SITE SUITABILITY ANALYSIS FOR SOLAR PV POWER PLANT IN NORTHEASTERN DISTRICTS OF KARNATAKA STATE USING GIS

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SC13B158

Guide:

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INTRODUCTION

- Increased need for sustainable energy sources amidst global warming due to use of carbon based fuels to generate energy
- Support from governments by providing tax credits and programs to look for new methods of renewable energy generation
- Solar Energy – one of the major source of renewable energy
- The government of India considers use of these resources critical step towards more sustainable future
- Under Solar Mission, aim is to reach a grid-connected power of 100GW by 2022.
- The country has vast potential for solar power generation with most parts receiving 4-7 $kWh/m^2/day$
- Solar energy can be harnessed in the country by both Concentrating Solar thermal power(CSP) and Photovoltaic (PV) method

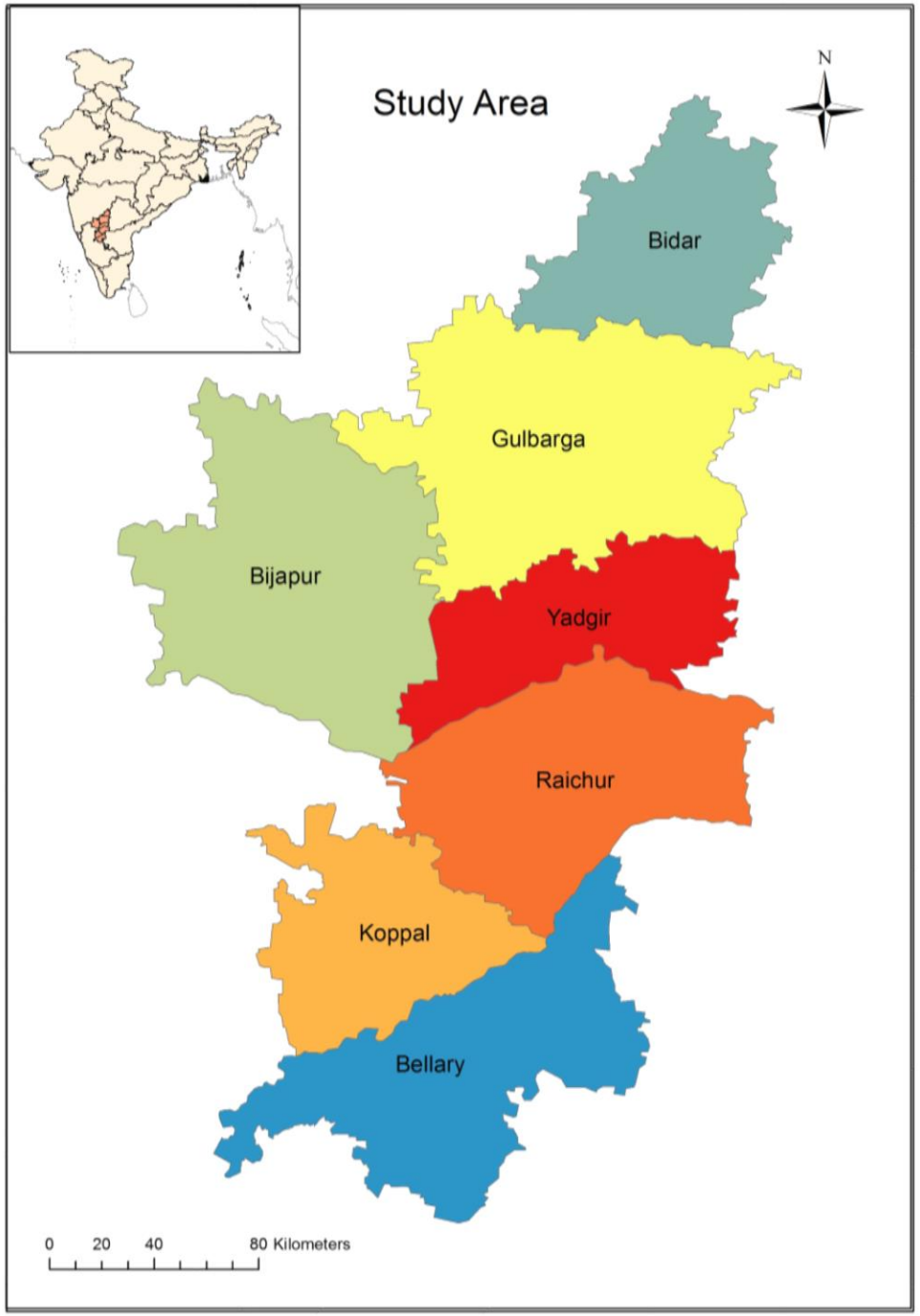
OBJECTIVE

- To identify criteria based on technical, socio-economic and environmental importance to exploit solar energy
- To generate all the required map layers to identify the suitable location for the construction of solar PV power plant
- To generate a Land Suitability map for the entire study area based on 5 classes (Excellent, Good, Fair, Low and Poor) of suitability and also find a district-wise distribution of these classes

THE STUDY AREA

- India has vast potential for solar power generation
- States like Gujarat, Rajasthan and Tamil Nadu have already an established network of solar power plants
- These states are generating solar power at large scales of 1000s of MW
- But the state of Karnataka is still to progress on that frontier. Even though there's high potential for solar power, the region lacks large scale power projects.
- For this project, seven north-eastern districts of Karnataka state were chosen as the study area
- It includes Bidar, Gulbarga, Bijapur, Yadgir, Raichur, Koppal and Bellary districts

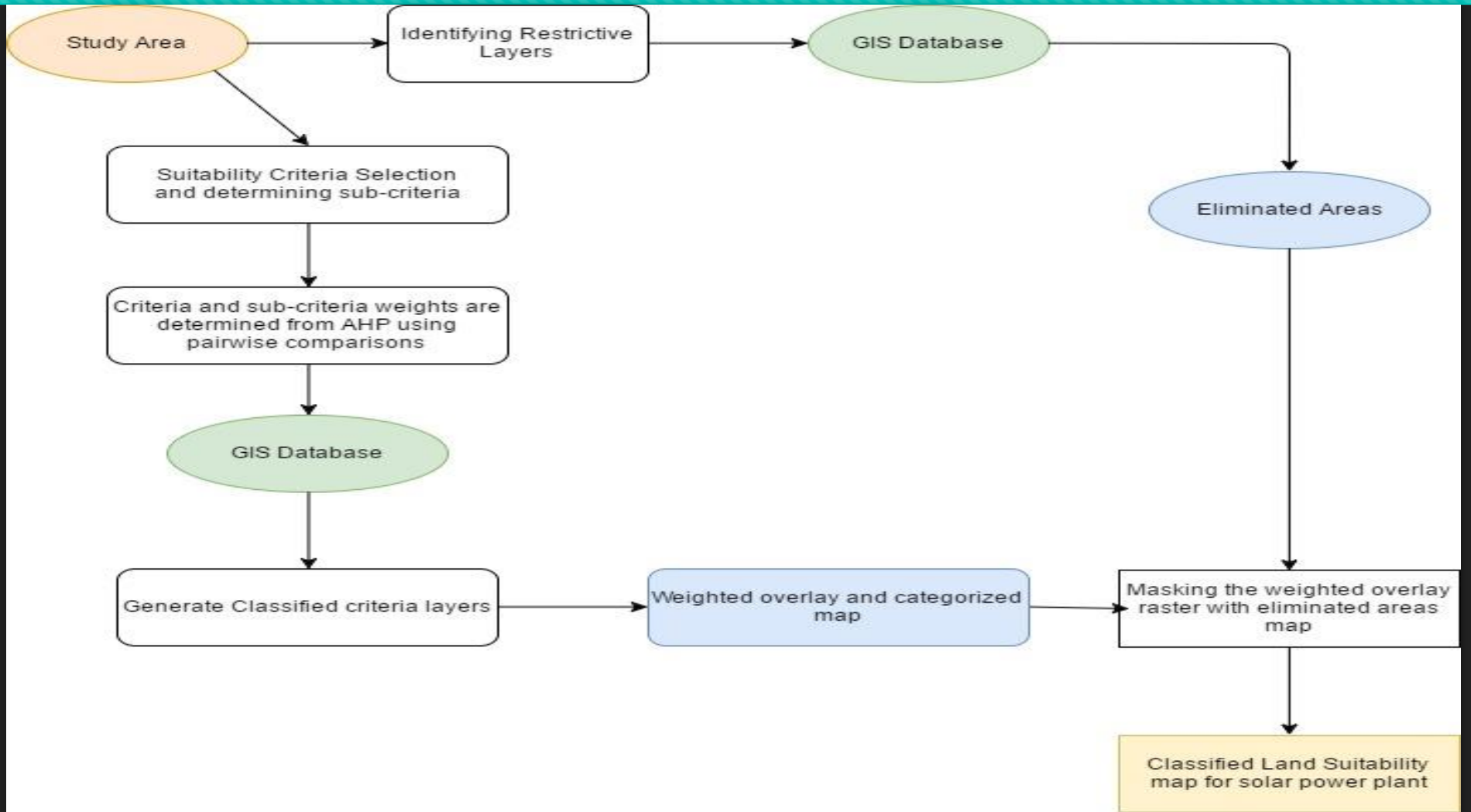
- The region is mostly semi-arid with annual solar radiation incident over the region amounting around 2000 kWh/m^2/year
- Insufficient electric supply throughout the year and power outages in the region
- Capable of solar power generation throughout the year
- Since the region is in Deccan plateau, these flatlands are well suited for large scale plants.
- Lies in the focus of three major urban agglomerations Bengaluru, Hyderabad and Pune helping the infrastructure requirements
- Several financial incentives to establish industries and explore solar energy in the region by both State and Central governments



PROPOSED FRAMEWORK

- Identify the areas to be eliminated/dismissed in the region for establishing solar power plant by identifying criteria based on technical, economic, social and environmental constraints
- Generating map layers associated with defined constraints and preparing a map of all eliminated/dismissed regions in GIS
- Identifying and evaluating the criteria influencing the solar energy potential for land suitability modelling using the Multi-criteria Decision approach (MCDA)
- Determine the weights of evaluation criteria using Analytic Hierarchy Process (AHP)
- Generate all the criteria map layers in GIS
- Overlaying of map layers in GIS via Simple Additive Weights (SAW) method and preparation of the land suitability map of regions for establishing solar power plant

