Suitability Analysis And Estimation Of Power For Siting Solar Plants in Pune

A PROJECT REPORT

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in

Electronics & Telecommunication

Submitted by

AKASH SOLUNKE (B190953003)

DARSHAN S.PATIL (B190953017)

VARAD KULKARNI (B190953038)

Under the Guidance of

PROF. ANJALI JAGTAP

INNOVATION & LEADERSHIP
www.isquareit.edu.in

DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION

HOPE FOUNDATION'S

INTERNATIONAL INSTITUTE OF INFORMATION TECHNOLOGY,

HINJAWADI, PUNE(MH)-411057

SAVITRIBAI PHULE PUNE UNIVERSITY

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www.isquareit.edu.in

This is to certify that

AKASH SOLUNKE (B190953003)

DARSHAN S.PATIL (B190953017)

VARAD KULKARNI (B190953038)

Class: BE(E&TC) have satisfactorily completed Project titled, '**Suitability Analysis And Estimation Of Power For Siting Solar Plants In Pune**' under my supervision as a part of Bachelor of Engineering in **Electronics and Telecommunication (A.Y. 2022-2023)** of Savitribai Phule Pune University.

Prof. Anjali Jagtap
Project Guide

Prof. Risil Chhatrala
HoD(E&TC)

Principal

Place : Pune

External Examiner

Date :

CERTIFICATE

DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION

HOPE FOUNDATION'S

INTERNATIONAL INSTITUTE OF INFORMATION TECHNOLOGY,

HINJAWADI, PUNE-411057

This is to certify that **Name of the student (Exam seat no)** Class: BE(E&TC) has satisfactorily completed a Project titled, '**Suitability Analysis And Estimation Of Power For Siting Solar Plants In Pune**' under my supervision as a part of Bachelor of Engineering in **Electronics and Telecommunication (A.Y. 2022-2023)** of Savitribai Phule Pune University.

Prof. Anjali Jagtap | Prof. Risil Chhatrala
Project Guide | HoD(E&TC)

Principal

Place : Pune | External Examiner
Date :

Declaration

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that We have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed. We take sole responsibility for the work presented by us in this report. We also declare that we will submit our completed project along with all necessary hardware and software to the department at the end of the 2nd semester.

Signature...............

STUDENT NAME ....

Signature...............

STUDENT NAME ....

Signature...............

STUDENT NAME ....

Place : Pune

Date :

Abstract

Over the period of time our dependency on exhaustible natural resources have grown to folds. We are so much engaged in the use of natural resources in our daily life that it has put into risk the availability of natural resources to the future generations.

Natural resources like oil, coal, and natural gas are getting consumed at rates far greater than the rate at which they are produced by nature. Global demand for these natural resources have increased to folds since last decade and is still increasing. The dependency on natural resources needs to be curtailed to have a better and clean future.

The proposed work in this report provides the suitability analysis and estimated power generation, for siting solar power plants in the location of city Pune, Maharashtra. It analyzes and evaluates locations for its compatibility for siting up of a solar power plant. The work also covers generation LAND USE LAND COVER Map of Pune district.

The result is provided in level of suitability as extremely suitable, strong suitable, moderate suitable and low suitable.

Keywords:

Solar radiation, LULC, Transmission line, Railway, Road, Water line, Water bodies, Site suitability, GIS.

Contents

Certificate ii

Declaration iv

Abstract v

Contents vi

List of Figures viii

List of Tables x

1 Introduction 1

2 Literature Survey 4

3 Proposed Methodology 11

3.1 Study Area 11

3.2 AHP 14

3.3 Requirement analysis 16

3.3.1 Software Requirement 16

3.3.2 Maps Requirement 16

3.3.3 Data Requirement 17

3.4 Impact analysis 18

3.4.1 Impact of project on society 18

3.4.2 Impact of project on environment 18

3.5 Professional ethical practices to be followed 18

4 Project Implementation **19**

4.0.1 System Implementation 28

4.0.2 Software Implementations 41

5 Results and Discussion **42**

5.1 Results 42

6 Conclusions and Future Scope **44**

6.1 Conclusions 44

6.2 Future Scope 44

References **44**

List of Figures

1.1 Area of interest 2

3.1 Block Diagram for Solar Suitability Map 11

3.2 AHP Matrix 15

4.1 Sentinel data of Pune district 20

4.2 Clipped Pune from Sentinel data 21

4.3 LULC using Random Tree 22

4.4 LULC using SVM 24

4.5 LULC using Maximum Likelihood 26

4.6 Solar Irradiation Map of Pune 28

4.7 Pune Slope map 29

4.8 Aspect map 30

4.9 Pune transmission line map 31

4.10 Euclidean distance map of transmission line map 32

4.11 Pune railway map 33

4.12 Euclidean distance map of railway line map 34

4.13 Pune road map 35

4.14 Euclidean distance map of road map 36

4.15 Water Line map of Pune 37

4.16 Euclidean distance map of water lines 38

4.17 water bodies map 39

4.18 Euclidean distance map of water bodies map 40

5.1 Pune District Solar Suitability Map 43

List of Tables

3.1 Data and its Sources 17

4.1 Random Tree algorithm pixel counts 23
4.2 Support Vector Machine algorithm pixel counts 25
4.3 Maximum Likelihood algorithm pixel counts 27
4.4 AHP count for each map 41

