -0.00854 \times 75 + \frac{3000}{80} - 30$$

Therefore, the Fuel Moisture content in the grassland is: 15.677%
Danger Index Model equation is as followed:
The Fuel moisture content in the forested areas is calculated as a function in the Danger IndexModel.
<u>Equaion:</u>

$$F=3.35 x W\, x exp^{\{-0.0897 x M+0.0403\, x\, V\}}$$

Where:
F= Fire Danger Index
W= Fuel weight
V= Wind Velocity
Environmental conditions:
F= Fire Danger Index
W= Fuel sum as seen in figure
V=100km/h
M=15.677

$$F=3.35 x W\, x exp^{\{-0.0897 x 15.677+0.0403\, x\, 100\}}$$

R=0.0012 x 78.12 x W
R=0.0937 x W
<u>Fire Spread:</u>

To determine the fire spread, the vegetation was assigned values of rate of spread. These valuescan be found in the equations above. The values reflect the rate of spread. The swamps, wetlands and saltmarshes' values were half of the forest values.
Therefore, the following table demonstrates the rate of spread for each of the type of vegetation within scenario 1. Scenario 2 includes freshwater wetlands, forested wetlands, mangrove swamps and saltmarshes as grassland.

Vegetation	Rate of Spread
Dry Sclerophyll Forest	0.0937
Littoral Rainforests	0.0937
Rainforests	0.0937
Shrublands	0.0937
Wet Sclerophyll forests	0.0937
Grasslands	0.825
Freshwater wetlands	0.04685
Forested wetlands	0.04685
Mangrove swamps	0.04685
saltmarshes	0.04685

Table 2.2.1. Rate of Spread for Vegetation values

The vegetation values were assigned to appropriate rate of spread values and was transformed into raster from Polygon. This raster was named Fire Spread.
The vegetation values were assigned to appropriate rate of spread values and was transformed into raster from Polygon. This raster was named Fire Spread.
<u>Slope and fire spread:</u>
The following equation was used to determine the rate of fire and slope combined
Rate of slope and fire spread = Fire spread x exp (0.069 x slope)
Slope and fire spread was determined by combining the DEM slope and the vegetation values as seen in the table above. The ANUDEM was used to determine the slope factor as seen in figure 3. This was done by using the spatial analyst tool. The fire spread is the raster
To determine the spread of the slope, the slope was multiplied by 0.069 using the 'Math' tool to rescale the values. The 'Exponent 'tool was used to determine the fire spread.
<u>Fuel Component</u>
The fuel load of the area was combined into a raster. The surface, elevated fuel and bark were considered as components. These values were based on the Overall Fuel Hazard guide (McCarthy et al. 2009). The combined results can be seen in figure
<u>Fire Intensity</u>
Fire Intensity= 18600 x fuel load x rate slope spread x 0.27777 x 0.1
18600 is the approximate energy that a eucalypt fire will burn in joules^2 .0.2777 and 0.1 convert km/hr to m/s and t/ha to kg/m^2 . The result is the fire intensity model.

2.3. Conservation Model

The study aims at identifying locations which may involve minimal to no damage to conservational aspects. The conservation model has been developed to identify the locations which should be eliminated from consideration for construction of the site based on the conservation of endangered flora, endangered fauna which may be further endangered if a construction of such a site is undertaken near them. The study also aims at preventing construction around specific vegetational areas such as swamps, mangroves, and wetlands where the damage to the conservational area would be significantly high. To eliminate the regions which would maximise the damage to the conservations, the conservation model has been developed. The company aims at restricting construction of the site anywhere closer than 500m in range from the sighted location of the endangered flora and fauna. The construction has been restricted to anywhere closer than 75m in case of vegetational area whereas the distance has been capped at 250m when it comes to the wetland areas. A fuzzy membership function based on the above conditions gives a result that displays the regions where the construction should be avoided.

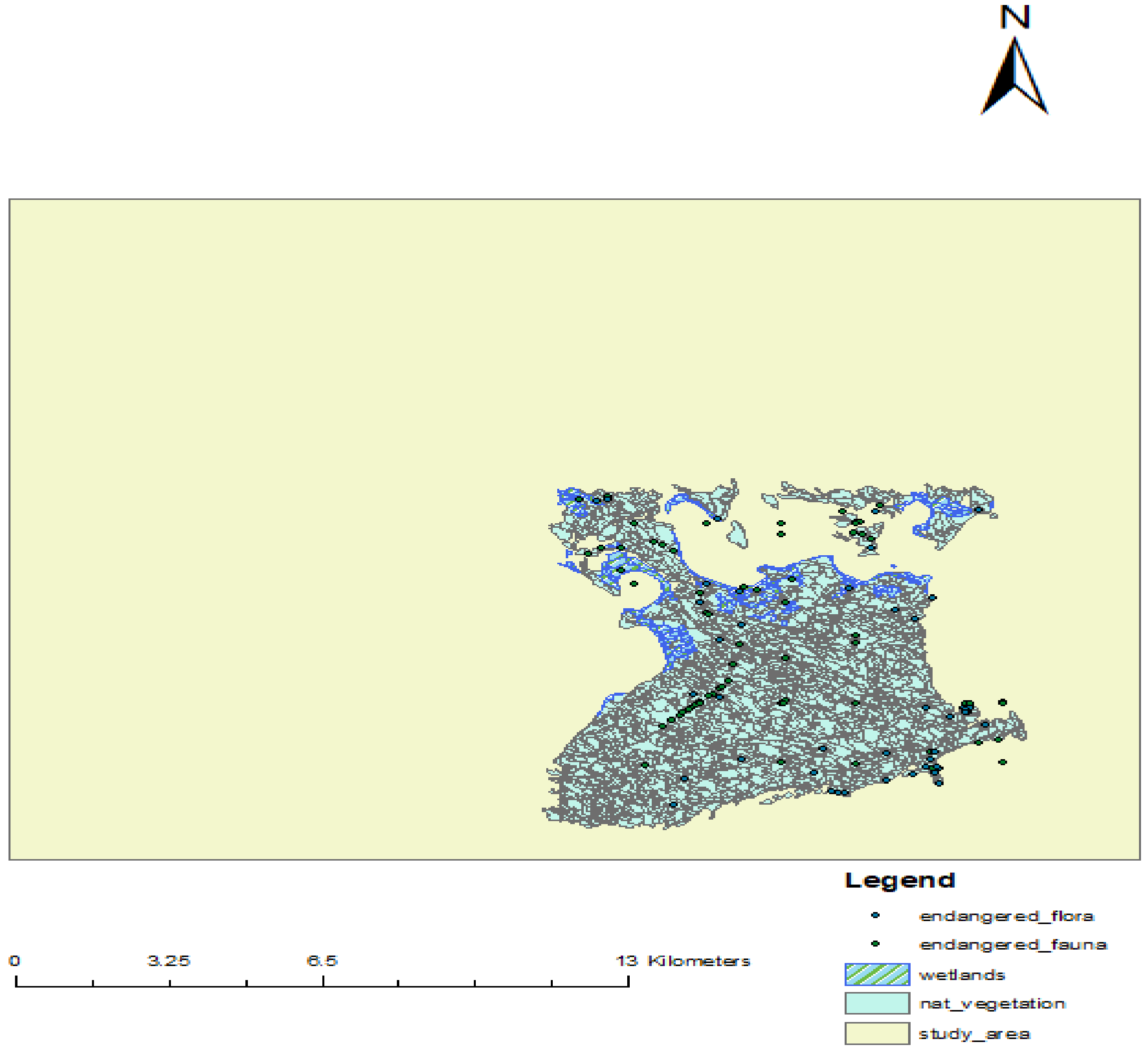

Image 2.3.1: Overview of Smith's Lake area w.r.t Conservation Model

Dataset	Minimum (m)	Maximum (m)
Endangered Flora	100	500
Endangered Fauna	100	500
Vegetational area	25	75
Wetlands	50	250

Table 2.3.1: Fuzzification criteria of different layers for building Conservation Model

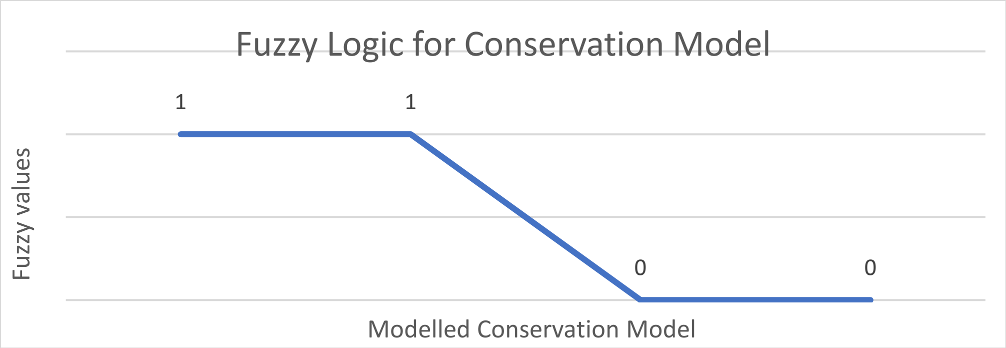

Image 2.3.2: Graph for Fuzzy Logic of Conservation Model

2.4. Building Constraints Model

The aim of developing the building model is to ensure the location of construction minimises the cost of construction by not identifying locations farther from existing structures such as roads and power lines. The unsealed roads and sealed roads have been extracted from the roads shapefile. The reason for separating these data is that the building can be placed anywhere from 30m from sealed road whereas it cannot be placed anywhere closer than 10m when it comes to unsealed roads.

The powerlines shapefile provides a polyline shapefile that contains identified locations where a power grid is located. The distance from the powerline should be minimised as much as possible to ensure a low cost of construction. The powerlines have been capped at a minimum distance of 50m from any construction location to maintain safety distance from the power lines as well as stay close enough to minimise the cost of construction.

The building model is developed in way that it identifies the locations of construction to be close from unsealed roads but not more than 10m and no more than 30m from sealed roads. This is to avoiding identifying locations of construction which may fall over the road and allow for wrongful locations to be identified in the model.