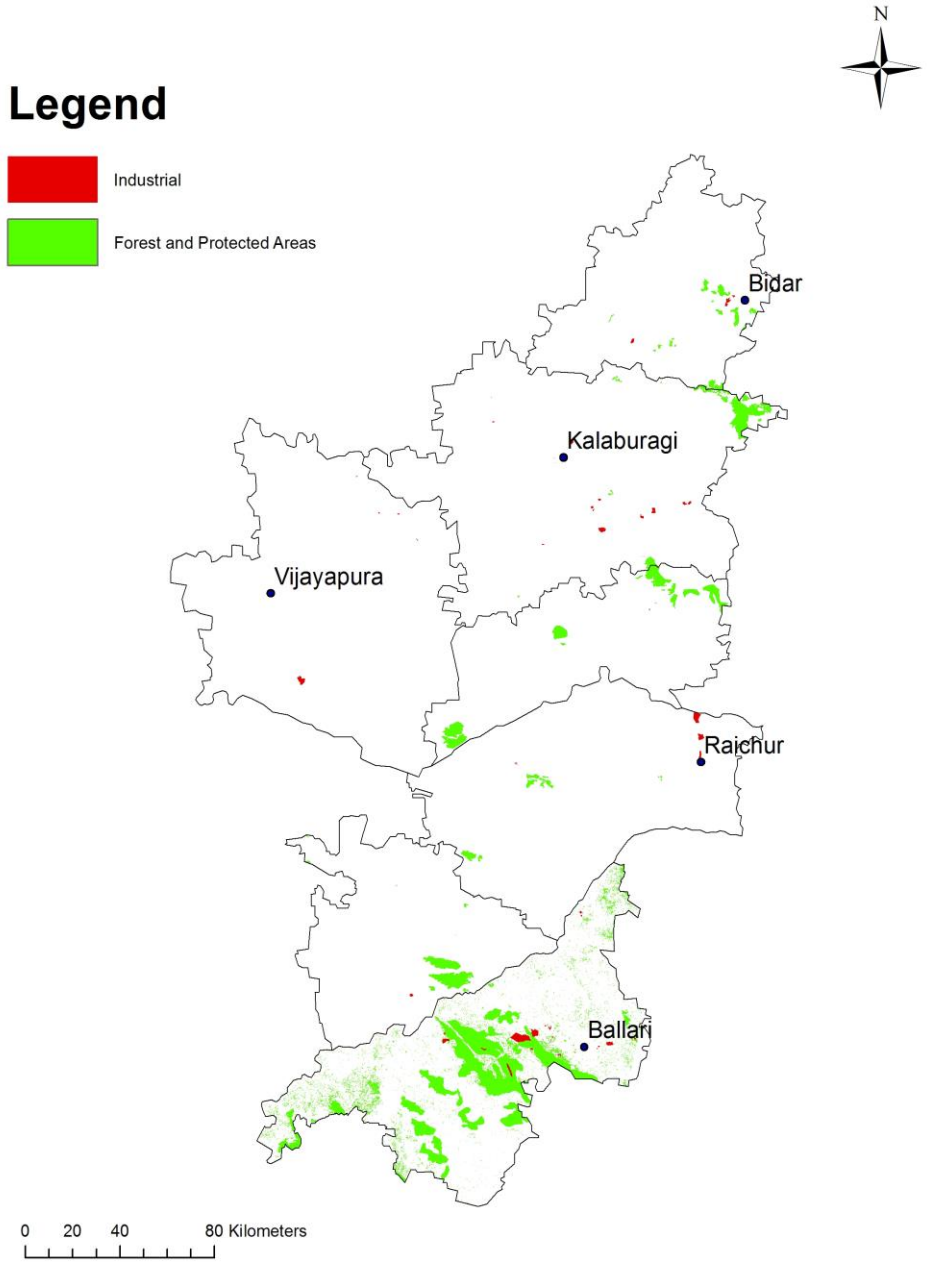
PROPOSED FRAMEWORK



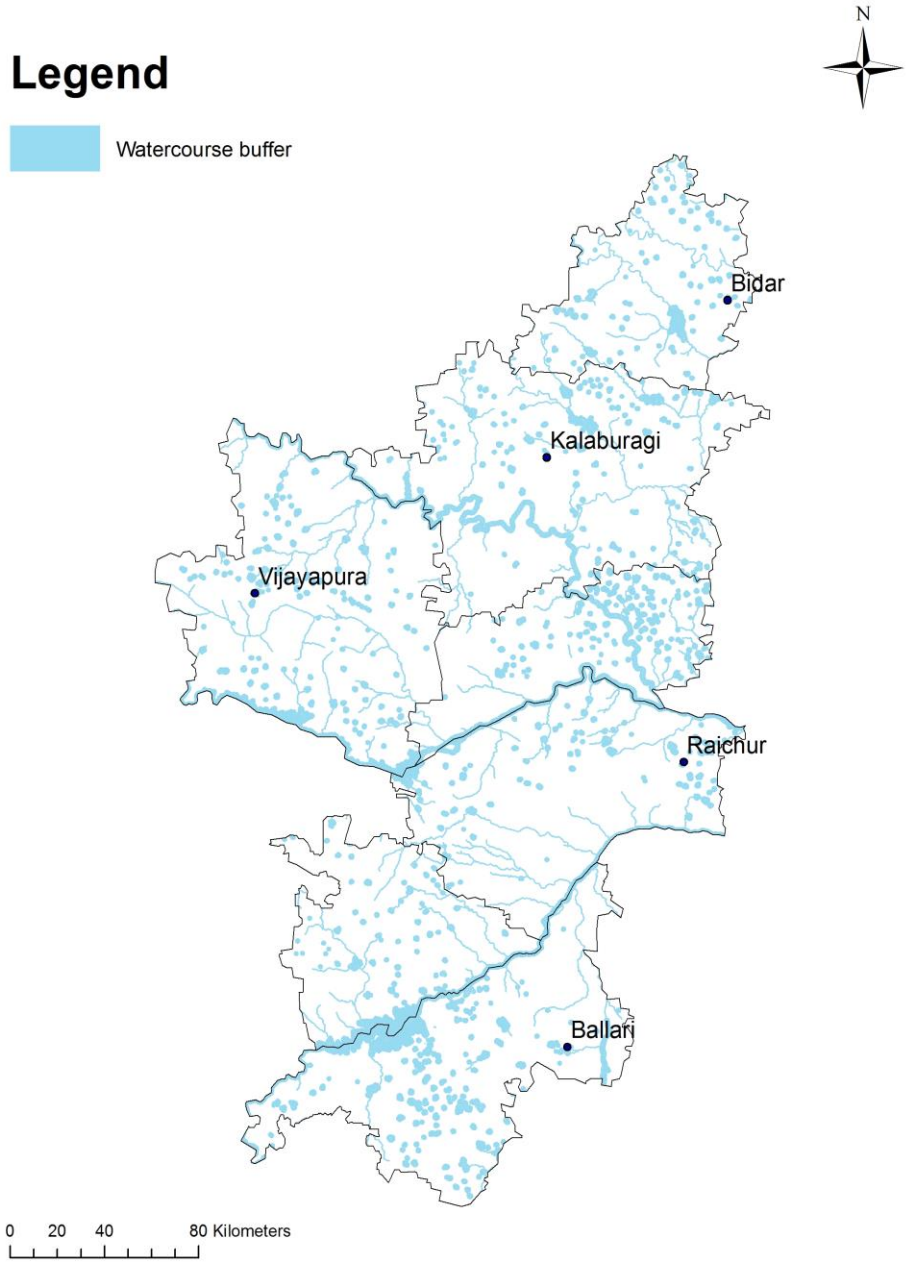
ELIMINATED AREAS

- It's necessary to remove some of the inappropriate areas from the study considering all the social, economical, technical and environmental constraints and areas to be eliminated are:
- Regions with a solar radiation lower than 1300 kWh/m^2/year
- Regions with land-use category of protected regions such as national natural monuments, wildlife conservation areas and national parks etc
- Regions located closer to the minimum distance determined for the criteria of cities and populated centres (3000m from cities, 1500m from towns, 500m villages)
- Land-use such as forest, industrial areas, quarry and mining areas are not suitable options for the construction of solar plant
- Regions with a distance less than 0.1km from roads
- Regions with a distance less than 1km from rivers, wetlands, dams, 500m from lakes, 300m from streams
- Regions with a slope greater 8% is considered as unsuitable area