5.1 Pixel Count of Solar Site Suitability Map 43

Chapter 1

Introduction

Renewable energy sources are most preferable compared to fossil fuels as they are usually free, widely available with limited or no environmental impacts. Seeking for clean energy is essential in order to ensure more diversified energy portfolio for their domestic economies, shift towards green economies and attain sustainable development. This study aims to provide a GIS based model for multi-criteria suitability analysis that can be employed in identifying the potential sites for photovoltaic power plants and also the amount of power generated from the potential site.The particular slope–land topography and surface aspect are affected by the solar radiation scattering on the earth's crust and deflect an equal distribution of solar energy globally. Solar energy is cost effective and has low operational cost, which increases accessibility, and has low contraction costs and a high rate of distribution from the power line.The analytical hierarchy process (AHP) was applied to categorize the site suit- ability process in the Earth's crust through the support of the GIS software.

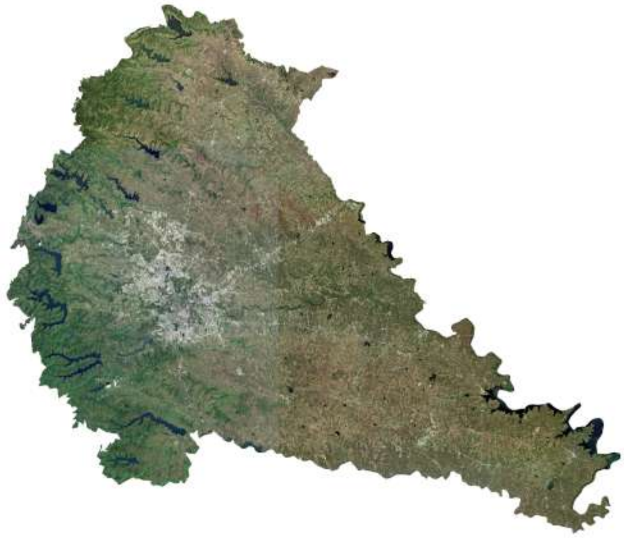

Figure 1.1: Area of interest

In India more than 70 percent of its energy is produced by fossil fuels.Energy is not just linked to climate but also linked to our Gross Domestic Product (GDP). As a developing country a enormous supply of energy is required to continue a GDP growth. Even if nuclear energy is a cleaner energy source than fossil fuels, but it also has a negative impact. One of the safest and clean energy production method is solar energy. Because India is located in the equatorial region of earth, it has good solar energy potential. It can generate revenue form a barren land as well as installing solar panels on water bodies or water areas.
One of the main issues to make a solar farm is that it requires a high initial capital. So we want our solar farms to be as efficient as possible. The efficiency of solar farm is influenced by a number of factors, that factors includes solar radiation, land use land cover, slope, aspect, proximity to transmission line/grid, proximity to road, proximity to rail, proximity to water bodies/ water areas. This leads us to my study —Site suitability analysis of solar farm using Geoinformatics, Our main goal is to find most appropriate location for a solar farm in the district of Pune, that can be best location currently.

Solar energy is cost effective and has low operational cost, which increases accessibility, and has low contraction costs and a high rate of distribution from the power line.The analytical hierarchy process (AHP) was applied to categorize the site suitability process in the earth's crust through the support of the GIS software. The AHP method understands that although there are several criteria, the magnitude of each criterion may not be equal. For instance if you have to choose between two restaurants, the taste and the waiting time are two factors, however both of them may not have equal importance in your perception.

We used a raster method which is a raster calculator is then used to apply your AHP matrix weightings and aggregate the layers.

Chapter 2

Literature Survey

In order to assess a site's feasibility for the construction of solar farms based on photovoltaic (PV) solar cell technology in the district of Pune, state of Maharashtra, India, this article uses geoinformatics methodologies. One can map the elements impacting the appropriateness of the PV solar farm site by analysing the data on different Analytical Hierarch Process (AHP) approaches are used to assign each component a distinct weighting. The Land Use Land Cover (LULC) map was created using LANDSAT 8 datasets processed using remote sensing (RS). Later, the slope and aspect map for the research region was modelled using the Cartosat-1 Digital Elevation Model (CartoDEM), a National DEM created by the Indian Space Research Organisation (ISRO). Additionally, global horizontal radiation[1].