The building model is built using the Euclidean distance tool which helps plotting the distance criteria for each layer. It outputs a raster file for every layer which contains the range of distances from the input polyline vector. To convert the different ranges of distances in a range which could help build the building model, the raster file has been fed to the fuzzy membership tool which outputs a value 1 for all locations where the construction should be restricted. And a value of 0 where the construction should be allowed. All intermediate ranges between these are given a value between 0 and 1. The combination of the fuzzy membership for each layer gives us the building model. This combination of the models is carried out using the fuzzy overlay tool.

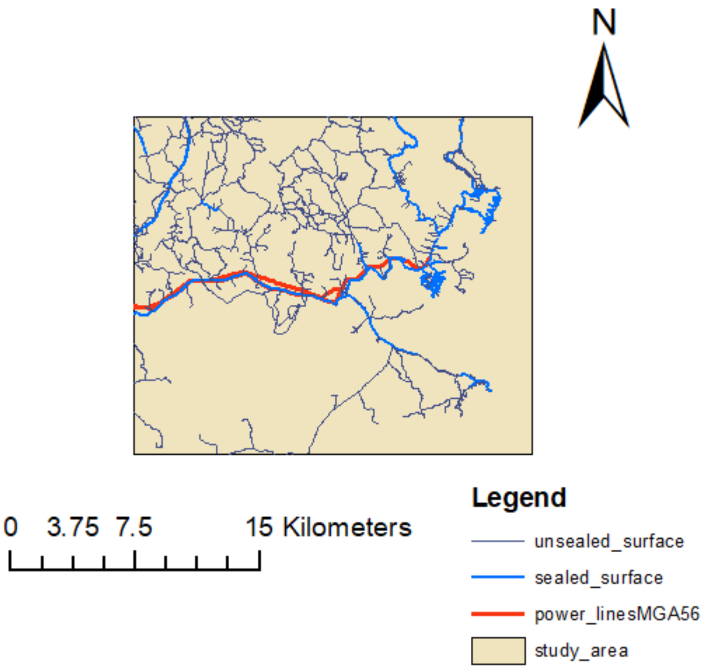

Image 2.4.1: Overview of Site w.r.t Building Models

Dataset	Minimum	Maximum
Unsealed Roads	10	200
Sealed Roads	30	200
Power Lines	50	200

Table 2.4.1: Fuzzification criteria of different layers for Building Model

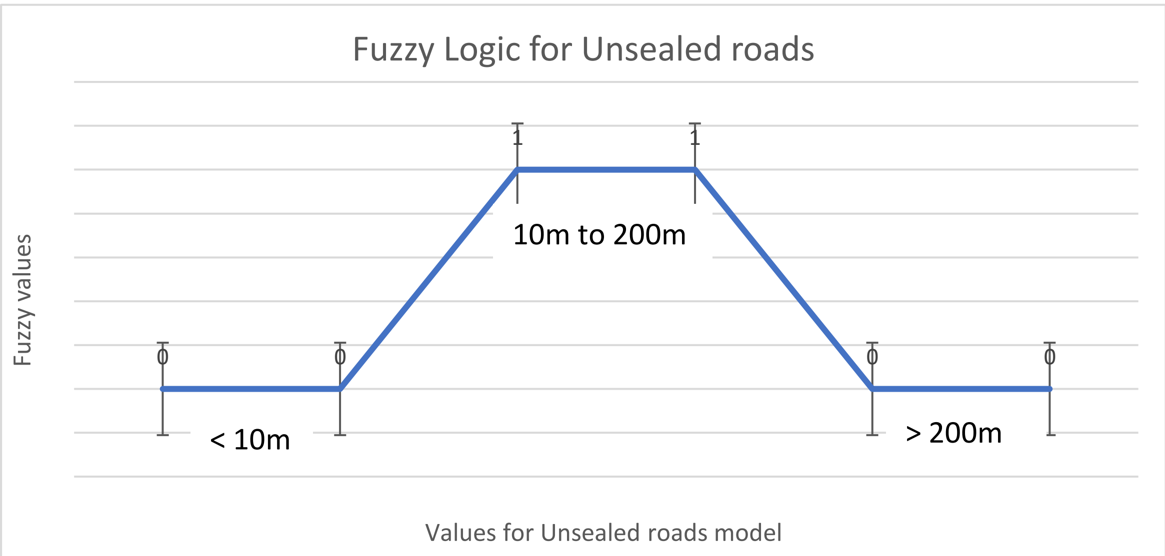

Image 2.4.2: Graph for Fuzzy Logic (Unsealed Roads).

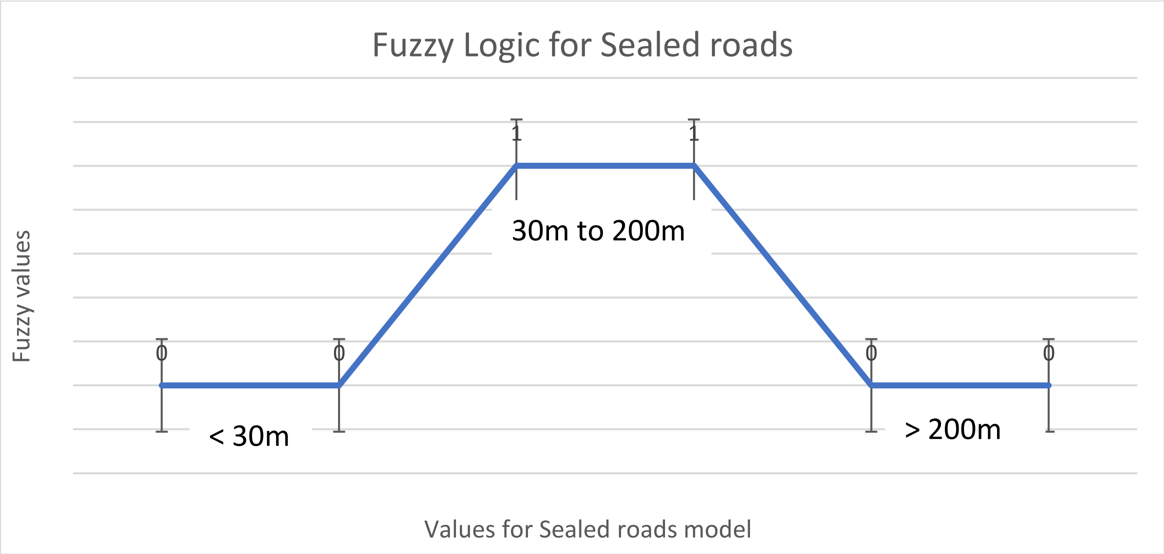

Image 2.4.3: Graph for Fuzzy Logic (Sealed Roads).

2.5. Site Suitability Modelling

Building costs, fire risk and pollution potential (as predicted by erosion potential) were analysed to determine possible sites for expansion. To achieve this, fuzzy memberships were applied to the erosion model (section 2.1) and fire risk model (section 2.2.) to produce standardised rasters for analysis. For erosion, it was assumed that any region below the mean value for the study site would be suitable. A negative linear fuzzy relationship was therefore applied between 0 t ha^{-1} y^{-1} and 2.025 t ha^{-1} y^{-1} (Image 2.5.1). While 4000 kW/m is suggested to be the upper limit of controllable fire in forests such as those in the Smiths Lake area (Luke and McArther, 1978), a conservative value of 3000 kW/m was applied in this report. A negative linear fuzzy relationship was subsequently applied to the fire risk model between the minimum value modelled (4.86 kW/m) and 3000 kW/m (Image 2.5.2).

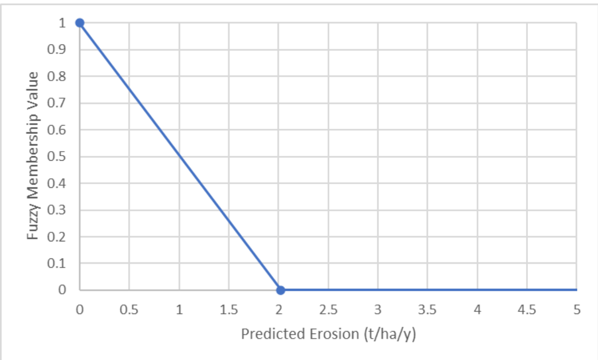

Image 2.5.1. Soil erosion fuzzy membership relationship

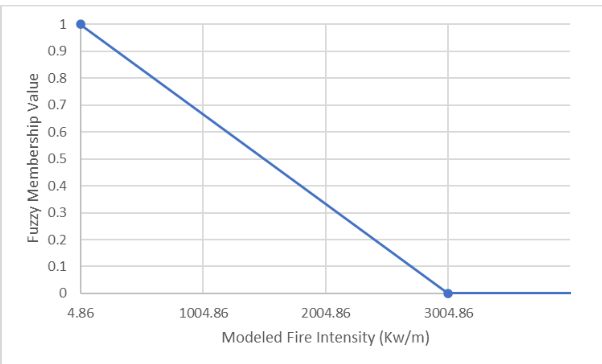

Image 2.5.1. Fire risk modeling fuzzy membership relationship

Building cost rasters were developed by inversing the conservation fuzzy membership raster (section 2.3) and subtracting it from the building constraint fuzzy membership raster (section 2.3), identifying areas with low environmental impact and building cost (equation 2.5.1). To provide further flexibility during the decision-making process, building costs were also calculated assuming an importance weighting of 0.8 to 0.2 in favour of building constraints (equation 2.5.2) and environmental impacts (equation 2.5.3). Each raster was standardised by applying a positive linear fuzzy membership between 0 and the highest value in each respective raster.

Equation 2.5.1. Building Cost = Building Constraints – (Environmental Impacts)$^{-1}$

*Equation 2.5.2. Building Cost = (0.8 * Building Constraints) – (0.2* (Environmental Impacts)$^{-1}$)*

*Equation 2.5.3. Building Cost = (0.2 * Building Constraints) – (0.8* (Environmental Impacts)$^{-1}$)*

The fuzzy membership rasters were overlayed to develop site suitability models given the weightings associated with the various building cost rasters. Furthermore, a fourth site suitability model was developed giving weightings of 0. 1 to both the fire and erosion models and a weighting of 0.8 to building cost equation 2.4.2. This was done under the assumption that decision makers may take steps during construction to mitigate fire and erosion risk. Such actions would likely increase cost making building constraints more important. A conditional raster was also applied to each model to exclude any potential sites greater the 1500m from the existing field station.