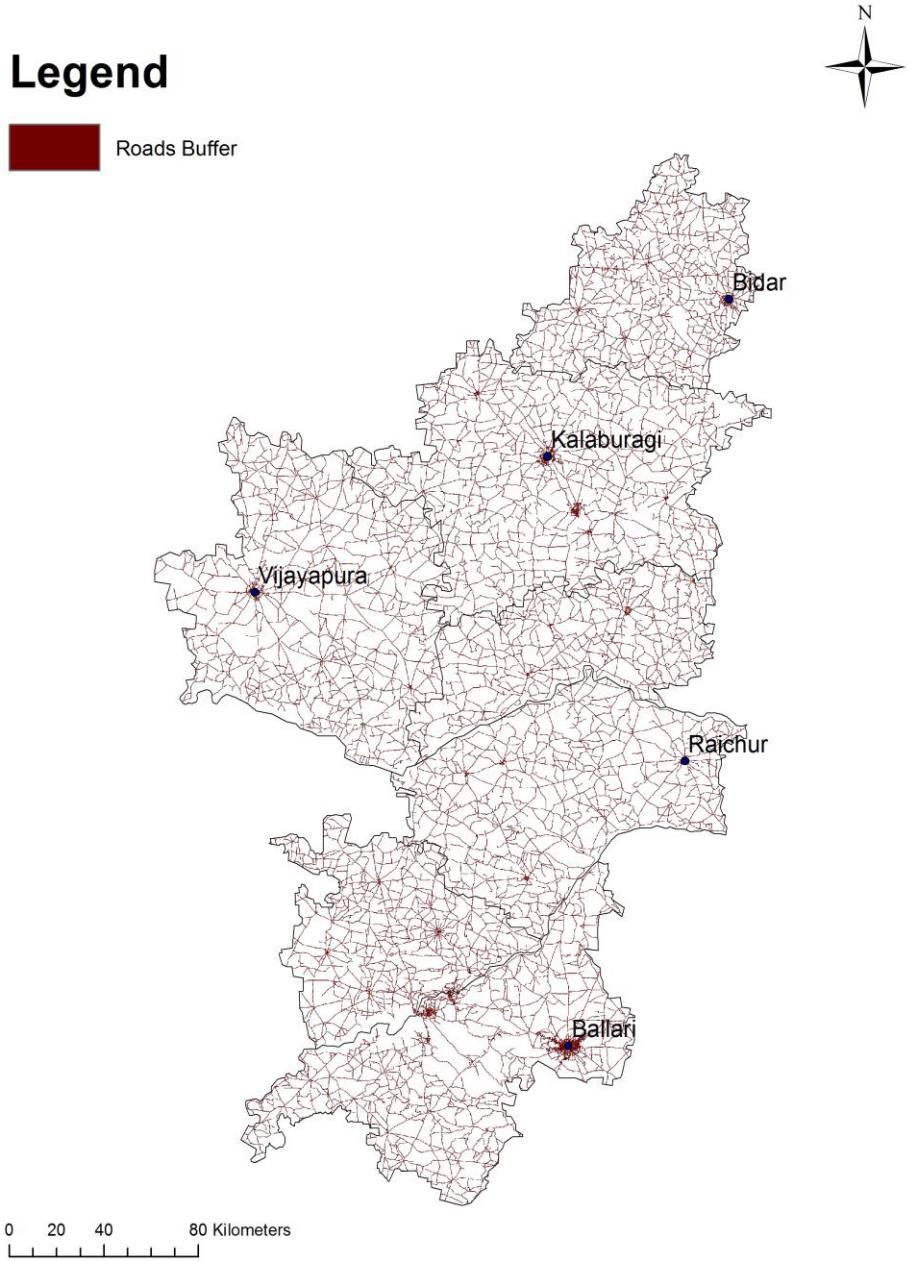
Industrial, Forest and Protected Areas



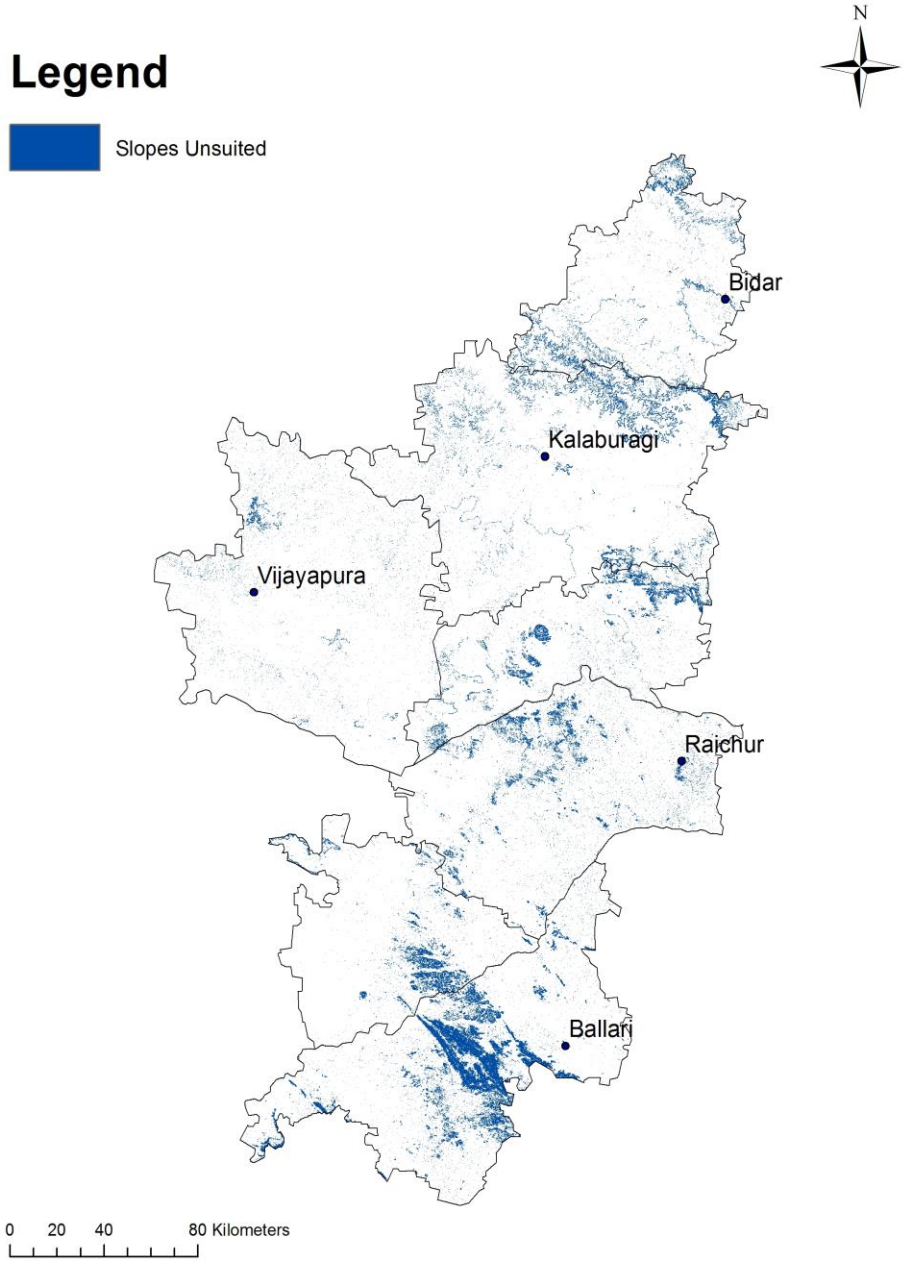
Water bodies buffer



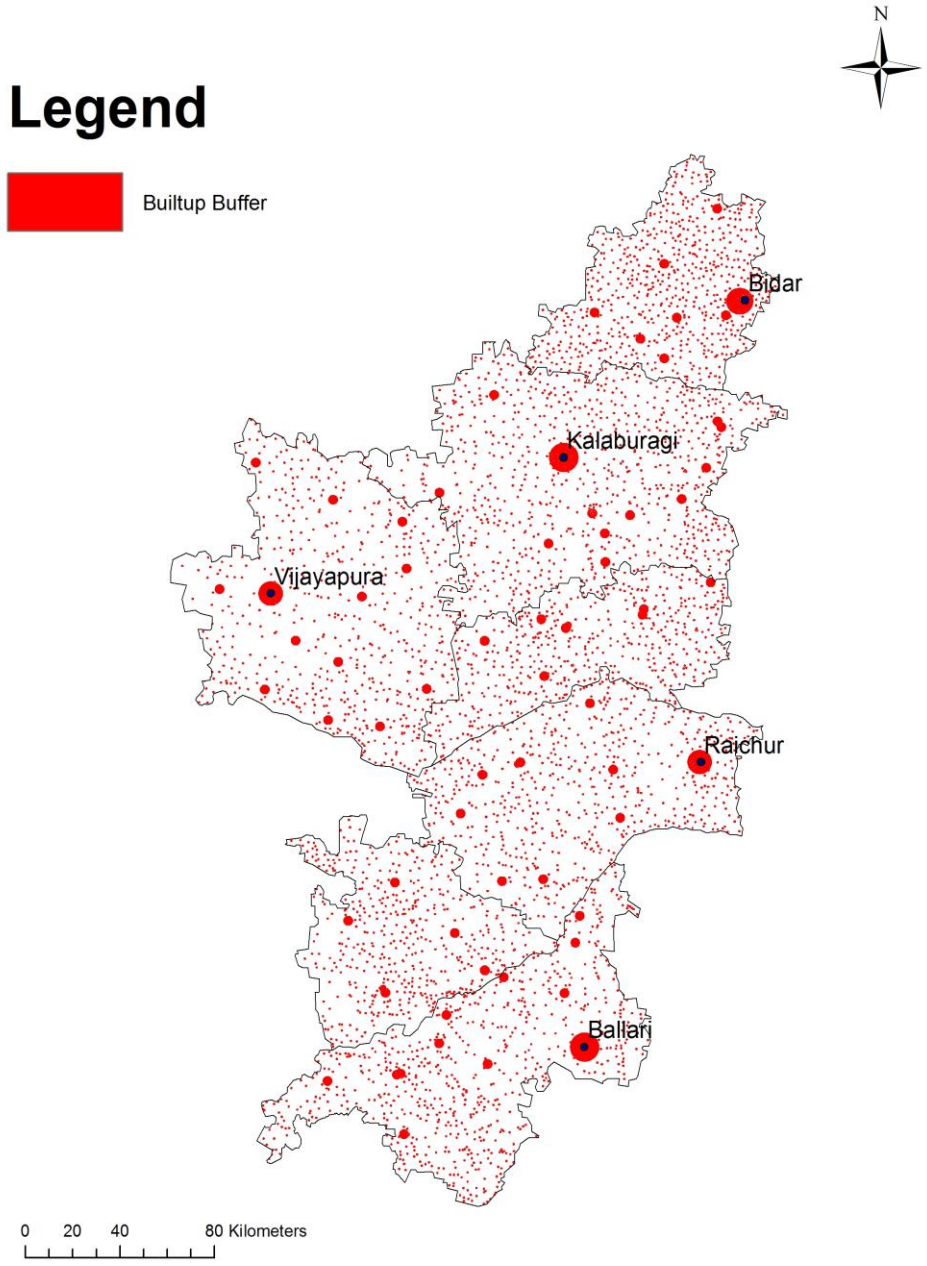
Road buffer



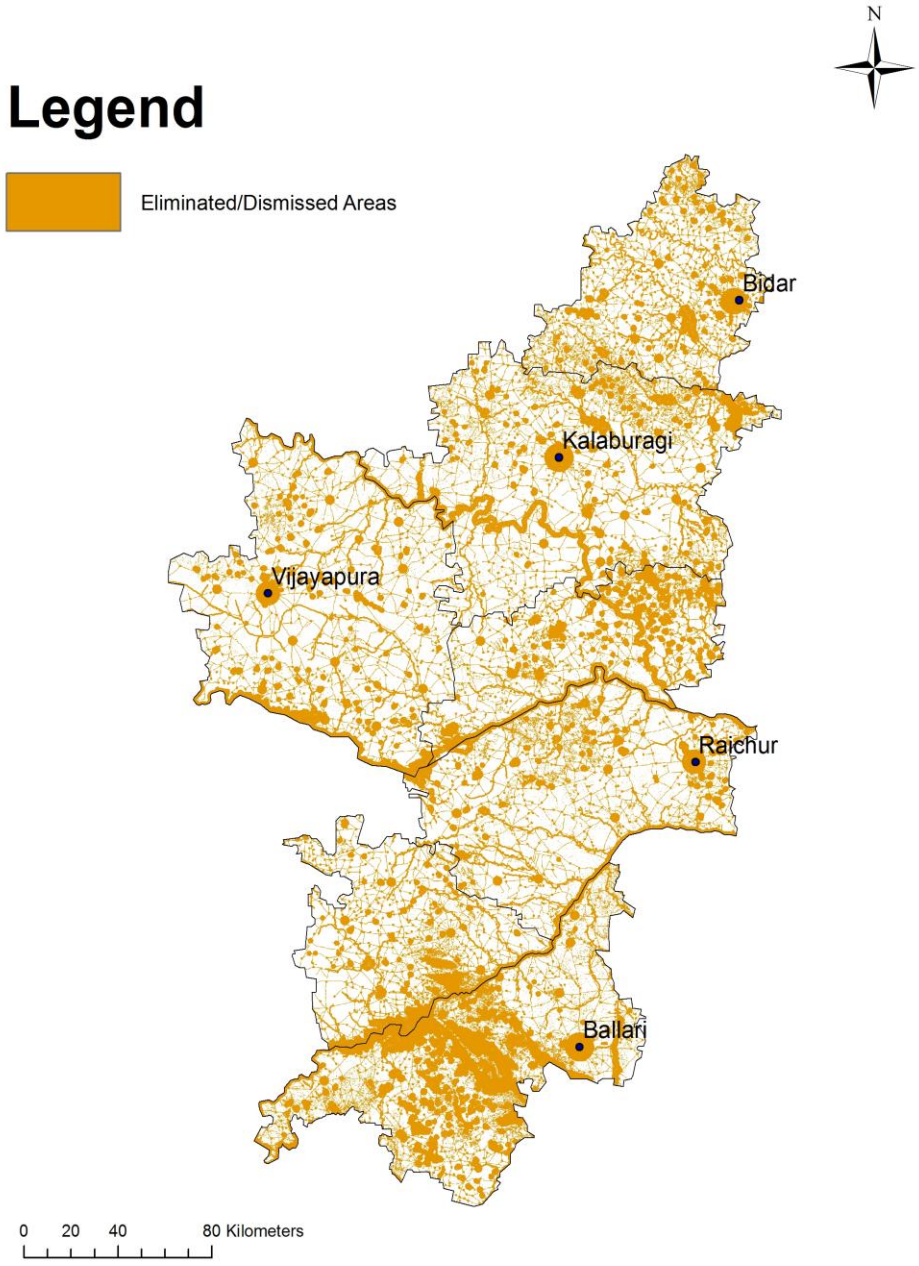
Unsuited Slopes



Built-up Areas and buffer

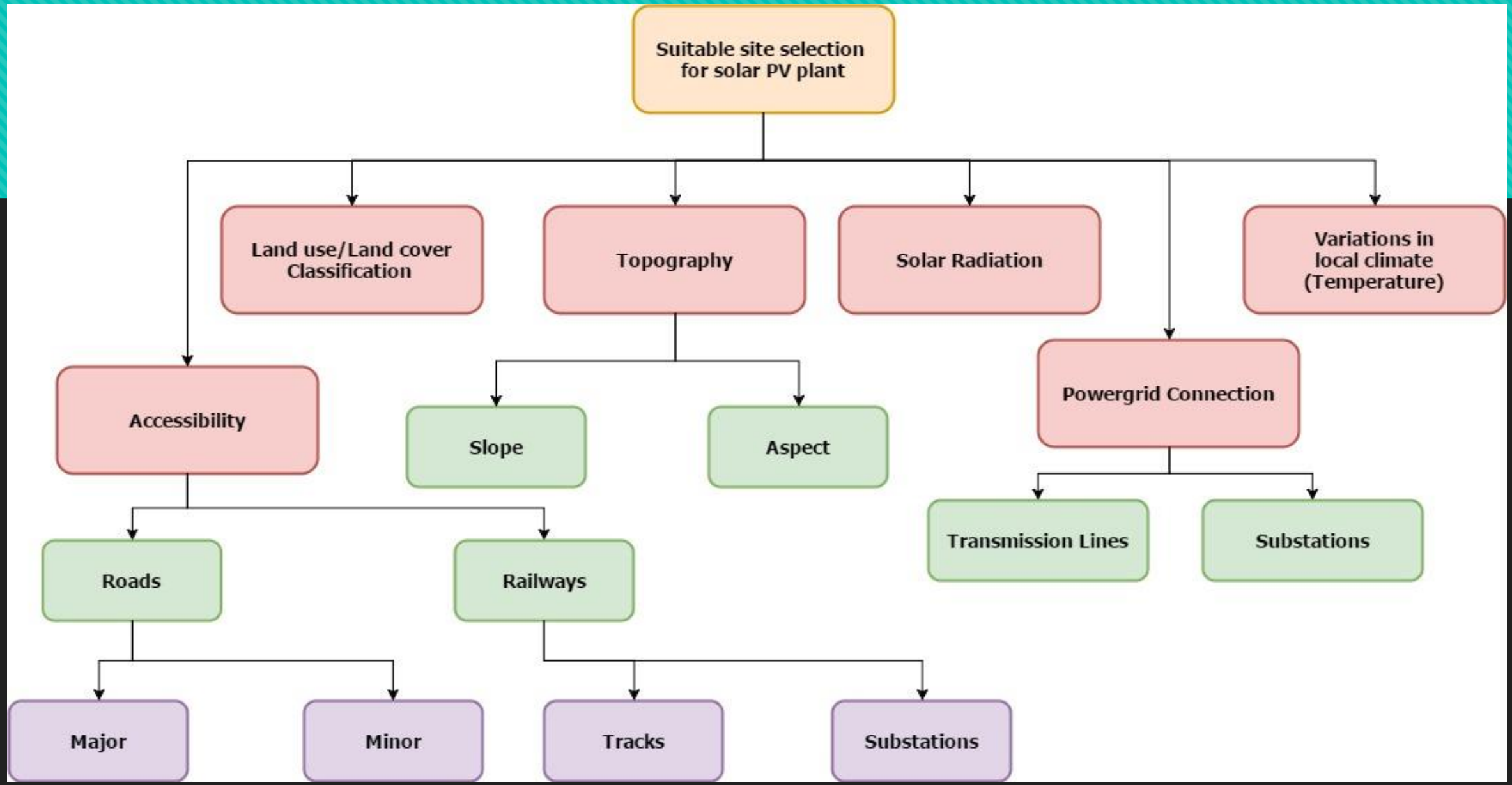


Combined map of Eliminated/Dismissed Areas



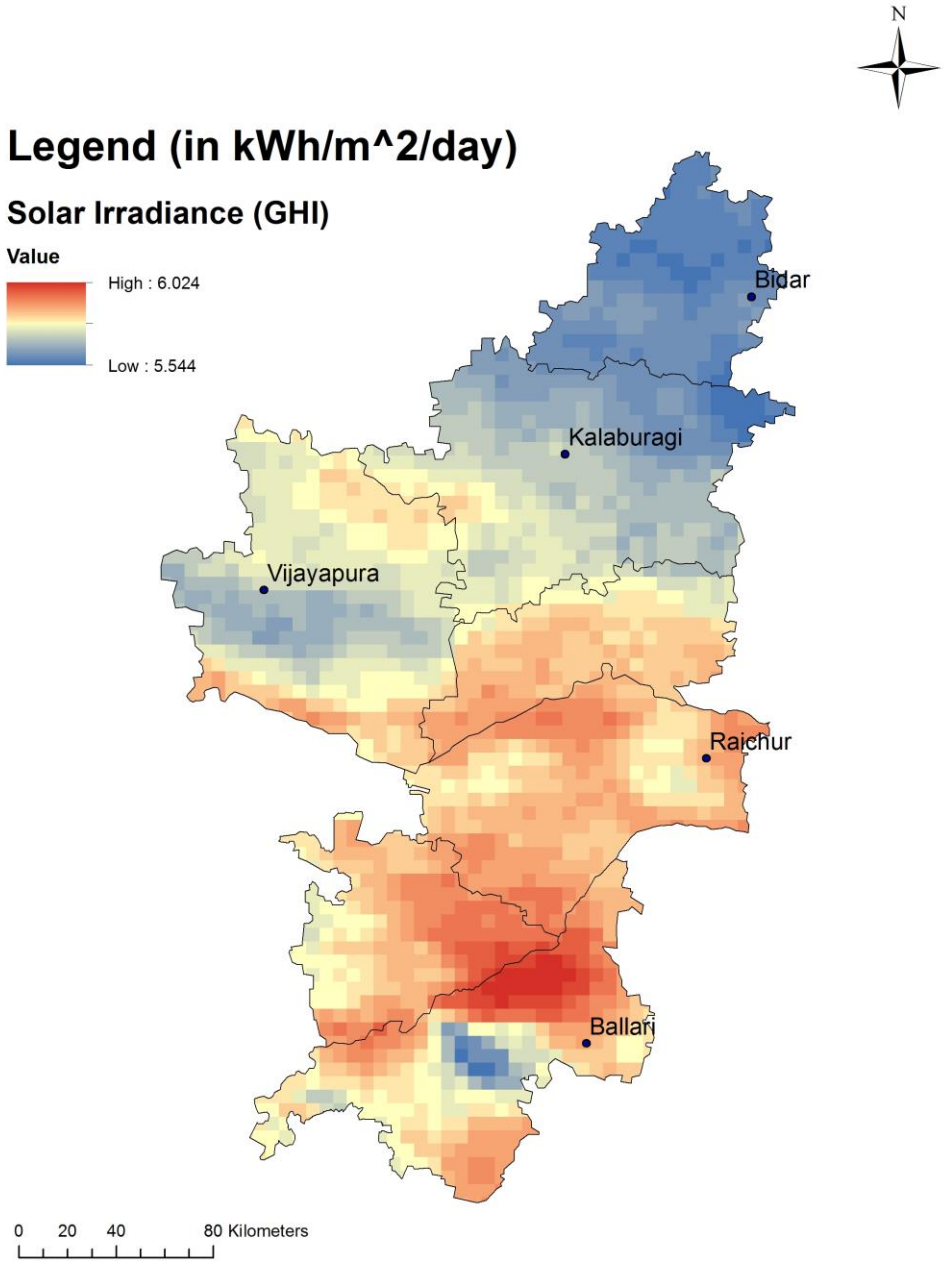
EVALUATION CRITERIA

- There are a lot of criteria to select suitable locations in different groups to establish a solar power plant
- 6 main criteria were considered for the study by reducing the complications of study and prioritising the GIS related criteria
- The hierarchy of the evaluation criteria are shown in the following figure


Suitable site selection for solar PV plant
Land use/Land cover Classification
Topography
Solar Radiation
Variations in local climate (Temperature)
Accessibility
Slope
Aspect
Powergrid Connection
Transmission Lines
Substations
Roads
Railways
Major
Minor
Tracks
Substations

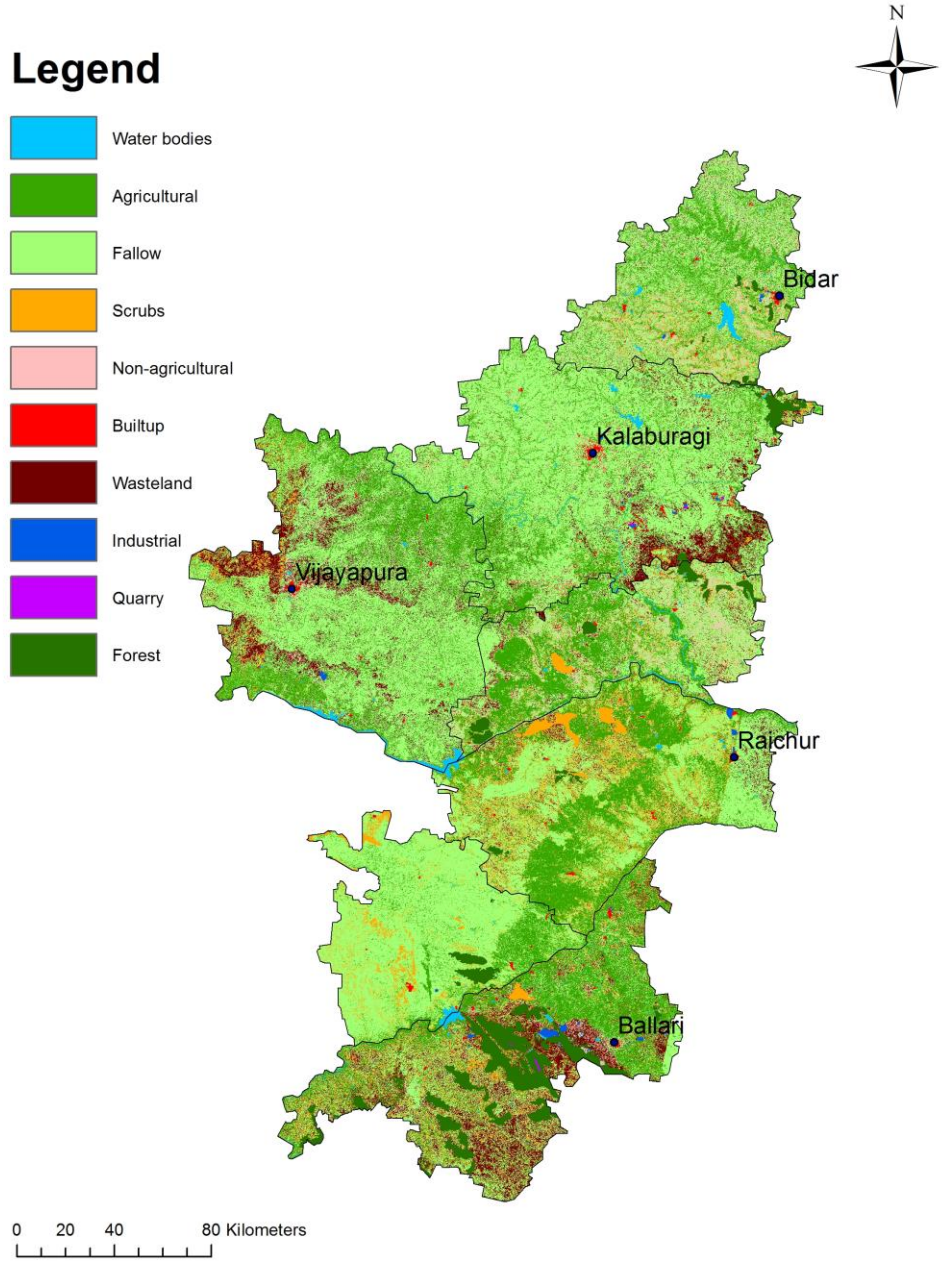
SOLAR RADIATION

- Solar radiation is one of the most important factor for choosing an optimal location for solar power plant
- Required sufficient radiation throughout the year with minimum of 3.5 kWh/m^2/day
- Data used – monthly observation of Surface Incoming Shortwave Radiation (SIS) over 6 years (2010-2015) – obtained form the Satellite Application Facility on Climate Monitoring (CMSAF)