Site suitability models were standardised by applying a positive linear fuzzy model relationship between the minimum and maximum values of each output (Images 3.5.1, 3.5.2, 3.5.3 & 3.5.4.). Areas with a standardised suitability scores greater than 0.5 were identified as potential sites. Of these potential sites, only areas of 2000m^2 or greater were identified to allow ample room for development (Images 3.5.5, 3.5.6, 3.5.7 & 3.5.8).

View factor and winter and summer solar radiation were also calculated from the ANUDEM used in erosion modelling. These values were extracted for each possible site to assist with ranking.

3. Results

3.1. Soil Erosion Modelling

S factor modelling (Image 3.1.1) returned values ranging from 0 to 20.265. Larger values ranging between 4.927 to 12.6 are concentrated south of Smiths Lake on the eastern extent of the study site, the north-western corner of the study site and along a line running from the south-eastern bank of Myall Lake to the south-eastern bank of Smiths Lake. Extensive areas of 0 to 3.258 values are found in the central, south and south-west regions of the study site. Small areas of high values relative to the study site (between 12.636 to 20.265) are found in the north easter tip of the study site, the easternmost point of the study site and along two branches of a river in the north-western corner.

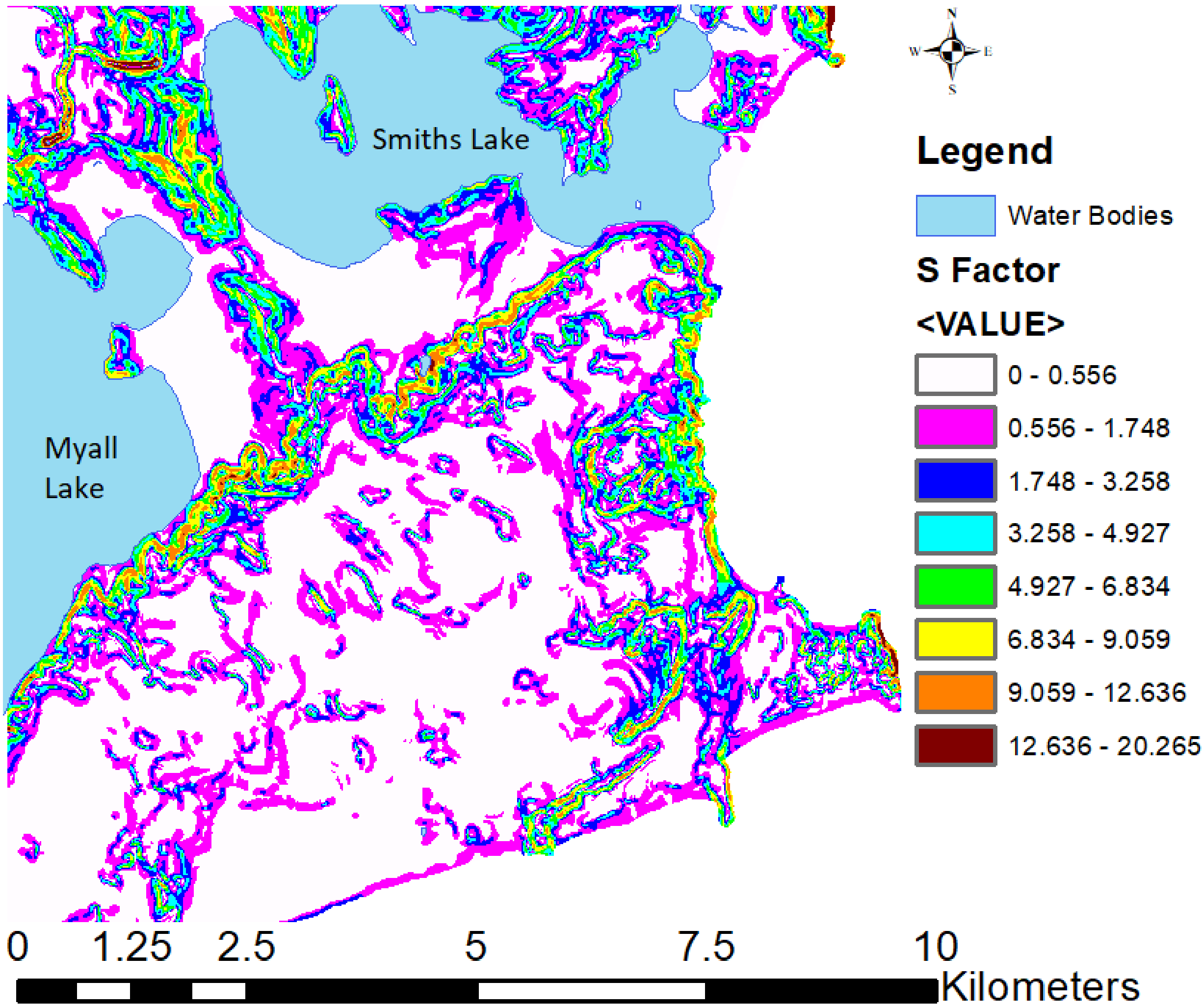

Image 3.1.1. S factor raster developed from ANUDEM and used in soil erosion modelling.

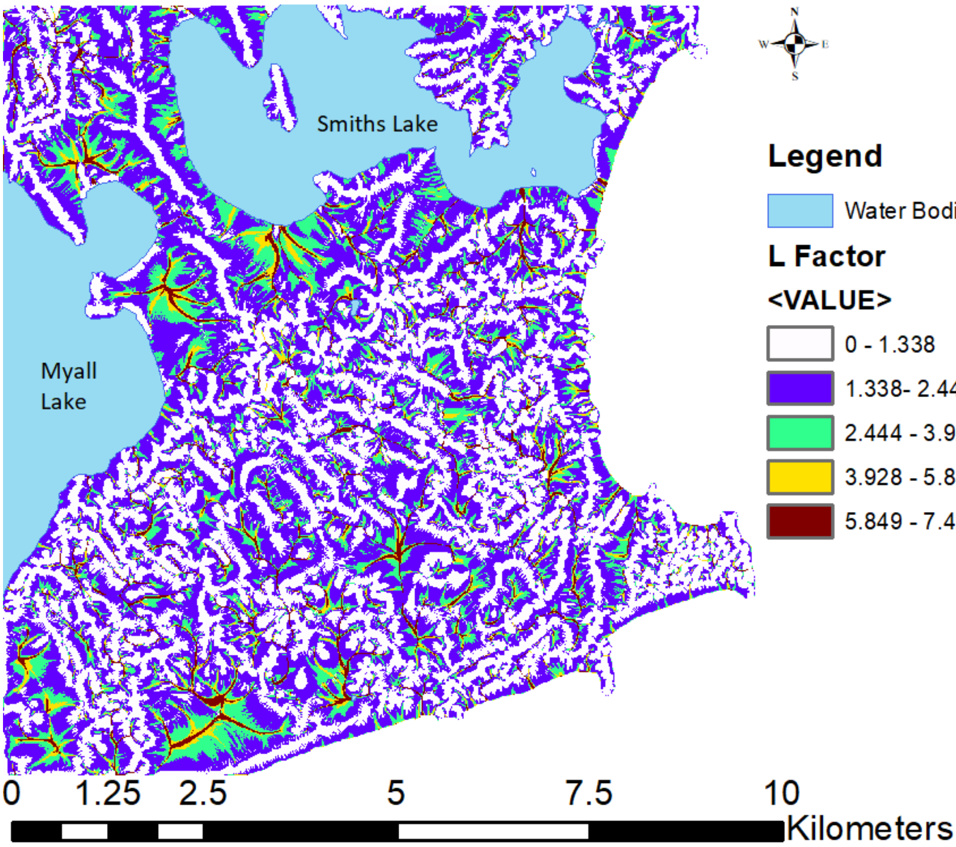

Image 3.1.2. L factor raster developed from ANUDEM and used in soil erosion modelling.

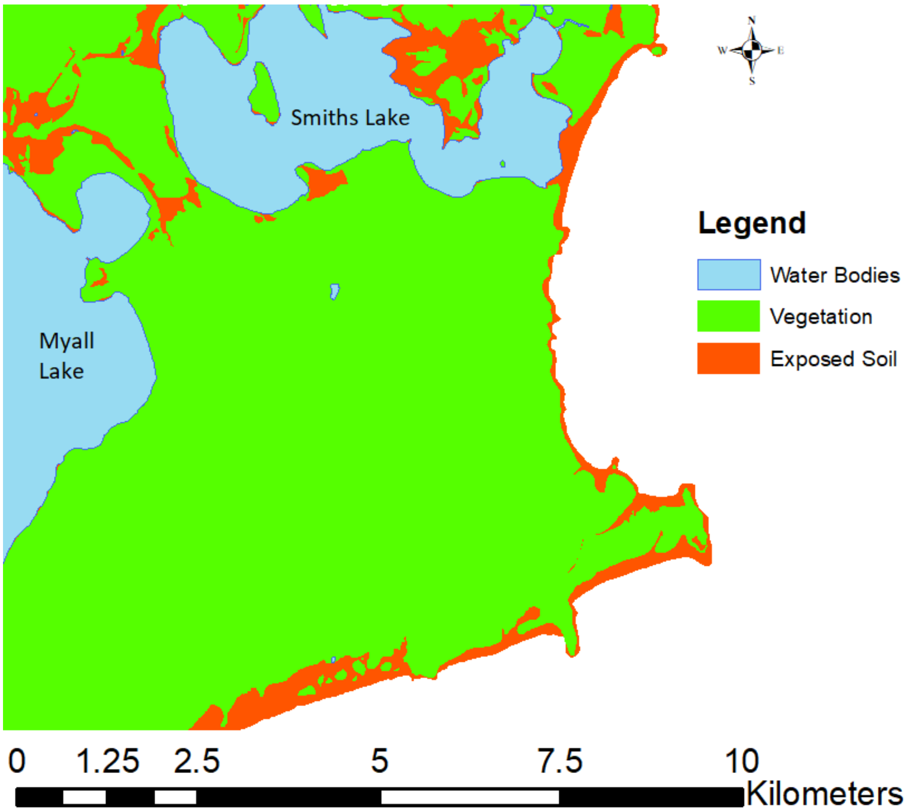

Image 3.1.4. Distribution of intact vegetation (C factor = 0.004) and exposed soil (C factor = 0.042) across study site.

L factor values (image 3.1.2) ranged from 0 to 7.421. Most of the study site had a modelled L factor between 0 to 2.444. Areas of increased values between 2.444 to 7.421 are dispersed across the study site. Where bands of 2.444 to 3.928 developed, they almost always proceeded into L factor values of 3.928 to 5.894 then 5.894 to 7.421. Also of note, large areas of higher values (2.444 to 7.421) were concentrated around the northeast and southwest of Myall Lake and Smiths Lake, respectively.

The study site mostly contains intact vegetation (Imaged 3.1.4) which was assigned a C factor value of 0.004. Exposed soil (C factor = 0.042) is restricted to coastal areas, around Smiths Lake and the throughout region between Smiths Lake and Myall Lake.

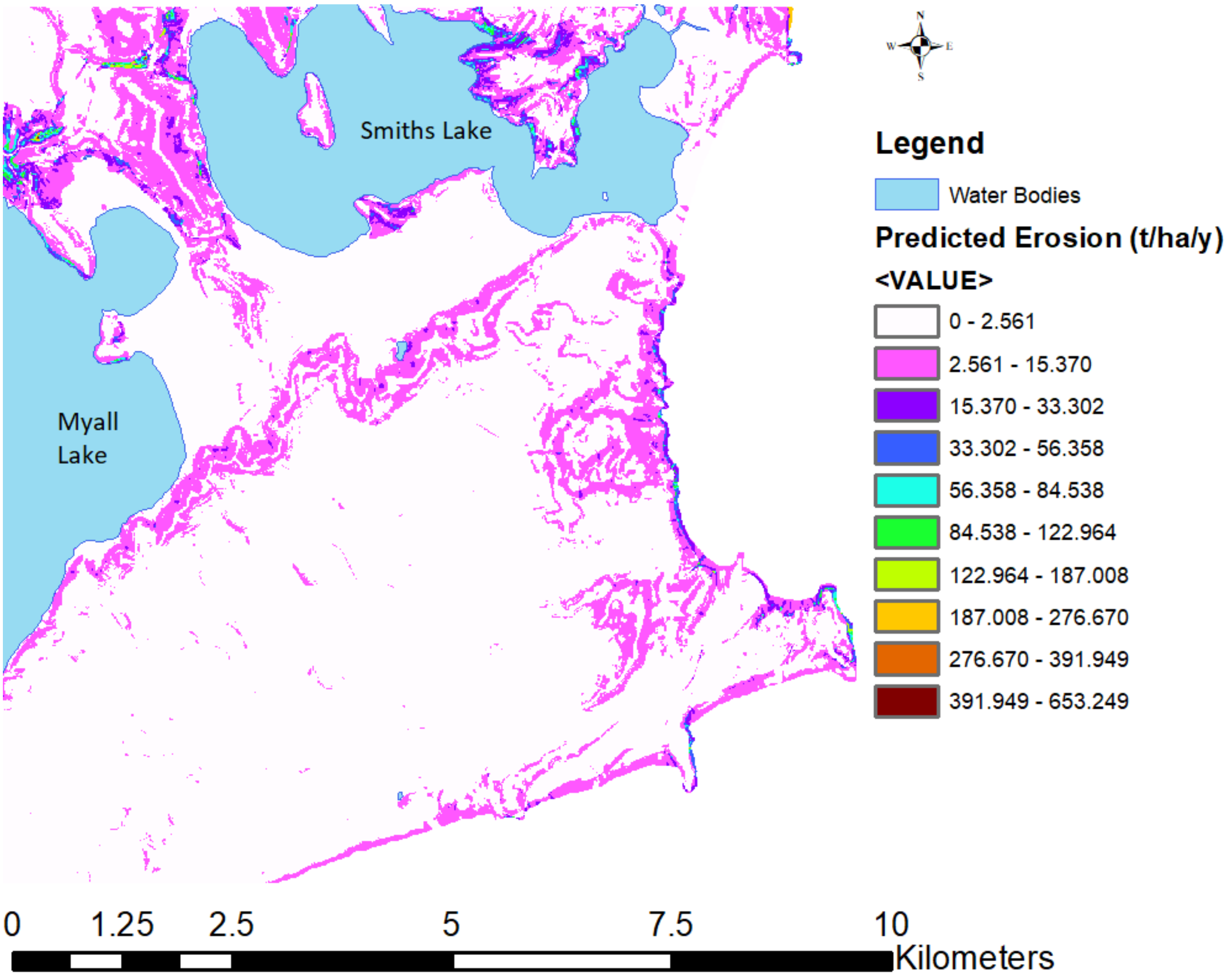

Image 7. Soil erosion model for Smiths Lake Field Station study area developed using the Universal Soil Loss Equation.

The soil erosion model (Image 3.1.4) returned values ranging from 0 to 653.249 tones per hectare per year (t ha^{-1} y^{-1}) with a mean value of 2.025 t ha^{-1} y^{-1}. Most of the study area is expected to experience soil erosion of 0 to 2.561 t ha^{-1} y^{-1}. Most of the remaining area is predicted to loose between 2.561 to 15.370 t ha^{-1} y-1. Values between 15.370 to 56.358 t ha^{-1} y^{-1} are modelled along much of the coast and significant portions of Myall and Smiths Lakes. Small areas in the north-western corner of the study sight returned extreme values (56.358 – 653.249 t ha^{-1} y^{-1}) relative to the study site overall. A small region of high values is also observed on the eastern tip of the study site (187.008 to 276.670 t ha^{-1} y^{-1}).

3.2. Fire Risk Modelling

Image 3.2.1. Fire Intensity Map, Scenario 1.

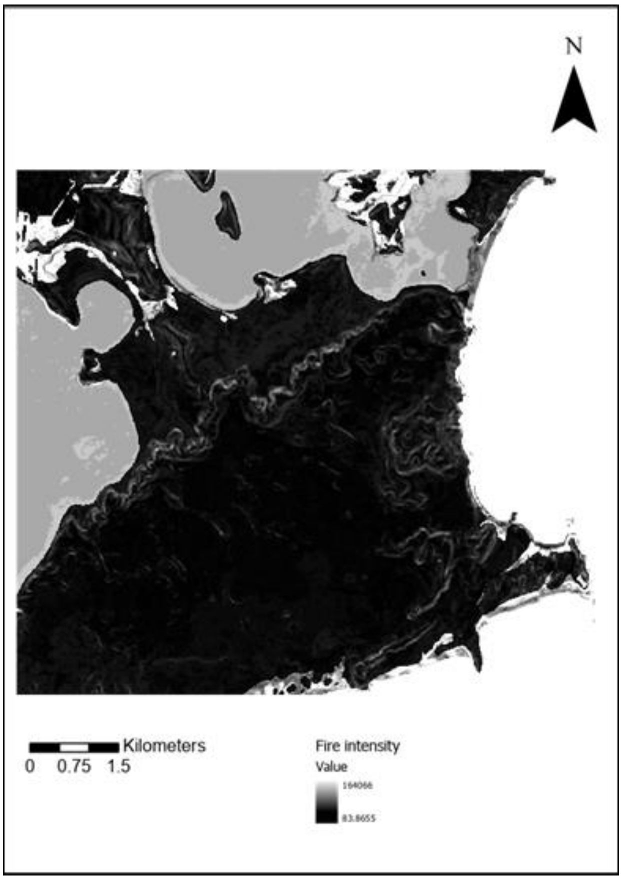

Image 3.2.2. Fire Intensity Map, Scenario 2.