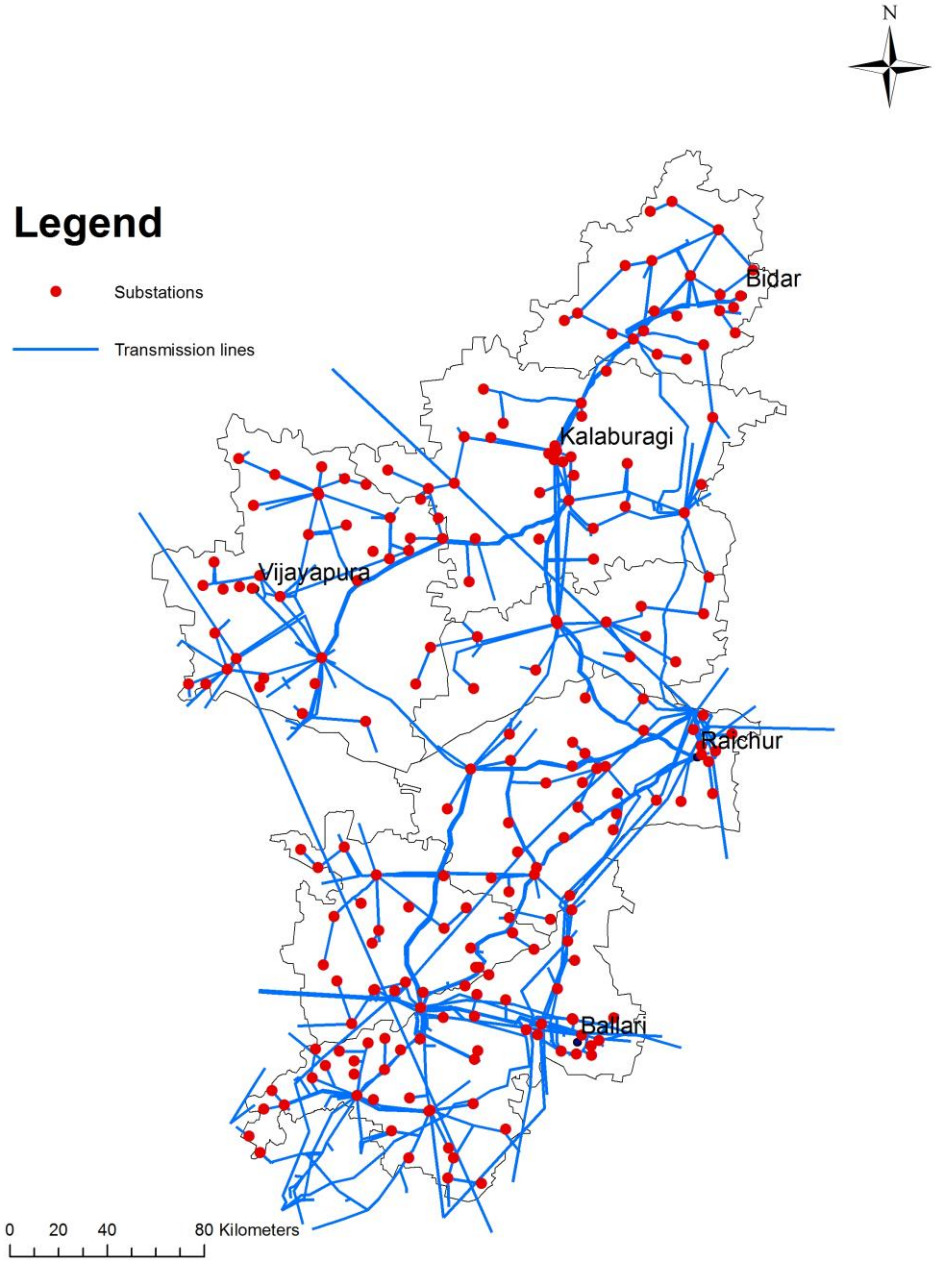
LAND USE/LAND COVER CLASSIFICATION

- Solar PV plants are ideally built on low value lands.
- Required to have the land use/land cover classification data in different levels such as agriculture, fallow land, wasteland, scrubs and non-agricultural land
- Wastelands are the most suitable locations
- LULC classification was done for the study, on Landsat 8 OLI data using the Bands 3, 4, 5, 6, 7
- Classification has an overall accuracy of 95.3%



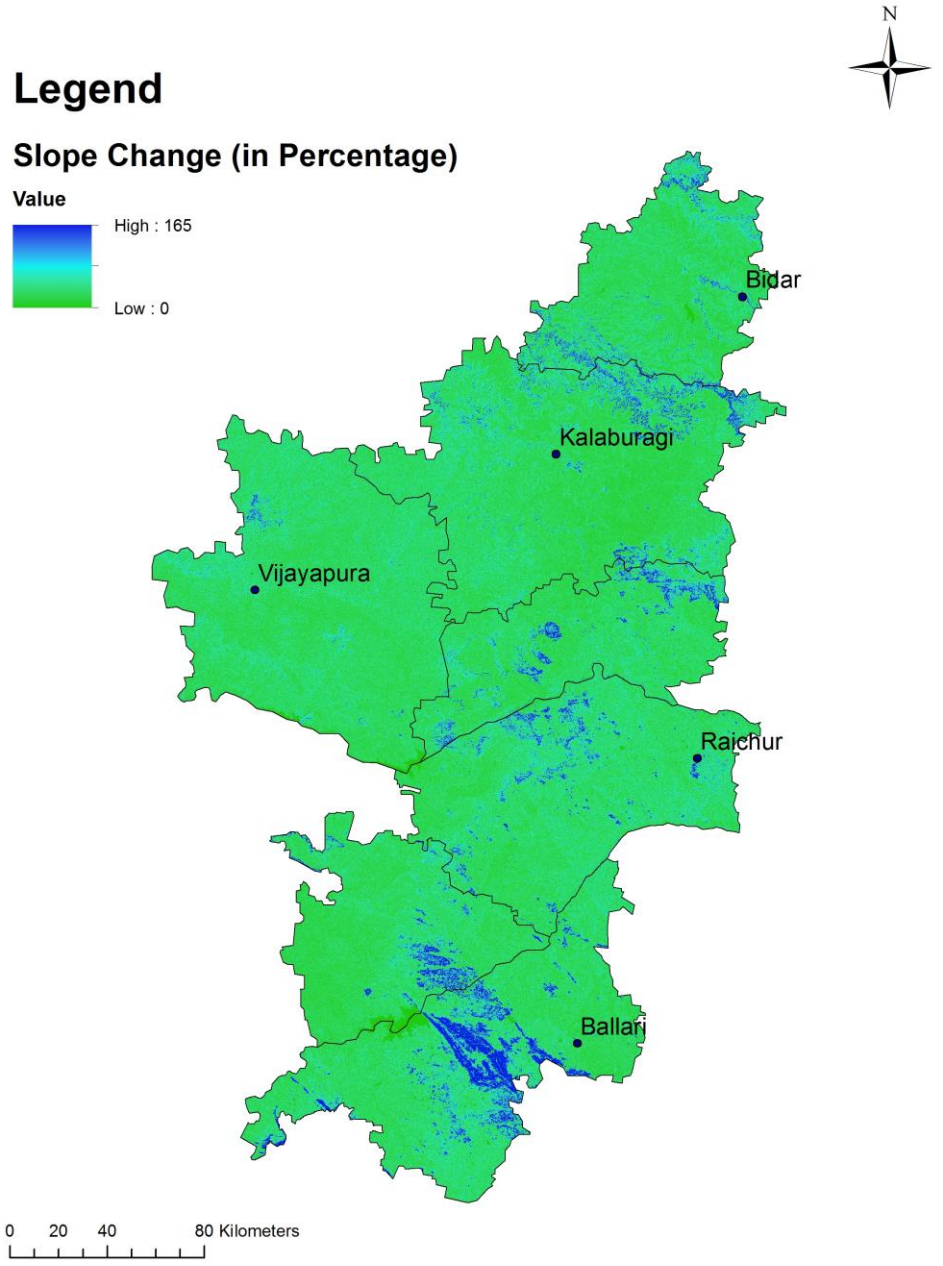
POWERGRID CONNECTION

- Connecting the solar plant with the powergrid is essential aspect of the study
- Proximity of substations and transmission lines is to be taken care of since costs of installation of power transmission lines are higher for longer distances
- Reduce electricity losses and economic advantages
- Data – KPTCL, Bengaluru
- Raster data was digitised, georeferenced using GIS to get the features of transmission lines and substations



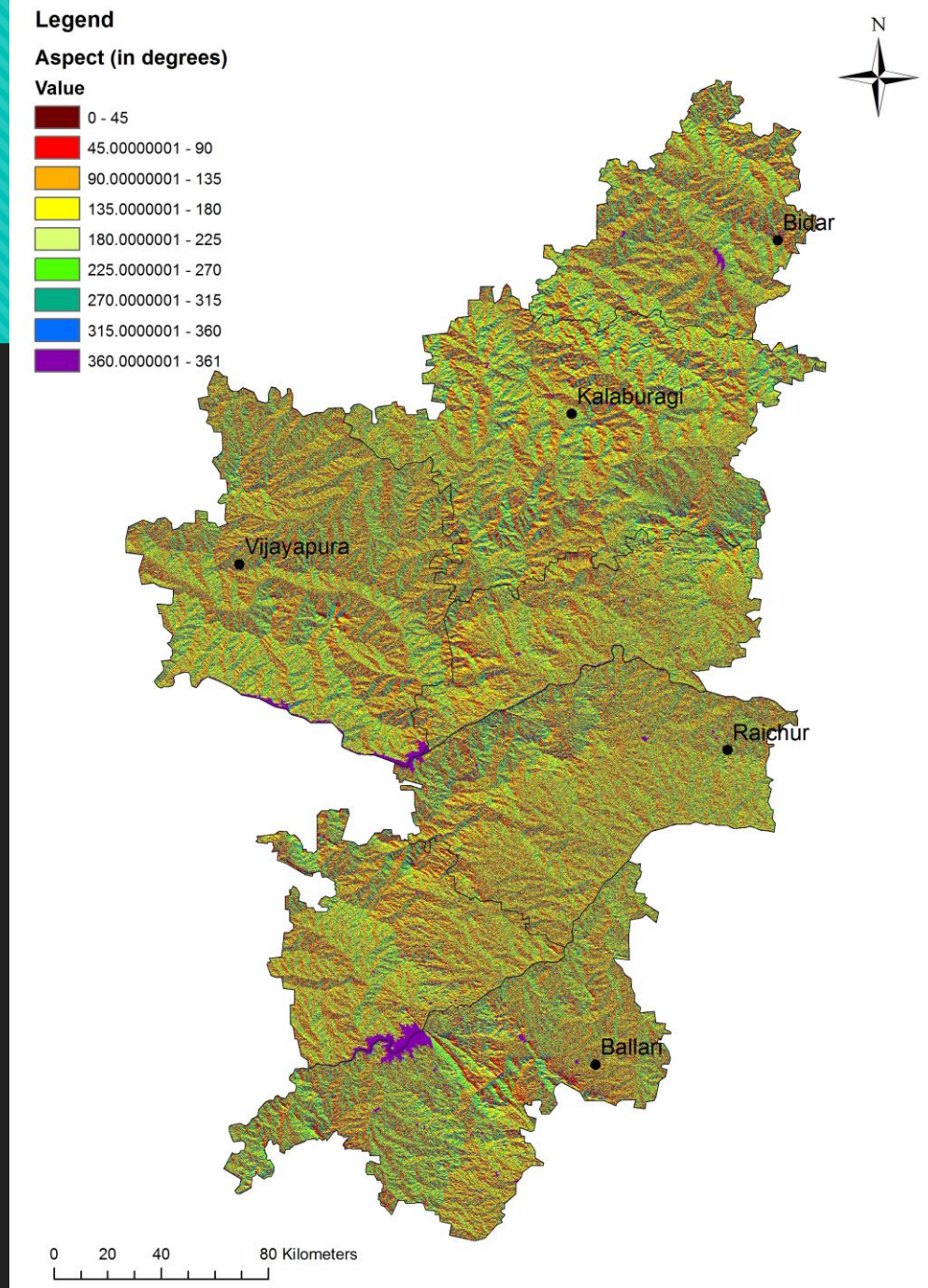
TOPOGRAPHY (SLOPE)

- Since solar plants are established in larger areas and shading in any manner should be avoided, site is expected to be flat ideally.
- Change in slope for the site should be minimal
- For this study, a slope change of less than 8% is considered as suitable
- Generally, slopes above 4% have lower priority due to panels shadowing the adjacent row of panels



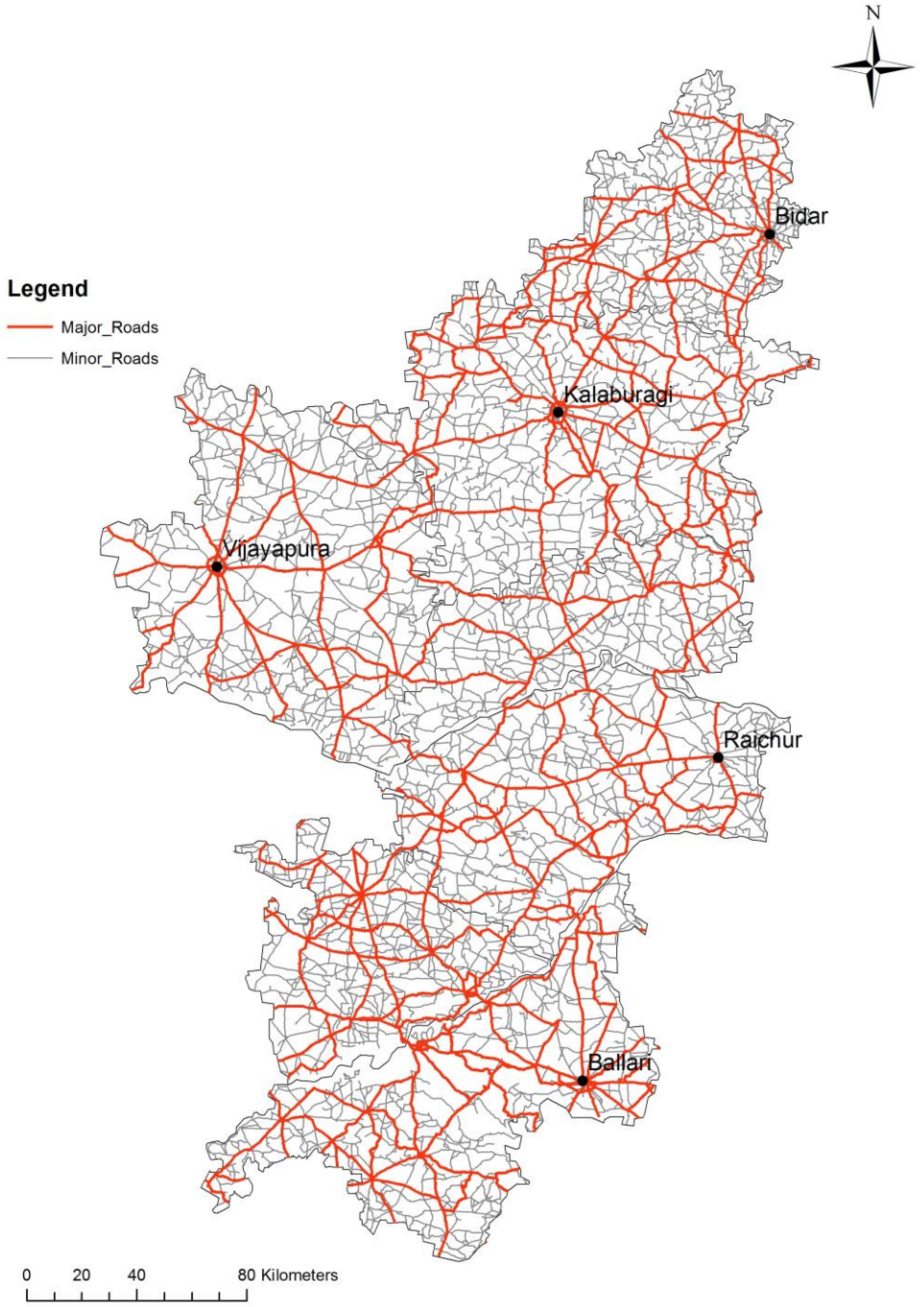
TOPOGRAPHY (ASPECT)

- Based on the location whether it's in northern or southern hemisphere on earth, slope of the location can be slightly south-facing or north-facing
- It helps in making installation of modules simpler and reduces costs of technical modifications to panels
- Aspect angles from 135° to 225° are suitable for the study
- Data – SRTM data from USGS explorer (resolution -1 arcsec) to generate slope change and aspect map