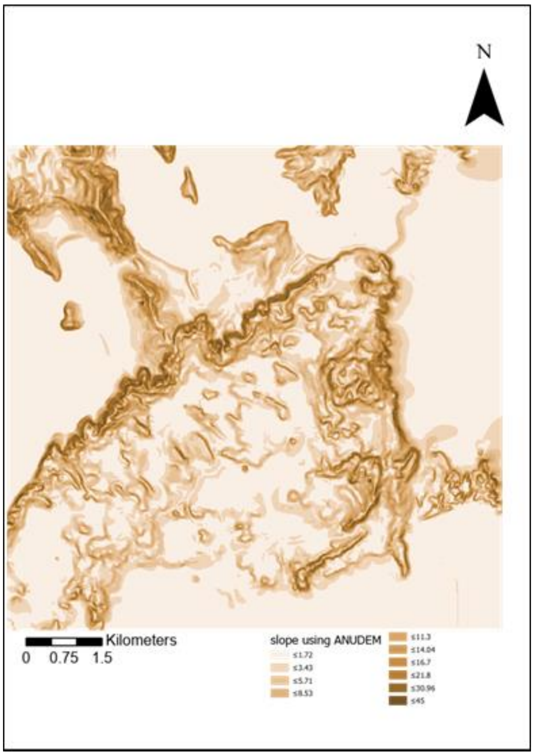

Image 3.2.3. Slope Using ANUDEM

Image 3.2.4. Slope and spread combined

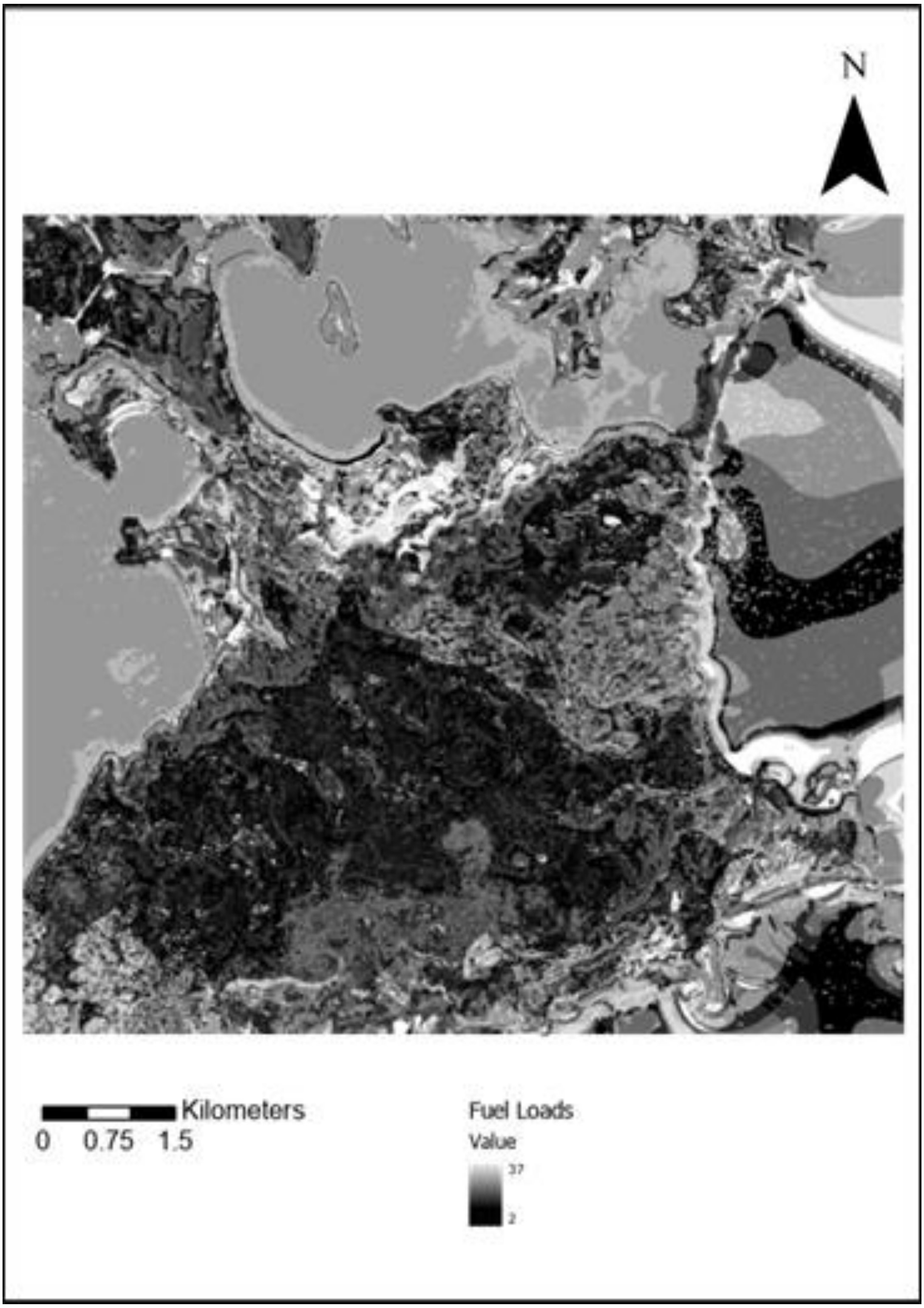

Image 3.2.5. Combined fire risk model for Smith's Lake study area

The first scenario was used in the final combined model. The lower values in the fire intensity models are areas which are more suitable to building and will be easier to manage during a fire. In both models most of study area has high fire intensity with areas around the lakes and coastline showing low intensity and therefore more suitability for building.

The lower values indicate areas where less energy will be consumed during a fire. Therefore, those areas will be the most suitable areas to build. The values were clear to see in the final model and did not need to be rescaled.

3.3. Conservation Model

The conservation model outputs a value of 1 for all the region where the construction could take place whereas a value of 0 for all areas where construction should be strictly restricted. All areas that fall in between these regions are given a value between 0 to 1. The max and min values for endangered flora and endangered fauna has been the same value, whereas a different value pair has been assumed for the vegetational regions. All these different raster files could be combined to generate the conservation model. This combined raster is developed using a Linear fuzzy membership overlay function using AND operator which basically sums up all the layers together.

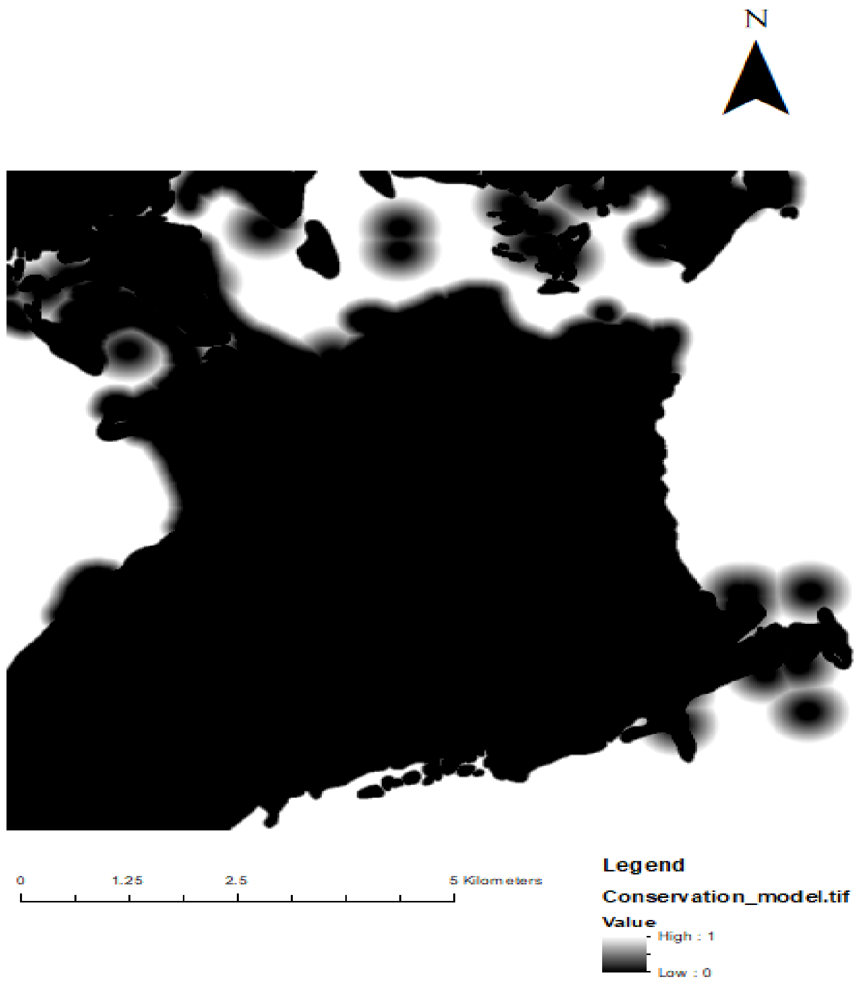

Image 3.3.1: Conservation Model for Smiths Lake Area

3.4. Building Constraints Model

The building model is generated in respect to the sealed and unsealed roads and the power grids. The condition that the building should be built anywhere between 30m to 200m for sealed roads and 10m to 200m for unsealed roads and finally about 50m to 200m from a nearby power grid line are provided as an input conditions to the fuzzy overlay tool which generates the building model as shown in the Image with all regions under the black zone being the regions where the construction of the building is permitted while the regions under white zone should be the restricted regions for the construction of the building site.