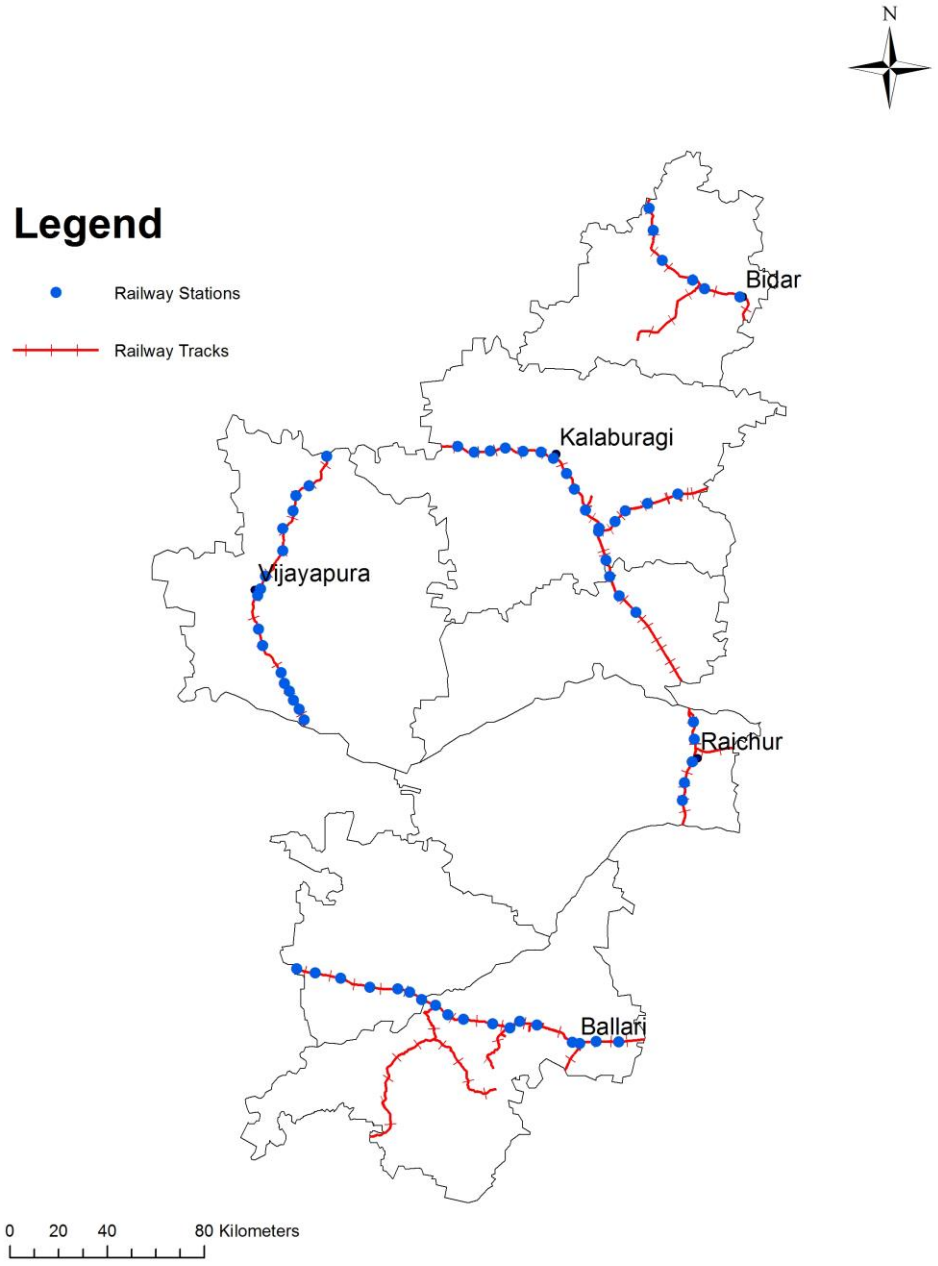
ACCESSIBILITY (ROADS)

- Access roads to the solar plants are necessary to provide the infrastructure
- Expensive to construct new access roads, therefore necessary to analyse this criteria, which would help reduce the cost of construction by providing easy access
- Two sub categories: Major roads – consisting of state and national highways, Minor roads – roads connecting rural areas



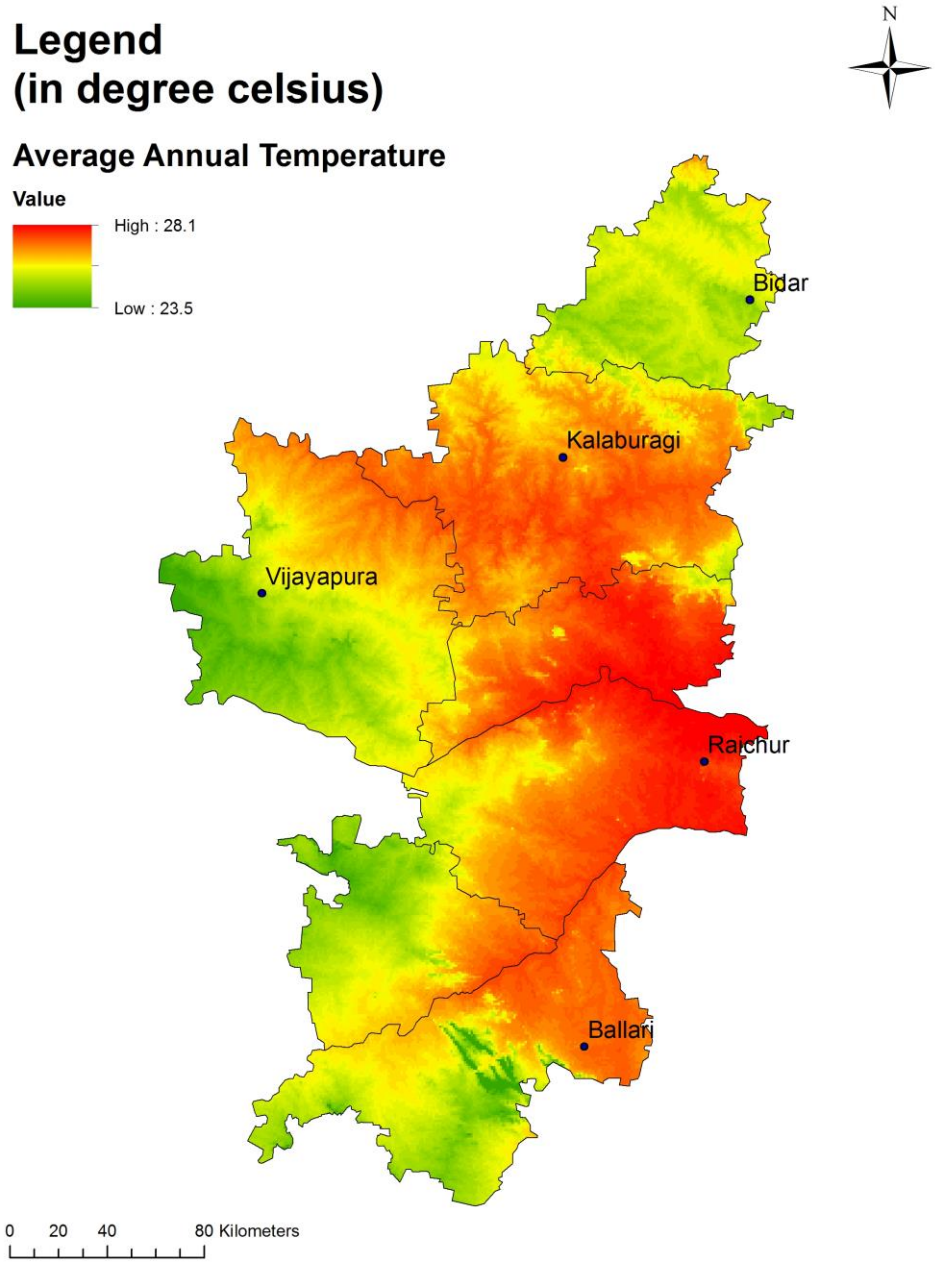
ACCESSIBILITY (RAILWAYS)

- Railways can also be used for transport of goods and equipment especially in large scale to the construction site
- Data – Roads and Railways network from OpenStreetMap database, verified and updated using Google Earth data



VARIATIONS IN LOCAL CLIMATE

- Site chosen for the plant should not suffer form extremes of weather, this will affect the efficiency of the power generated
- Here, temperature variations of 25°C – 45°C are considered favourable
- For every 1°C rise in temperature, amount of energy generated decreases by 0.45-0.5%
- Data – WorldClim –Global Climate Data, at a resolution of 30 arcsec



ANALYTIC HIERARCHY PROCESS (AHP)

- AHP is an effective tool for dealing with complex decision making, introduced by Thomas Saaty
- AHP aids the decision maker to set priorities and make the best decision by using a series of pairwise comparisons
- The AHP considers a set of evaluation criteria, and a set of alternative options among which the best decision is to be made and generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria.
- The higher the score, the better the performance of the option with respect to the considered criterion. Finally, the AHP combines the criteria weights and the options scores, thus determining a global score for each option, and a consequent ranking.
- In this study, a software called PriEsT was used to undertake this process

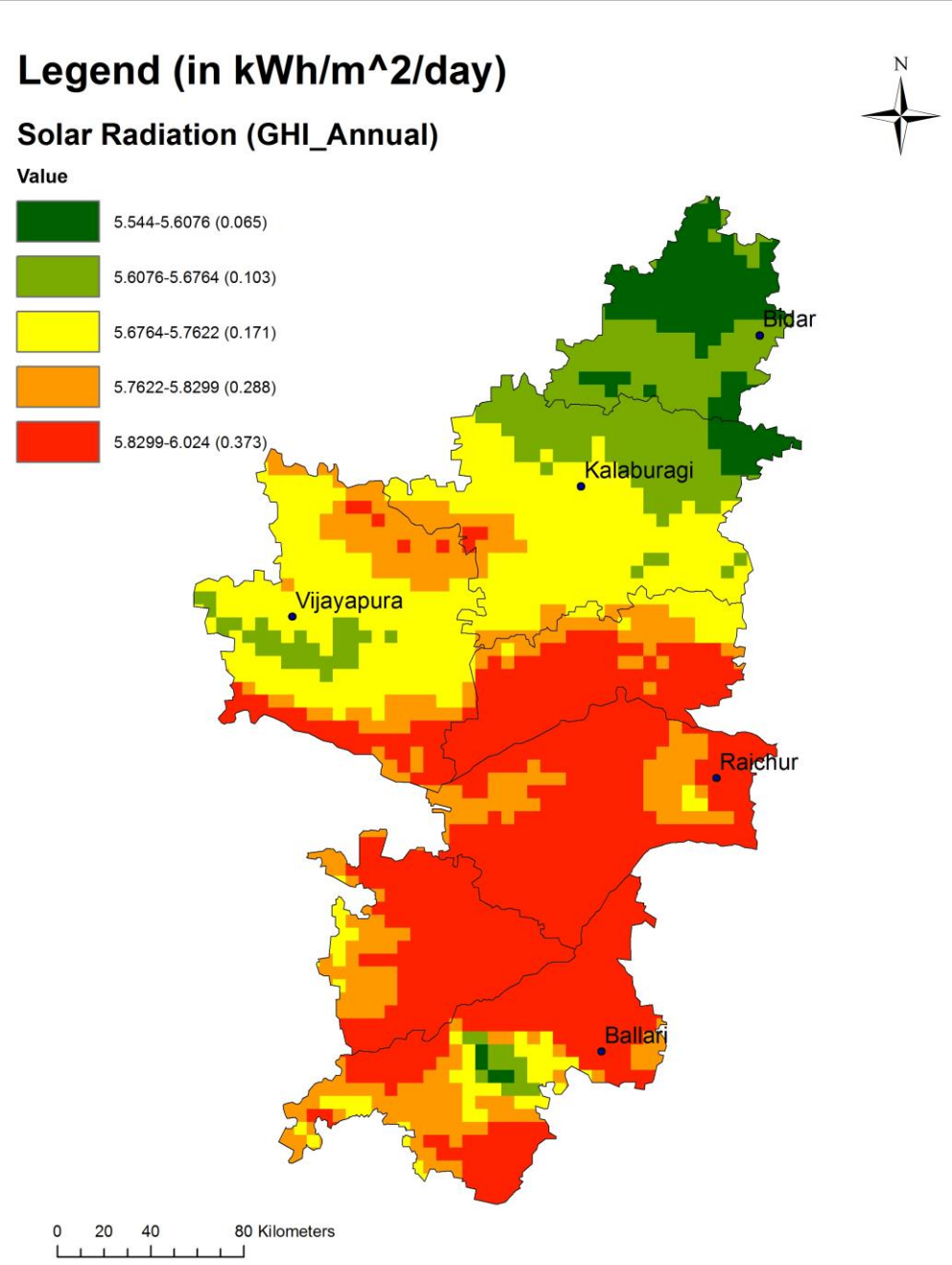
Criteria	Weights	Sub-criteria	Weights	Sub-criteria	Weights	Classification	Weights
Solar Radiation (in kWh/m^2/day)	0.378					5.8299 - 6.024	0.373
						5.7622 - 5.8299	0.288
						5.6764 - 5.7622	0.171
						5.6076 - 5.6764	0.103
						5.544 - 5.6076	0.065
Land cover	0.302					Wasteland	0.378
						Scrub	0.218
						Non-agri	0.218
						Fallow land	0.123
						Cultivated land	0.062
Power grid Connection (buffers in km)	0.136	Transmission lines	0.615			0-5	0.418
						5-10	0.266
						10-15	0.164
						15-20	0.108
						20-50	0.044
		Substations	0.385			0-5	0.417
						5-10	0.263
						10-15	0.16
						15-20	0.097
						20-50	0.063
Topography	0.096	Slope (in percentage)	0.818			0-2	0.467
						2-4	0.278
						4-6	0.16
						6-8	0.095
		Aspect (in degrees)	0.182			0-90, 270-360	0.105
						90-135, 225-270	0.258
						135-225	0.637

Criteria	Weights	Sub-criteria	Weights	Sub-criteria	Weights	Classification	Weights
Accessibility (buffers in km)	0.052	Roads	0.667	Major	0.833	0-5	0.432
						5-10	0.263
						10-15	0.162
						15-20	0.096
						20-50	0.047
				Minor	0.167	0-2	0.467
						2-4	0.278
						4-6	0.16
						6-8	0.095
		Railways	0.333	Tracks	0.222	0-10	0.469
						10-20	0.269
						20-40	0.143
						40-60	0.076
						60-80	0.043
				Stations	0.778	0-10	0.468
						10-20	0.271
						20-40	0.145
						40-60	0.08
						60-80	0.036
Avg Annual Temp. (in degree celsius)	0.036					23.5-25	0.417
						25-26	0.263
						26-27	0.16
						27-28	0.097
						>28	0.063

LAND SUITABILITY ANALYSIS MODELING

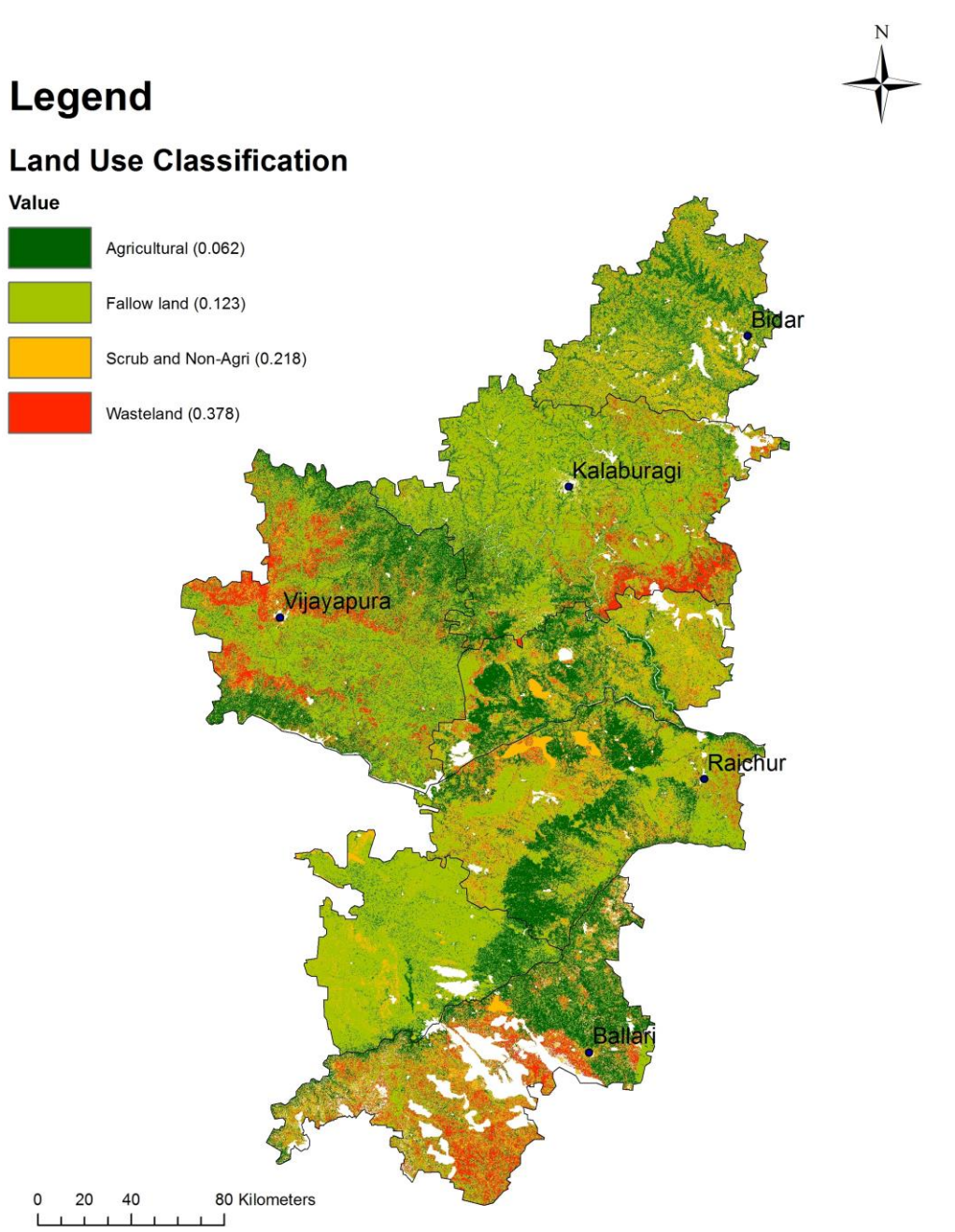
- Maps for all the criteria with their classification, restrictions defined were combined and integrated
- All the maps were prepared according to the criteria and sub-criteria defined with their calculated weights from AHP
- These layers are illustrated in following slides