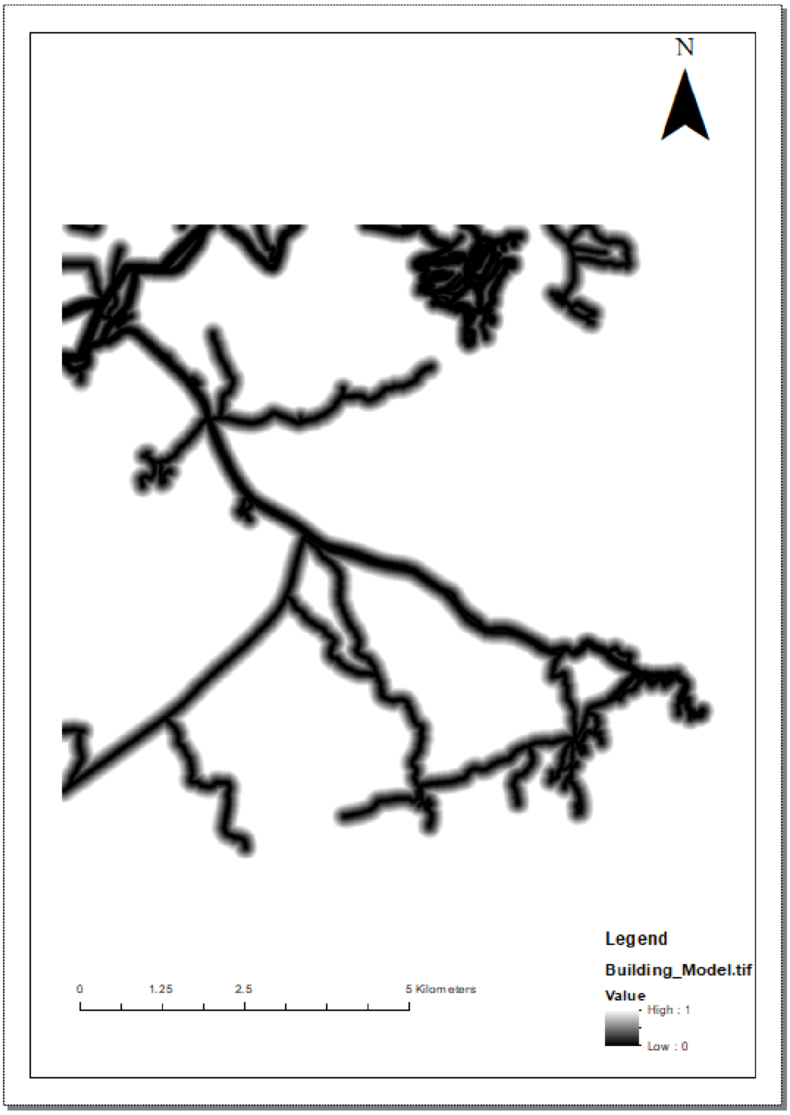

Image 3.4.1.: Building Model for Smith's Lake Area

3.5. Site Suitability Modelling

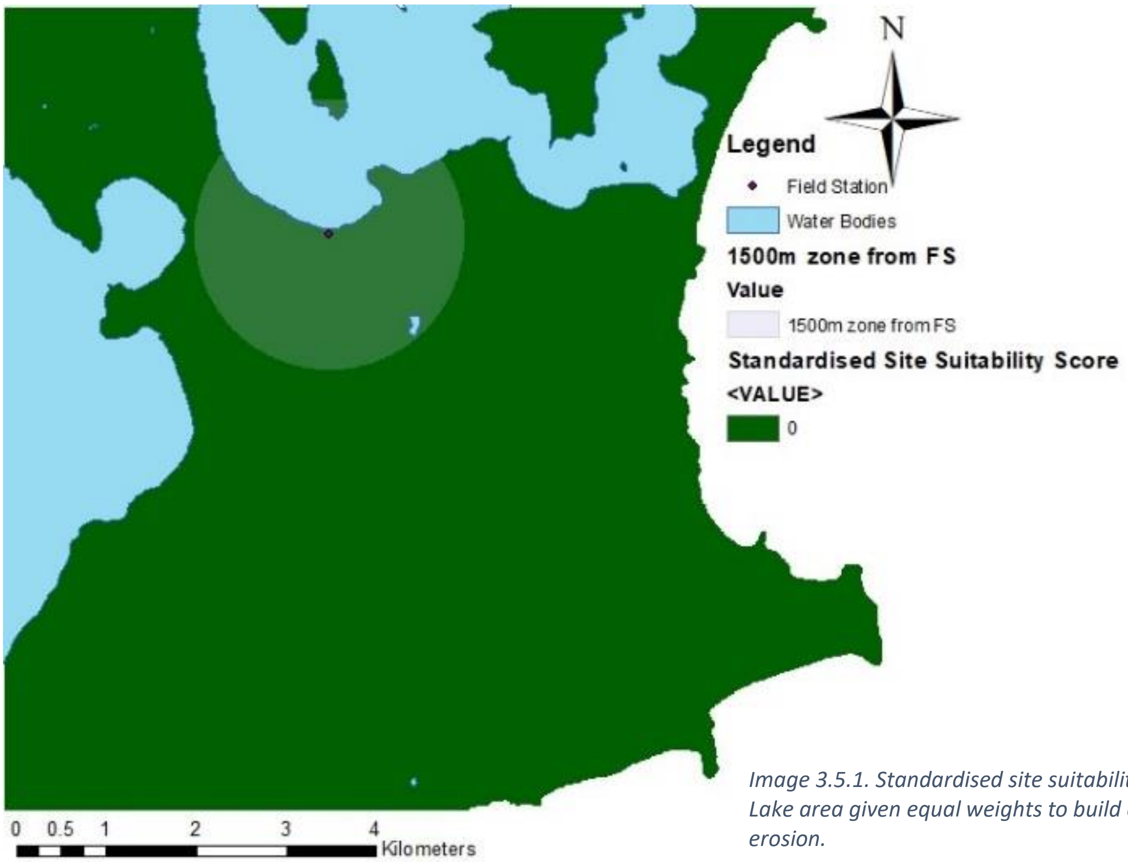

Image 3.5.1. Standardised site suitability model for Smiths Lake area given equal weights to build cost, fire risk and erosion.

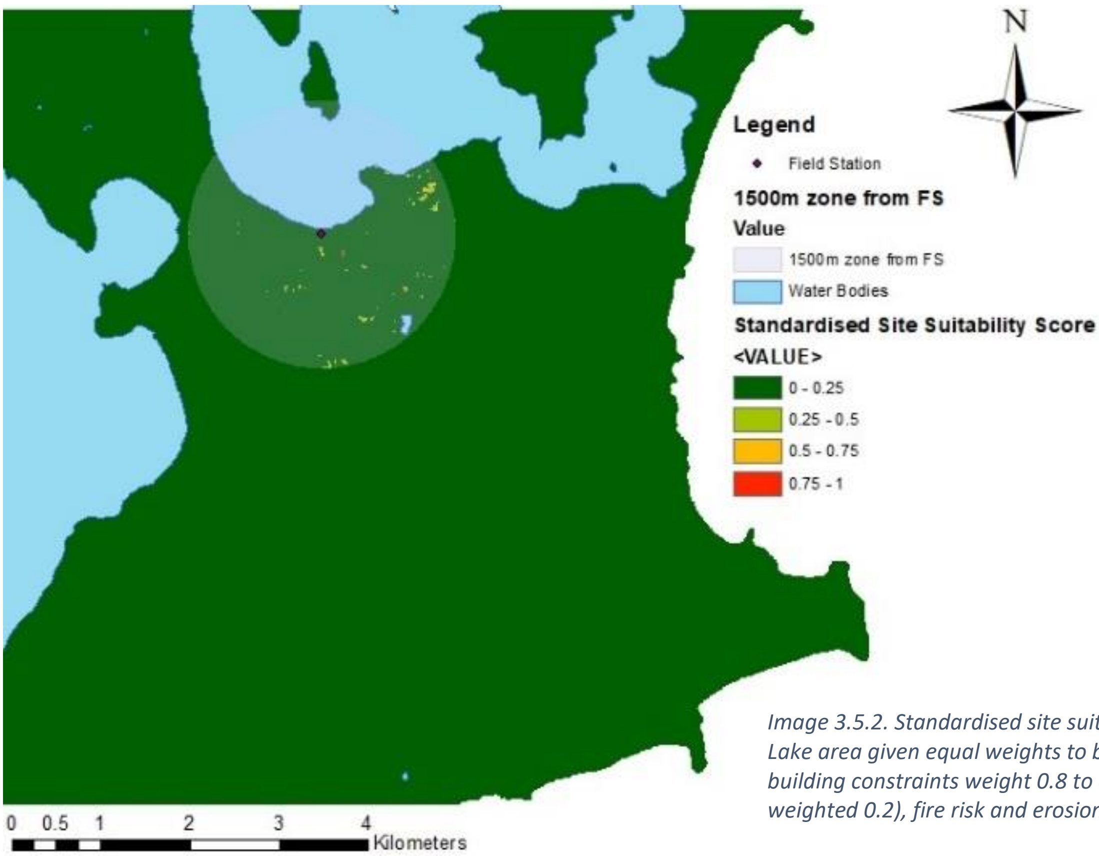

Image 3.5.2. Standardised site suitability model for Smiths Lake area given equal weights to build cost (comprised of building constraints weight 0.8 to environmental constraints weighted 0.2), fire risk and erosion.

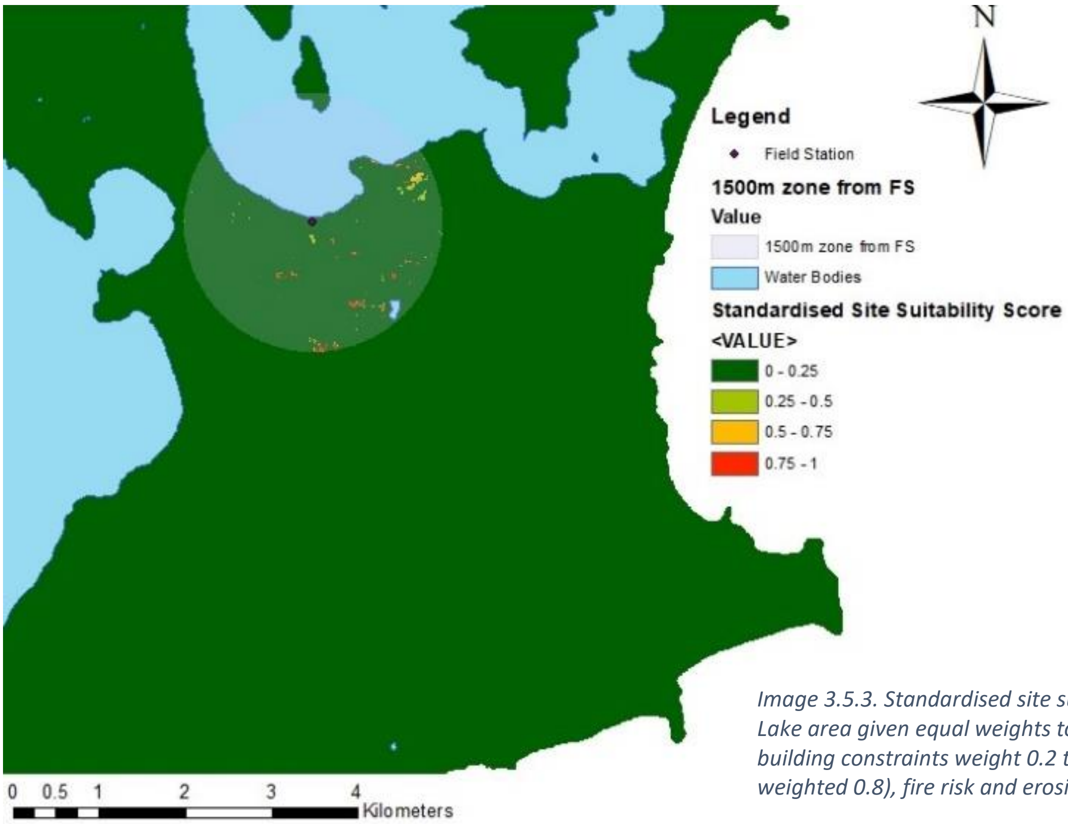

Image 3.5.3. Standardised site suitability model for Smiths Lake area given equal weights to build cost (comprised of building constraints weight 0.2 to environmental constraints weighted 0.8), fire risk and erosion.