Slope (0.818)
Aspect (0.182)
Raster Calculator (Topography)
Topography (0.096)
Transmission Lines Buffer (0.615)
Substations Buffer (0.385)
Raster Calculator (Powegrid)
Powergrid Connection (0.136)
Railway Track Buffer (0.222)
Railway Station Buffer (0.778)
Raster Calculator (Railways)
Railways (0.333)
Raster Calculator (Accessibility)
Accessibility (0.052)
Minor road buffer (0.167)
Major road buffer (0.833)
Raster Calculator (Roads)
Roads (0.667)
Land Cover Classification (0.302)
Average Annual Temperature (0.036)
Annual Solar radiation (GHI) (0.378)
Suitability Calculation (Simple Additive Weights)
Suitability Weighted
Eliminated (Dismissed) Areas
Masking Eliminated areas
Final Suitable Regions raster
P

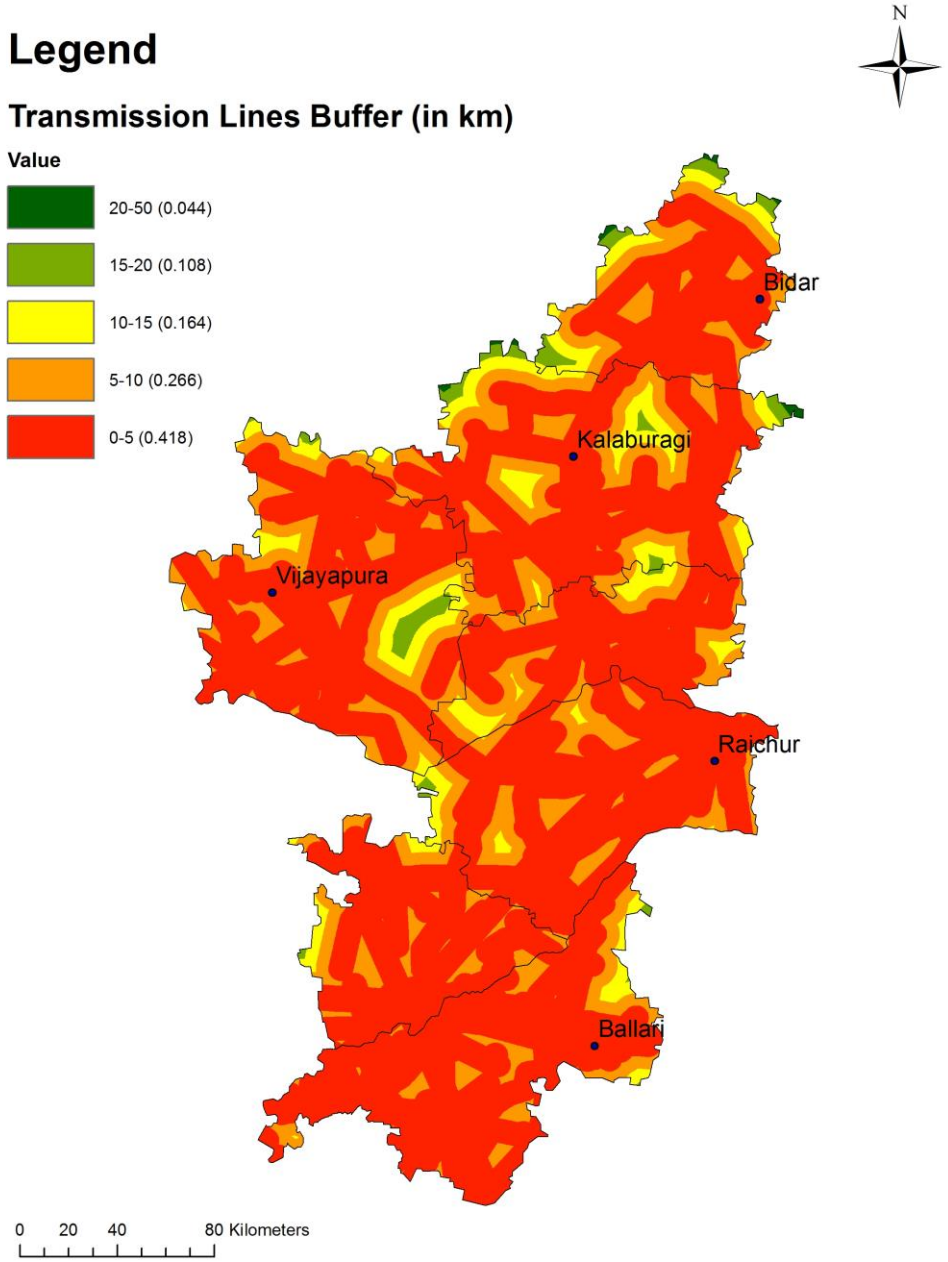


Weighted map of Solar Radiation

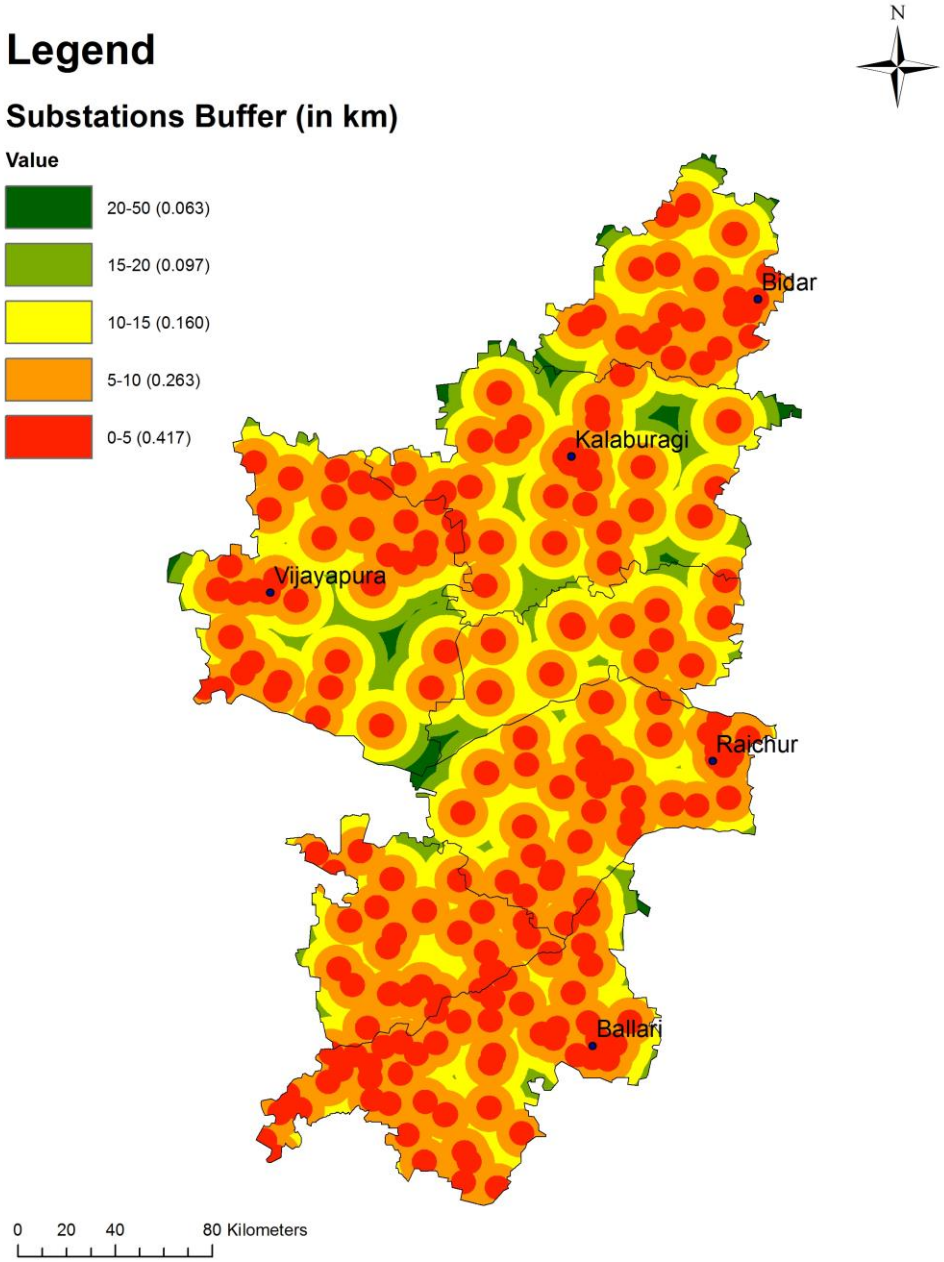
Weighted map of Land use/land cover classification