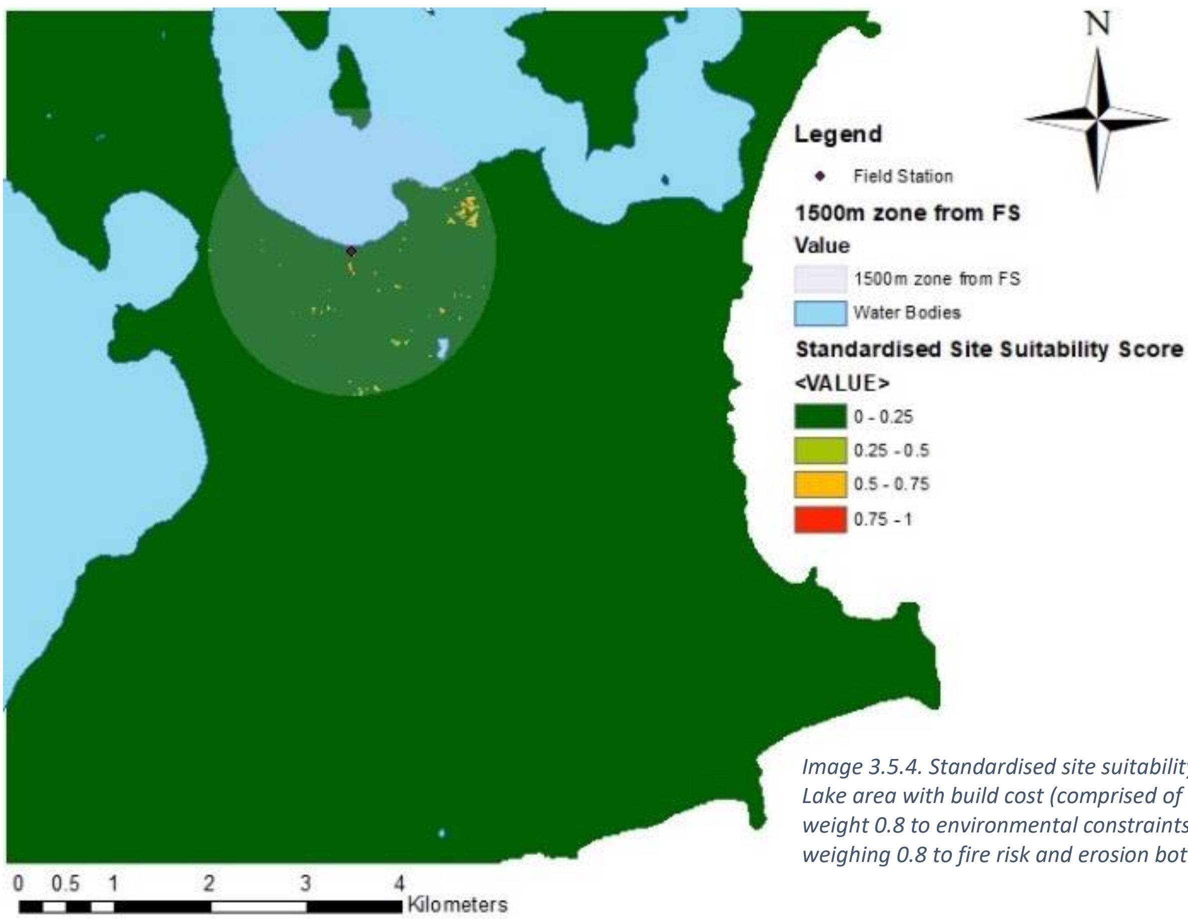

Image 3.5.4. Standardised site suitability model for Smiths Lake area with build cost (comprised of building constraints weight 0.8 to environmental constraints weighted 0.2) weighing 0.8 to fire risk and erosion both weighing 0.1 each.

When all factors were equally weighed, no areas return a standardised suitability score above zero (Image 3.4.1). When various combinations of weightings were modelled (Images 3.5.2, 3.5.2 and 3.5.4), the resulting sites of increased suitability exhibited similar distributions. Across each weighted model, concentrations of land northeast of the existing field station and dispersed patches to the south, southwest and southeast of the station returned standardised scores above 0.25. Of these models, the fire and erosion mitigation action model (image 3.5.4) returned the highest standardised score in the northeast concentration of suitable sites with areas between 0.5 to 1 while the conservation orientated model (Image 3.5.3) performed best in patches south of the existing field station with many patches score between 0.75-1.

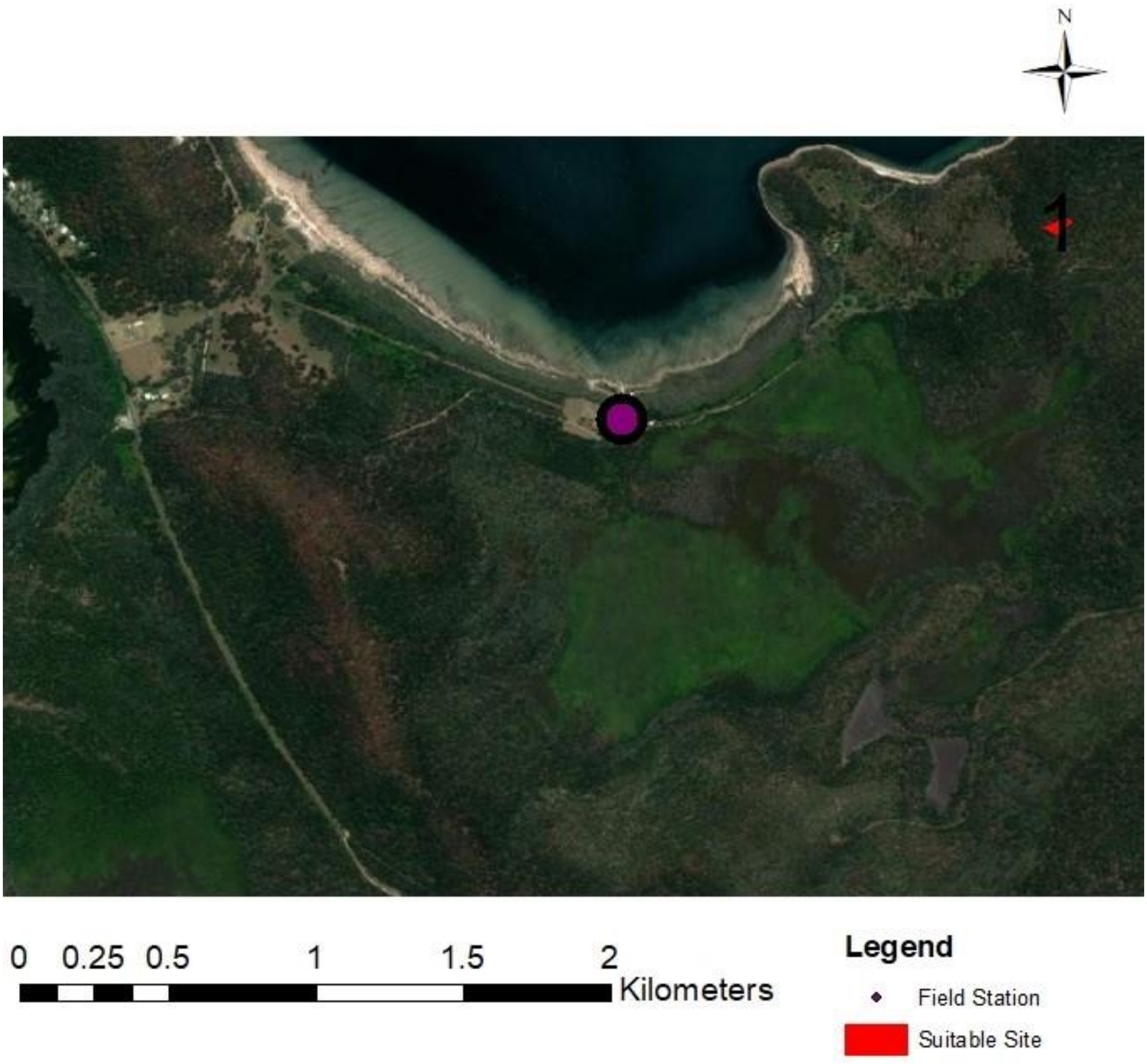

Image 3.5.5. Suitable Sites within 1500m of existing field station when equal weights are given to build cost (comprised of building constraints weighted 0.8 to environmental constraints weighted 0.2), fire risk and erosion.

Image 3.5.6. Suitable Sites with 1500m of existing field station when equal weights are given to build cost (comprised of building constraints weighted 0.2 to environmental constraints weighted 0.3), fire risk and erosion.

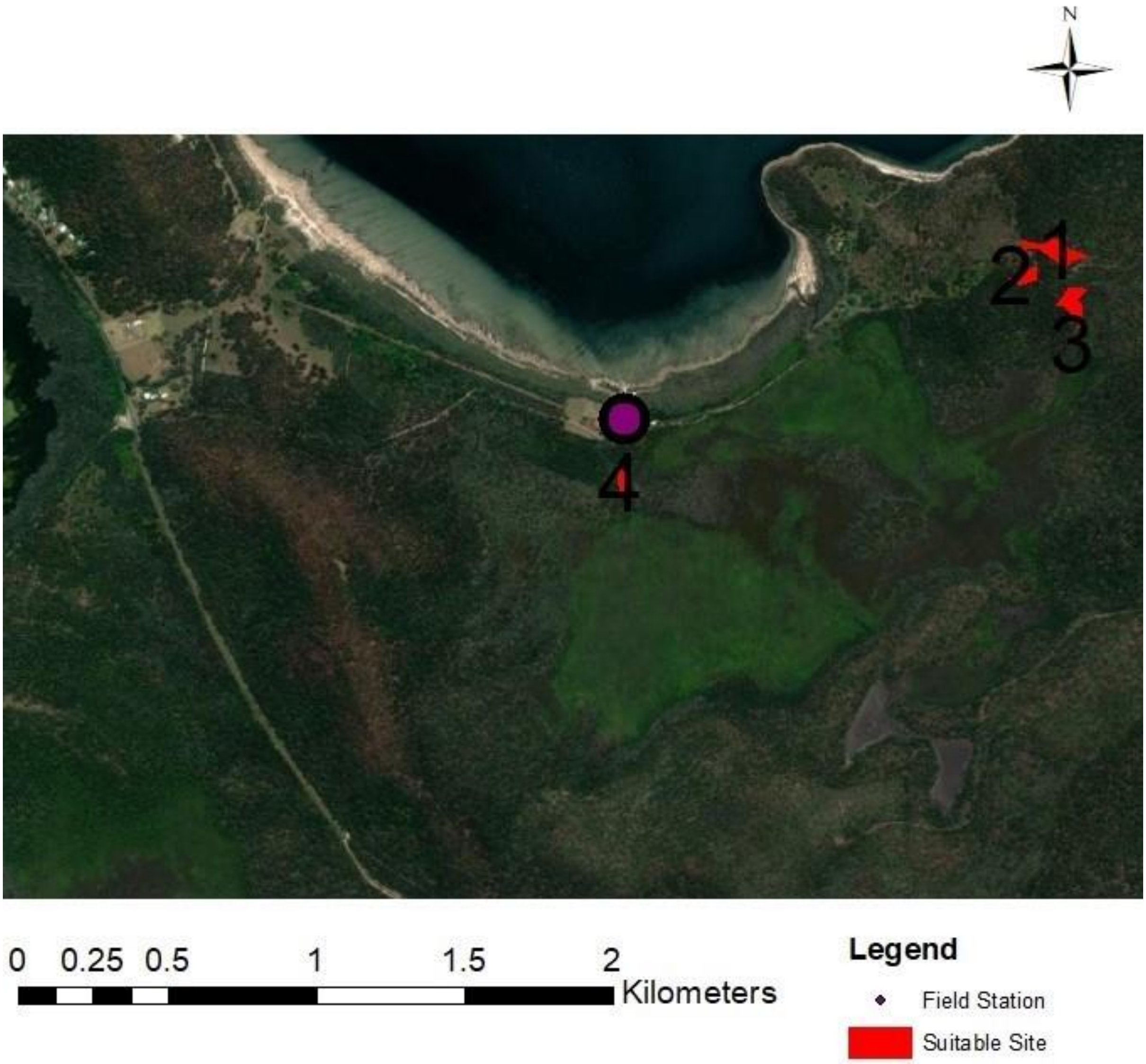

Image 3.5.7. Suitable Sites with 1500m of existing field station with build cost (comprised of building constraints weight 0.8 to environmental constraints weighted 0.2) is weighted 0.8 to fire risk and erosion both weighing 0.1 each.

Model	Site Number	Approximate Area (m^2)	Min SSS	Max SSS	Mean SSS	Visibility	Mean Winter Radiation (WH/m^2)	Mean Summer Radiation (WH/m^2)
Building Constraints prioritised	1	2000	0.508	0.632	0.575	Visible from road	409427	474257
Conservation prioritised	1	2800	0.572	1.000	0.937	Visible from road	377163	447580
	2	8100	0.507	0.841	0.646	Visible from road	408863	473679
	3	2000	0.509	1.000	0.934	Visible from road	401901	467982
	4	2900	0.635	1.000	0.974	Visible from road	411678	474782
	5	2600	0.536	1.000	0.933	Visible from road	404648	469698
	6	4200	0.552	1.000	0.948	Visible from road	402210	468230
	7	2200	0.515	1.000	0.870	Visible from road	403255	468458
	8	3000	0.513	1.000	0.825	Visible from road	370101	441101
	9	3300	0.620	1.000	0.952	Visible from road	406004	471026
	10	4300	0.504	1.000	0.895	Visible from road	417749	479466
Building Costs & Constraints priortised over Fire Risk, Erosion & Conservation	1	7000	0.523	0.981	0.699	Visible from road	420835	481674
	2	2400	0.537	0.836	0.700	Visible from road	426196	484938
	3	5100	0.513	0.923	0.664	Visible from road	418435	479642
	4	2600	0.503	0.929	0.736	Visible from road	404992	469969

Table 3.5.1. Summary statistics for suitable sites within 1500m of existing field station across various weight ranking scenarios.

Of the three weighted site suitability models, prioritising building constraints over conservation returned one suitable location (Image 3.5.5.), prioritising conservation over building constraints returned 10 possible locations (Image 3.5.6.) and prioritising building constraints and costs over fire risk, erosion and conservation returned four suitable locations (Image 3.5.7).

All 3 weighted models had a concentration of suitable sites to the northeast of the existing field station. The conservation prioritisation model also provided a further eight suitable sites to the south and southeast of the station while the building cost and constraints prioritisation model returned and additional site directly south of the field station.

The approximate area of each site ranged from $8100m^2$ in conservation prioritisation site 2 to $2000m^2$ at conservation prioritisation site 3 and building constraints prioritisation site 1.

Mean standardised site suitability values were typically higher in conservation prioritisation sites with values ranging from 0.825 to 0.974 excluding site 2 which returned a value of 0.646. Building constraints prioritisation site 1 returned the lowest mean standardised site suitability score at 0.575.

The highest mean winter radiation values were typically found in building cost and constraints prioritisation sites ranging from 426196 WH m^2 to 404992 WH m^2. The lowest summer radiation values were found in conservation prioritisation sites (441101 WH m^2 - 479466 WH m^2).

All sites from each model were visible from nearby roads.

4. Discussion

4.1. Soil Erosion Modelling

While the soil erosion model (Image 3.1.4) returned some extreme values, most of the study site returned between 0 to 15.370 t ha^{-1} y^{-1} of erosion. Based on soil erosion modelling previously performed in the Central Hunter Valley region, this is within an expected value range (Joshi, 2018). Furthermore, the most extreme values predicted by the model are primarily found along rivers or coastal areas. The field station would not be expanded into these areas therefore, the extreme values are unlikely to impact the outcome of this report.

Areas of erosion between 2.561 to 84.538 t ha^{-1} y^{-1} that intersect coastal regions or lake banks are of concern, as they may result in increased pollution if expansion of the Smiths Lake Field Station were to occur in these areas.

Although the range of soil erosion values is acceptable, there is significant uncertainty on the error associated with this model. While the ANUDEM model (Image 2.1.3) the S and L factors (Images 3.1.1/2) were calculated from had a RMSE of 5.08, no error measurement was provided with the K factor raster (Image 2.1.2). Furthermore, C factor values can vary significantly between different vegetation types at different stages of succession (Yan et al., 2003). Vegetation type and succession stage were not incorporated into our model with respective C factor values of 0.004 and 0.042 assigned to all areas of intact vegetation and exposed soil (Rosewell, 1993). It is therefore likely that this model fails to capture the true variability of soil erosion across the study site. future Smiths Lake soil erosion models should consider vegetation type specific C factor values to increase model accuracy.

4.2. Fire Risk Modelling

The areas which would be most controllable in a fire are those near urban areas, the lake and the coastline. The constraints that were used were assumed to be spatially and temporally consistent across the study. The change in wind, aspect and ridgelines were not considered. Ager (Ager et al., 2011) found that semi- empirically derived models do not include fire-fuel interactions in a circumstance of a fire. Weather conditions on the day are often not considered in the models and that is why the severe bushfire model was used (Kanga et al., 2014).

4.3. Conservation Model

The Conservation model combines the restricted locations for construction of site based on different conservational parameters such as endangered flora and fauna, vegetational areas and wetlands. All the regions under black are the places which have a very close proximity to the conservational areas, the regions which are highlighted under white are the ones where the building construction would not have any impact on the conservational areas. The regions in between these two zones have a value between 0 and 1, depending upon its proximity to the conservational regions with 0 being restricted zone and 1 being permitted zone for construction.

4.4. Building Constraints Model

The building model evaluates the different aspects of the site based on its proximity to power grids, sealed and unsealed roads. The building model is a combination of different raster layers which contain the proximity mappings from each layer mentioned above. This model provides an overall estimation where all the construction of the site should take place in order to have optimal distance from roads and power grids in order to have a low amount of cost for construction. The regions under the black zone are the locations where the construction should be considered, while the regions under white zone are the locations where the cost of construction of the building will be high due to its proximity to the nearby roads and power grids.

4.5. Site Suitability Models

Evidently, if expansion on UNSW's Smith's Lake Field Station is to occur, a compromise must be made on at least one of the factors that have been analysed to determine site suitability (Image 3.5.1). Subsequently, three weighted models were developed to provide decision makers with clear directive depending on the various factors they may wish to prioritise.

As can be observed from the number of suitable sites each model returned (Table 3.5.1), building constraints are a limiting factor for site suitability across the Smith's Lake study area. When building constraints are prioritised over conservation, modelling suggests just one suitable site (Image 3.5.5). This is compared to 10 sites when conservation is prioritised over building constraints. Furthermore, the mean standardised suitability score of the single building constraints prioritised site was 0.575, narrowly exceeding the 0.5 required score to be deemed suitable if decision makers choose to prioritise building constraints.

As previously mentioned, prioritising conservation provides significantly more options (Image 3.5.6). Most suitable sites typically returned high standardised values and it could be assumed that any site with a mean standardised score greater the 0.8 is highly suitable (Table 3.5.1). Site 4 returned the highest mean standardised value of 0.974. Furthermore, modelling suggest site 4 has the second highest mean winter radiation value of the conservation sites. This allows for building design to maximise winter sun. Inversely however, the site also has the second highest mean summer radiation so that trade off will need to be considered. If minimising mean summer radiation is desired, site 8 has the lowest value of the conservation prioritised sites and has a mean standardised score of 0.825.

While conservation site 2 has the largest area of $8100m^2$, it also has a lowest suitability score (0.646) compared to other conservation sites. If conservation is prioritised and the area needed is greater than $4300m^2$ (Site 10, secondly largest conservation site), multiple sites could be developed on. Additionally, the single building constraints prioritised site could be developed on along with conservation sites to offset the impact prioritising conservation has on building costs.

Finally, suitable sites when building constraints were prioritised over conservation, fire risk and erosion were also modelled. This was done to allow UNSW decision makers the option to employ mitigation methods against fire and erosion and to develop on otherwise unsuitable sites, especially if no sites in the previously discussed models were deemed suitable by decision makers. As this would increase costs, building restraints were also weighted above conservation concerns. The mean standardised score for the four sites deemed suitable by this model ranged from 0.664 to 0.736. This would indicate that despite removing much of the influence of fire risk, erosion and conservation, these sites are only somewhat suitable for achieving building constraint outcomes. Given this and the numerous options in the building prioritised and conservation prioritised models, its is not advised any of these sites are developed on.

Recommendations

Based on the outcomes of this report, several recommendations are presented below. Each recommendation presents the best advised sites for extension of UNSW's Smiths Lake Field Station given the prioritisation associated with each recommendation. Decision makers should determine which factors they wish to prioritise and consider the following recommendations accordingly:

If building constraints are prioritised over conservation impacts: Develop building constraint prioritisation site 1 (Image 3.5.5, table 3.5.1).

If conservation impacts are prioritised over building constraints and **Maximising winter radiation is prioritised over minimising summer radiation:** Develop conservation prioritisation site 4 (Image 3.5.6, table 3.5.1)

If conservation impacts are prioritised over building constraints and **Minimising summer radiation is prioritised over maximising winter radiation:** Develop conservation prioritisation site 8 (Image 3.5.6, table 3.5.1)

If conservation impacts are prioritised over building constraints and **Greater than 4300m^2 is required for expansion:** Develop on multiple Conservation prioritisation sites excluding site 2 (Image 3.5.6, table 3.5.1).

If conservation impacts and building constraints are to offset each other: Develop building constraints prioritisation site 2 (Table 3.5.1, image 3.5.5) with conservation prioritisation sites in accordance with winter radiation, summer radiation or area considerations as recommended above.

Prioritising building constraints over conservation, fire risk and erosion is not recommended.

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