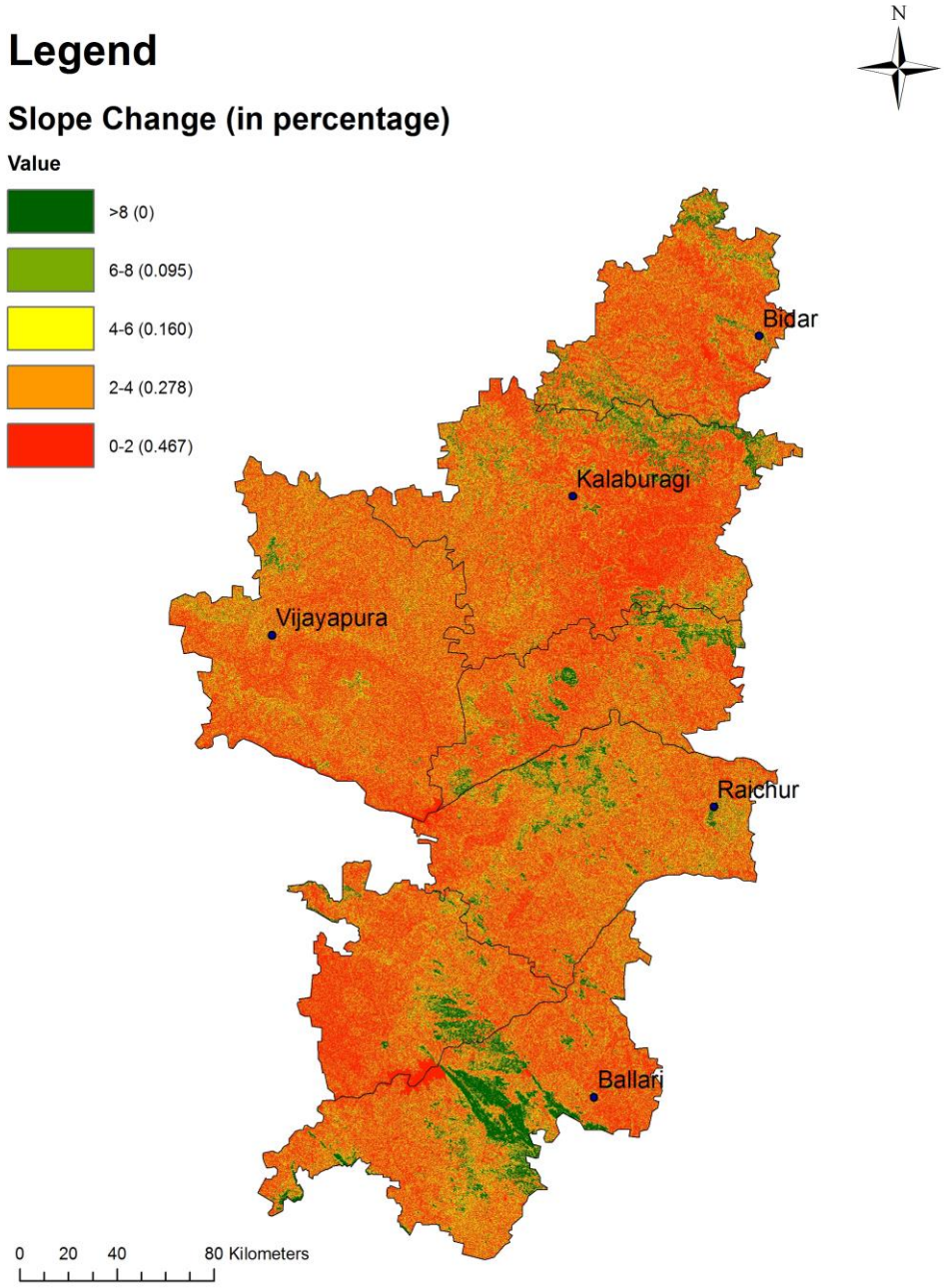


Weighted map of transmission lines buffer



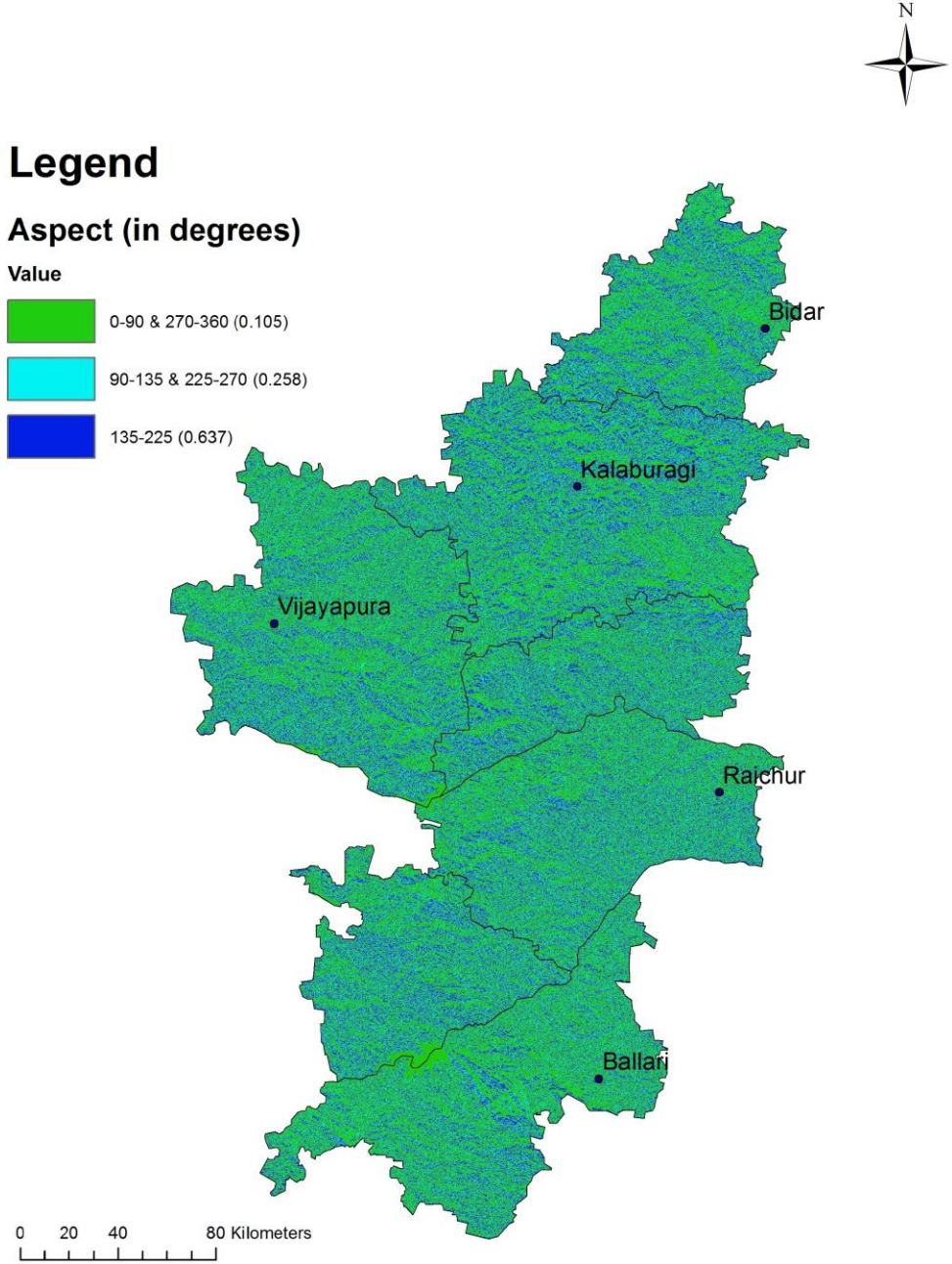
Weighted map of substations buffer

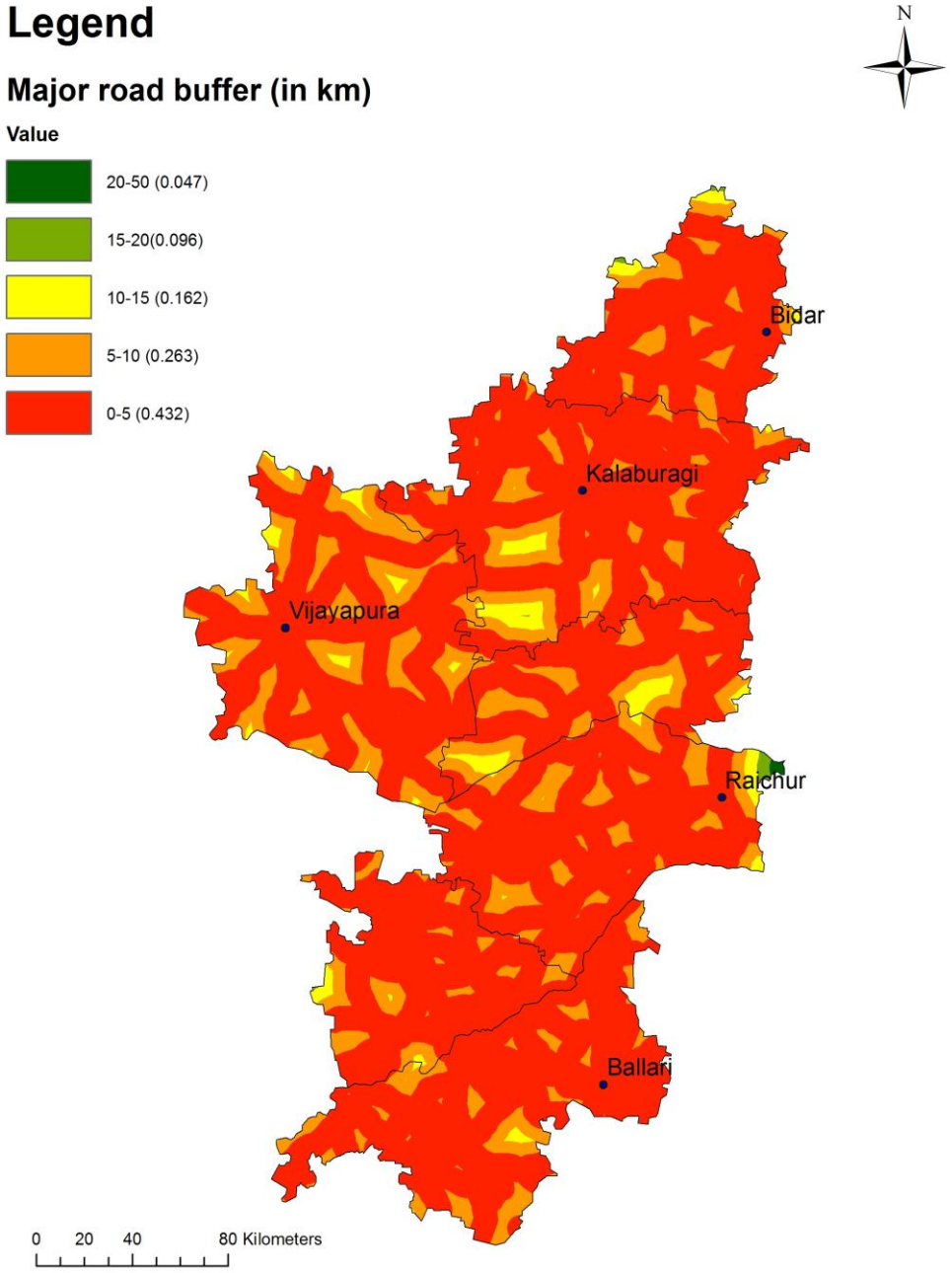




Weighted map of slope change

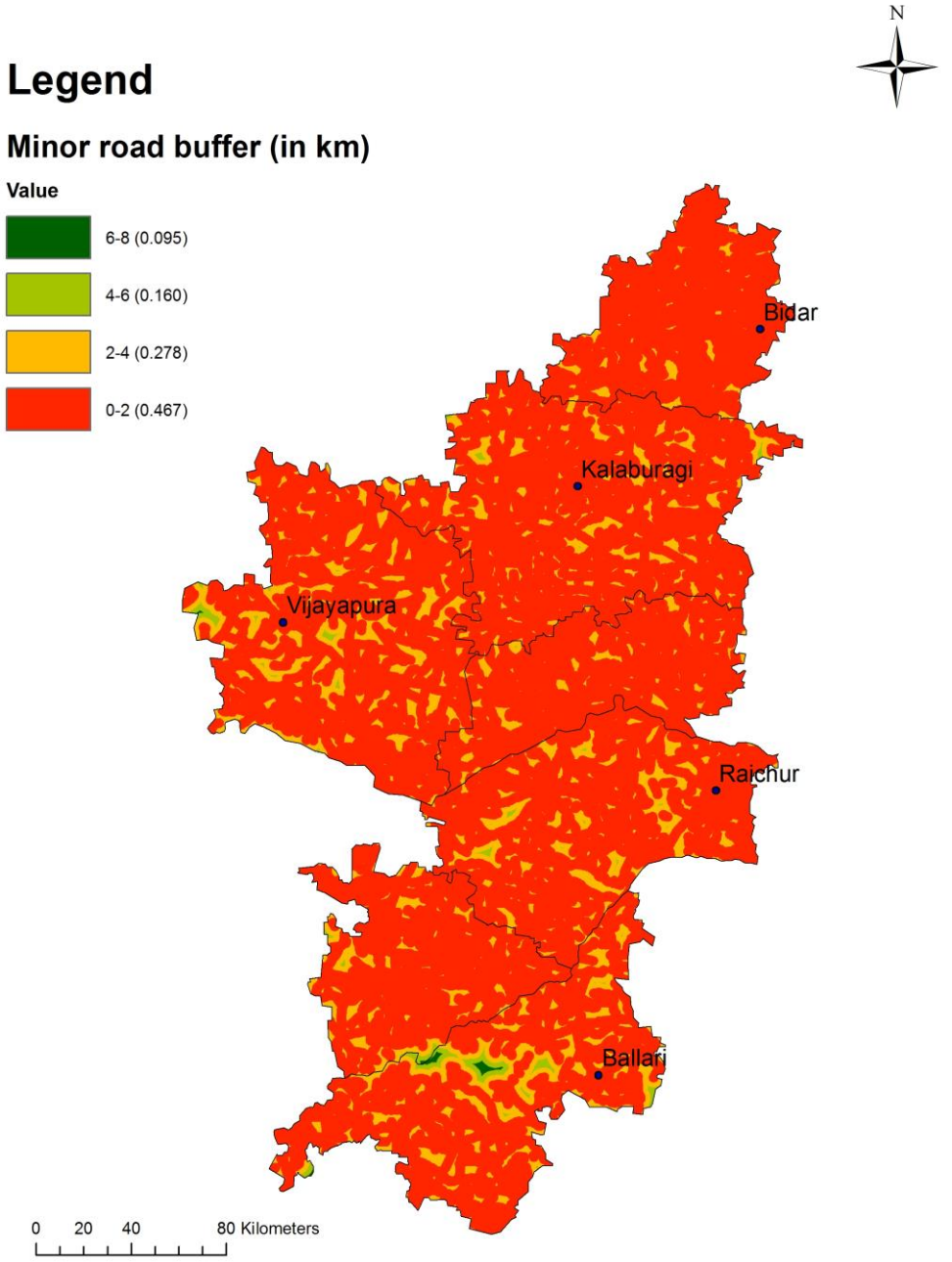
Weighted map of Aspect

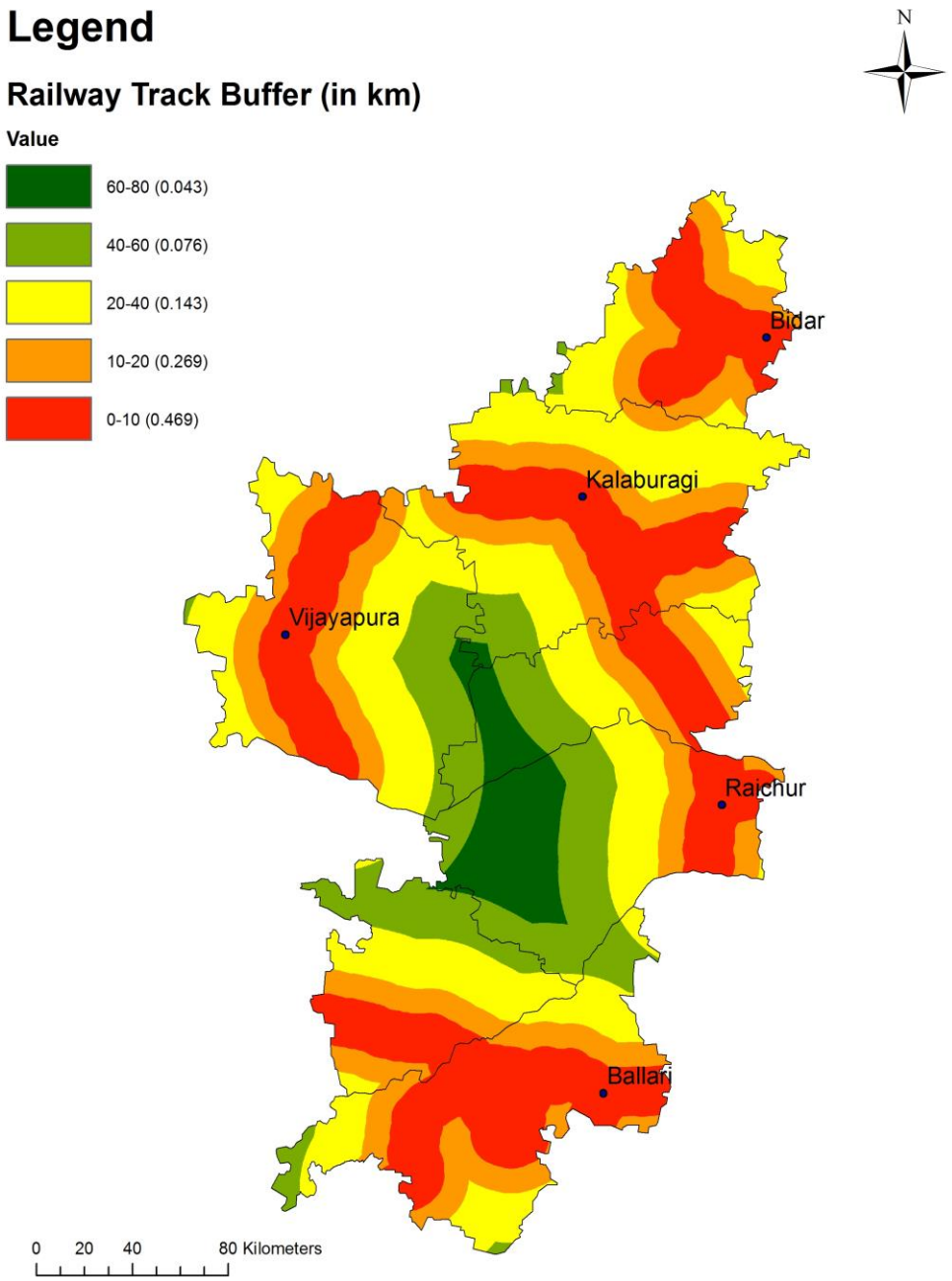




Weighted map of major roads buffer

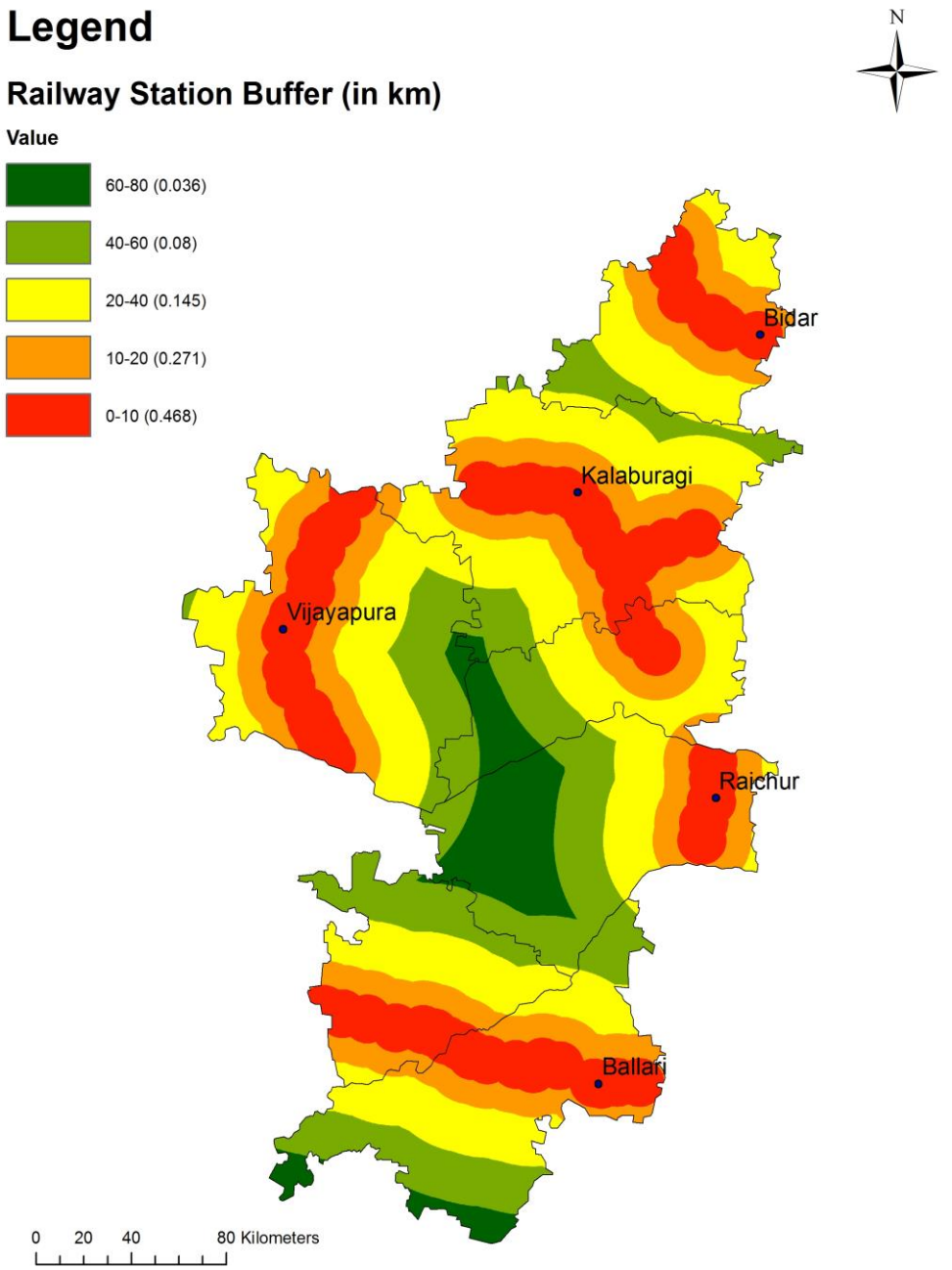
Weighted map of minor roads buffer

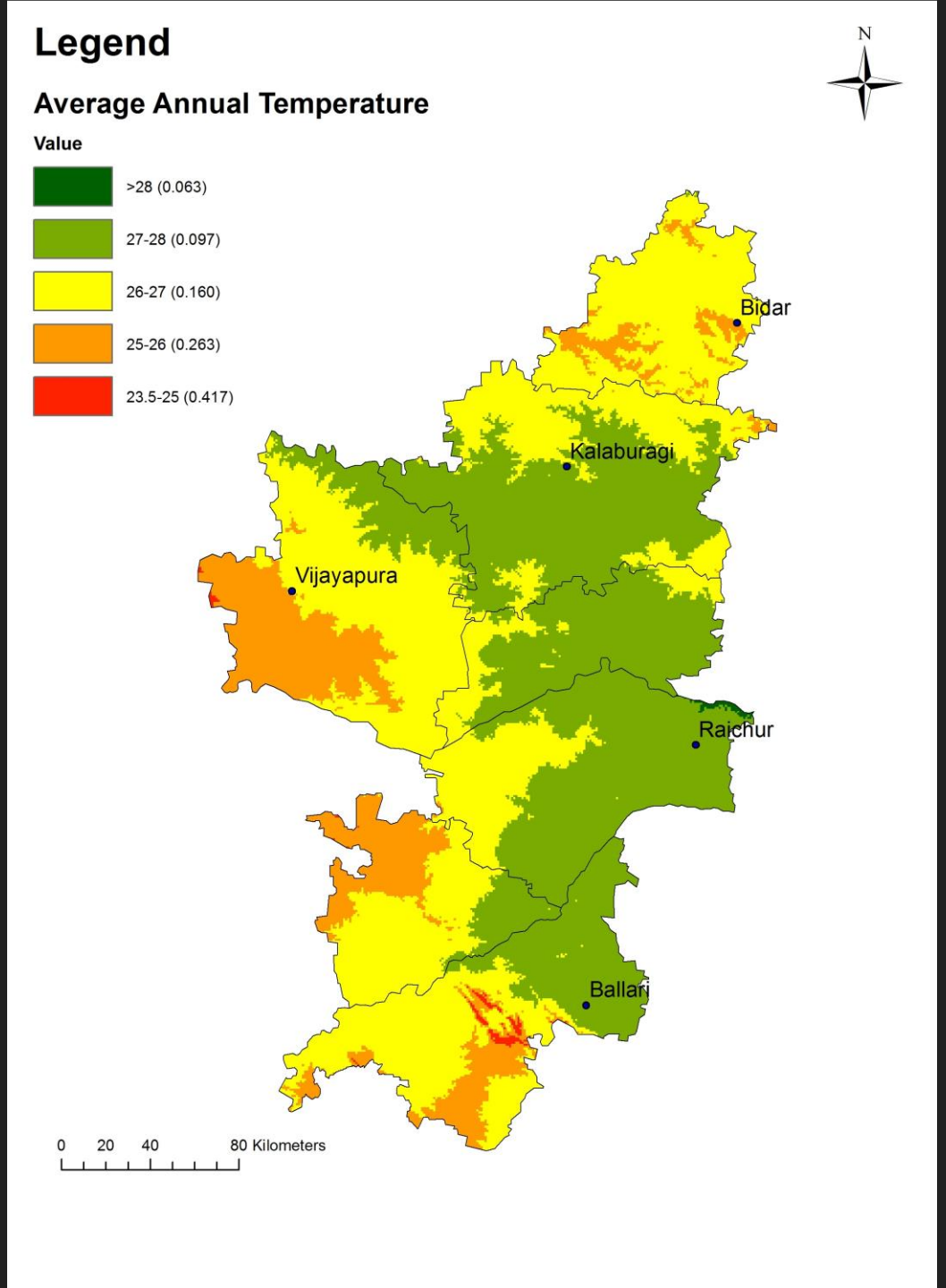




Weighted map of Railway track buffer

Weighted map of Railway station buffer

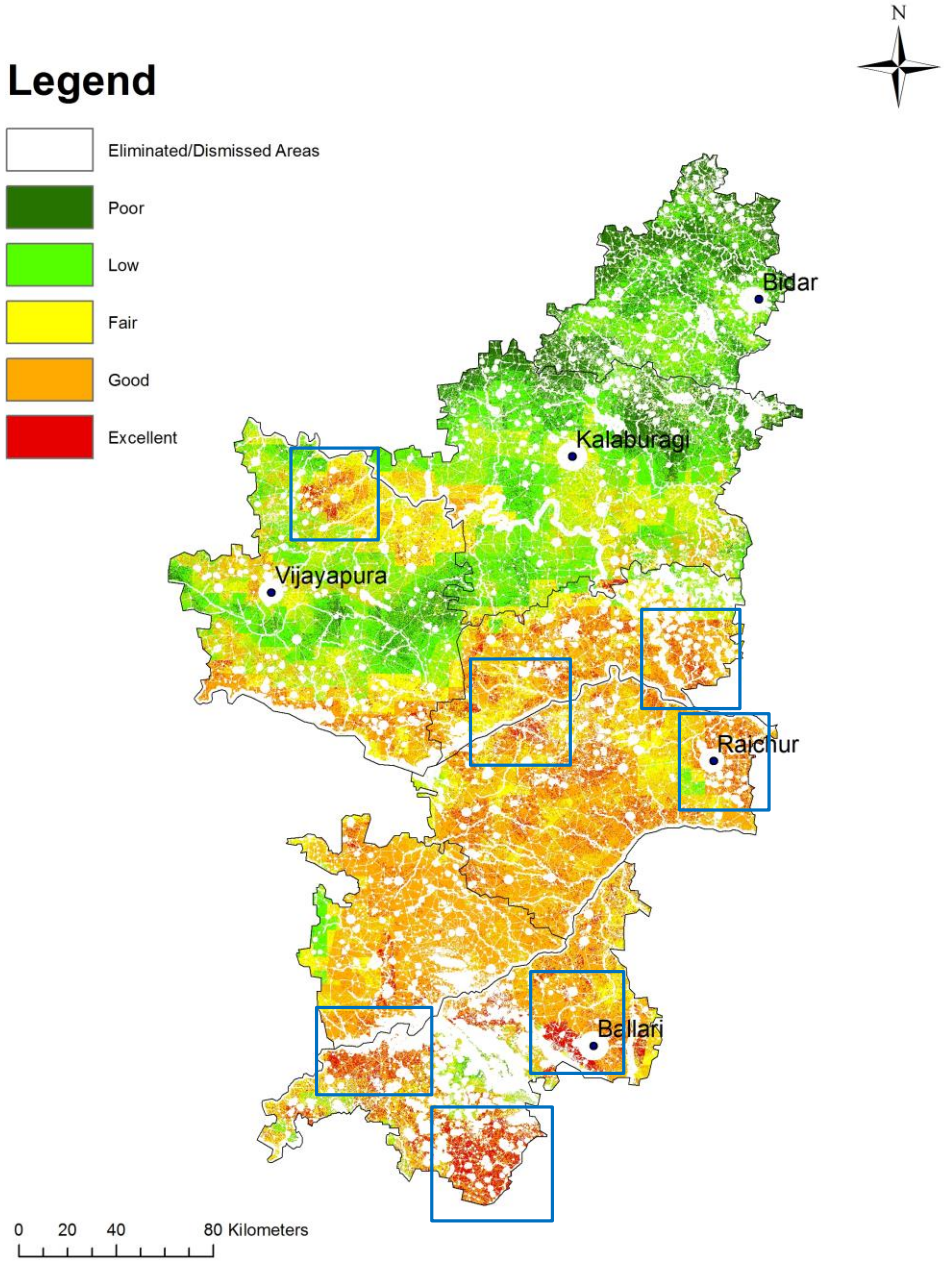




Weighted map of average annual temperature

LAND SUITABILITY MAP

- With generation of all criteria layers with their respective weights, Simple Additive Weights (SAW) method is used to overlay all these layers
- Raster calculator in ArcGIS desktop is used to obtain this land suitability map
- The suitability map with values ranging from 0.0471 to 3.999 was obtained
- Values were divided into 5 classes based on natural breaks
- Excellent (0.3063-0.399), Good (0.2536-0.3063), Fair (0.2091-0.2536), Low (0.1659-0.2091), Poor (0.0471-0.1659)



RESULTS AND DISCUSSIONS

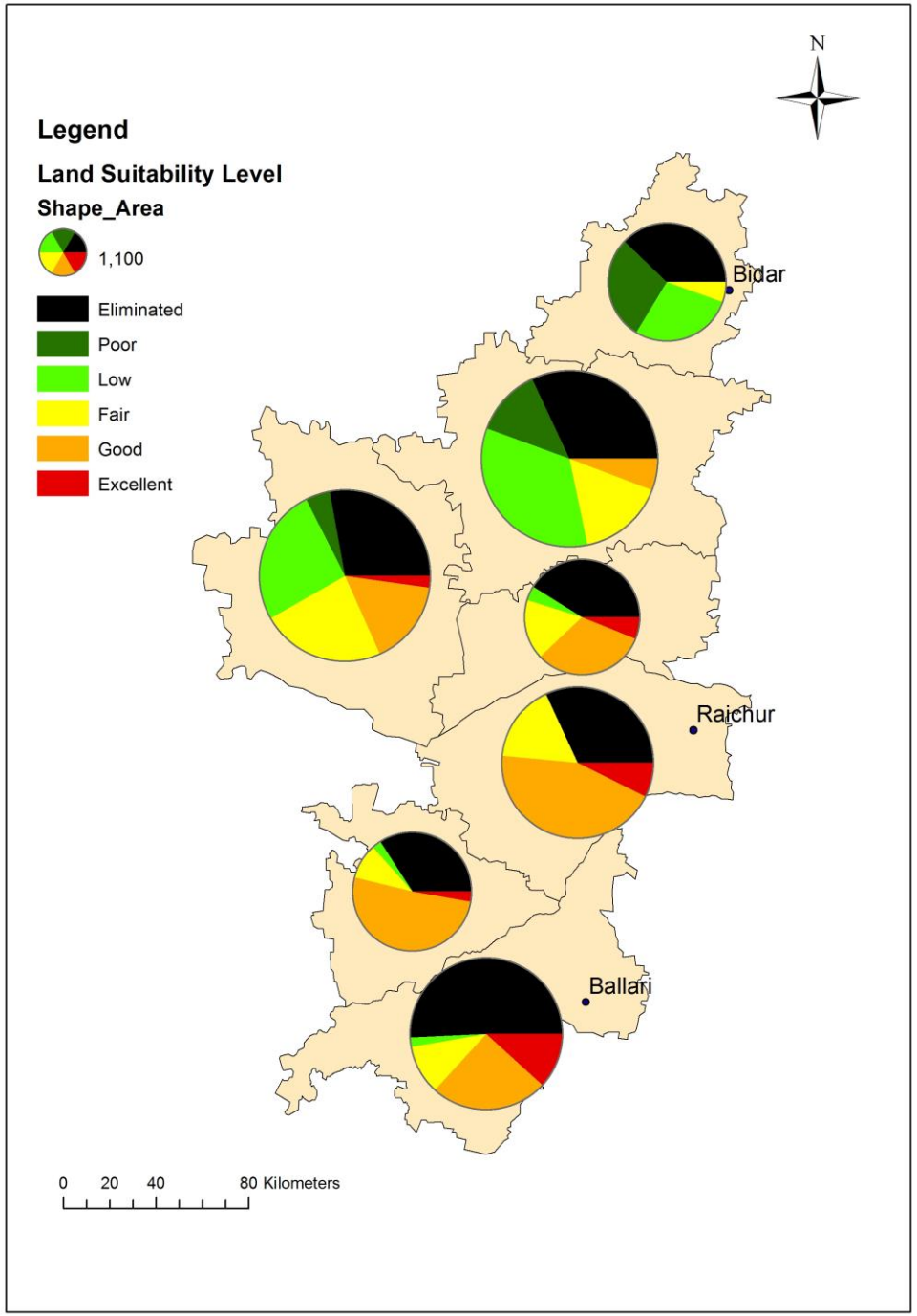
- It's seen that 4.32%, 23.11%, 15%, 15.63%, 6.28% of the study area are in excellent, good, fair, low and poor classes of suitability respectively. About 35.66% of the total study area is classified under eliminated areas
- Relation analysis between districts and land suitability classes shows how these classes are distributed in each of the districts in terms of percentage areas
- Similarly, relation analysis between land use classes and land suitability classes shows the percentage area distribution of land suitability classes in land use classes

District	Eliminated (%)	Poor (%)	Low (%)	Fair (%)	Good (%)	Excellent (%)	
Bellary	50.6	0.32	1.98	10.44	24.9	11.76	100
Koppal	34.1	0.06	2.49	9.55	51.14	2.66	100
Raichur	31.59	0.01	0.92	16.51	43.64	7.33	100
Yadgir	40.97	0.22	4.13	16.88	31.74	6.06	100
Bijapur	27.87	4.58	25.81	23.43	16.09	2.22	100
Gulbarga	31.83	12.41	33.71	15.89	5.75	0.41	100
Bidar	37.72	28.35	28.06	5.51	0.36	0	100

	Others	Agriculture	Fallow land	Scrub & Non-agri	Wasteland
Eliminated (%)	92.35	35.17	29.24	39.22	34.37
Poor (%)	1.53	9.19	7.3	2.03	1.16
Low (%)	1.86	13.2	21.78	8.92	3.81
Fair (%)	2.59	19.23	15.93	12.96	9
Good (%)	1.32	22.63	24.46	25.29	27.25
Excellent (%)	0.35	0.58	1.29	11.58	24.41
	100	100	100	100	100

RESULTS AND DISCUSSIONS

- Wasteland is seen to distributed in excellent, good, fair classes with area of 24.41%, 27.25% and 9% respectively
- 34.37% of wasteland is dismissed because of the restrictive criteria considered in earlier analysis
- Bellary, Raichur and Yadgir have larger share in the Excellent classes of suitable area
- And Koppal, Raichur, Yadgir and Bellary has larger share in the Good class of suitable area



CONCLUSIONS

- Since the initial investment in these plants is high, identifying the best suitable site for establishing the solar power plant is the most important step
- This study provides a practical approach, considering technical, environmental, geographical and economic criteria to assess and prioritize the region of north Karnataka for exploiting solar energy using GIS and AHP technique
- The obtained results shows that 4.32%(2353.97 km^2), 23.11% (12601.88 km^2), 15%(8180.10 km^2), 15.63%(8527.26 km^2), 6.28(3427.81 km^2)% and 35.66% (19451.4 km^2) of area the entire study region are classified as excellent, good, fair, low, poor and dismissed areas respectively
- Four districts Bellary, Raichur, Yadgir and Koppal are concluded as well suited for establishment of solar PV plant in decreasing order of suitability

FUTURE WORK

- The results of this study could be helpful for planners to analyse the solar power generation potential considering the type of semiconductor technology used in construction and their efficiency in power generation
- This study gives the template for further analysis of the study area at better resolution
- With this analysis, it's possible to identify more refined locations for establishing solar power plant
- It could also help in estimating the cost of the solar power plant

THANK YOU