In this work, we used a geographic information system (GIS)-based method to locate areas in Mongolia that would be appropriate for the development of massive solar photovoltaic (PV) power plants. Data based on seven criteria, including yearly global temperature, were employed in 30 30 m cells as a result. For each cell, data on horizontal radiation, yearly average temperature, height, slope, slope direction (aspect), and distances from major power lines and highways were gathered. layers for GIS for these Then, using four grades, seven criteria were transformed into rated value layers. Ten solar field experts used an analytical hierarchy procedure to find the answers to the seven criteria[2].

As many nations aim to become carbon neutral in the future, the use of solar One of the key initiatives anticipated is energy as a substitute for fossil fuels. However, not every place is equally ideal for the production of solar energy. Solar radiation is uneven to blame for this dispersion and a number of environmental elements. Multicriteria Decision Analysis (MCDA) has been used in a number of studies to find the best locations for solar power projects. To the best of our knowledge, despite the fact that creating renewable energy in Saudi Arabia has been put on the agenda, no research has addressed the issue of identifying the ideal solar plant location for the Al-Qassim region[3].

For every given situation, the environment and land are some of the limited natural resources. As a result, it is frequently crucial to maximise land use, prevent, or at least minimise environmental concerns. When choosing possible places for solar energy collecting, consider the societal effect. The method for locating possible solar energy collecting locations and available land areas is discussed in this chapter. Therefore, the Zambian laws on environmental protection and pollution control legislative framework have been enforced with the restricting and strengthening characteristics that impact site selection based on international regulation. Consequently, local environmental protection and pollution control legislation as well as international rules have been used to evaluate the potential for solar PV energy generation and locate possible sites[4].

The most important natural energy to replace fossil fuels globally is derived from renewable sources. Although fossil fuels are the most expensive and scarcest resource on earth, renewable energy produces less pollution. The most efficient form of renewable energy for daily use is solar energy. Solar power plants are essential for everyday use in the home. In this study, the potential location of solar power plants in Kolkata and the surrounding area of West Bengal, India, was identified using remote sensing and geographic information systems (GIS). For each weight calculation, the analytical hierarchy process (AHP) and the multi-criteria decision-making process (MCDA) were employed, and ArcGIS v10.8 was used for the weighted overlay analysis (WOA)[5].

The danger that using fossil fuels poses to global warming is causing humanity to explore for alternatives to traditional forms of energy. The usage of solar energy among them offers a significant potential for increase in the existing global energy mix. It is crucial to inform those who make decisions about the installation of new manufacturing facilities. In order to determine if the property in the municipality of Ourique in the south of Portugal is suitable for the installation of solar farms, this study combines Geographical Information Systems (GIS) and Multi-criteria Evaluation (MCE) methodologies. With the aid of subject-matter expertise and a thorough literature study, a number of exclusionary restrictions and weighting variables were applied in the modelling approach[6].

Using a Geographic Information System (GIS) and the Analytic Hierarchy Process (AHP), we evaluated the suitability of the Eastern area of Morocco to host large-scale Concentrating Solar Power (CSP) facilities in this study. Because of this, a high spatial resolution GIS database is constructed utilising layers made available by various governmental bodies. Additionally, a top-notch satellite solar map with a spatial resolution of 1 km2/pixel and twenty years of temporal coverage was employed since the potential of the Direct Normal Irradiation (DNI) is the most crucial factor for choosing a CSP location. Due to the necessity for cooling systems in CSP power plants, two cooling methods—dry and wet—were assessed for their usefulness in this area[7].

In comparison to fossil fuels, renewable energy sources are preferred because they are frequently free, readily accessible, and have little to no environmental effect. To secure a more varied energy portfolio for their domestic economies, transition to green economies, and achieve sustainable development, Kuwait and other Gulf governments must actively pursue clean energy. The goal of this work is to develop a GIS-based multi-criteria suitability analysis model that can be used to locate viable locations for solar power facilities. The suggested model helped to incorporate a variety of significant parameters and indicators that indicate Kuwait's diverse regions' appropriateness for solar power plant placement. As a result, Kuwait's suitable locations for solar energy facilities were identified[8].

The world is currently looking for alternate energy sources due to the rapid depletion of fossil fuels and the resulting inherent climate repercussions. As a result, nearly all governments, even those in underdeveloped regions, are turning to renewable energy sources. The sun is one such source, providing hygienic and environmentally favourable electricity. Both solar and other forms of energy may be converted into electricity. In the East Shewa Zone of Ethiopia, this study aims to estimate solar energy potential, identify feasible grid-connected solar photovoltaic (PV) farms, and determine their power generating capacity utilising a GIS-based technique and an analytical hierarchical process. The zone's 1129 km2 of land, according to the findings, is perfect for the construction of sizable PV solar farms[9].

Although photovoltaic (PV) solar power installations can help Saudi Arabia generate electricity, these facilities' efficacy and cost-effectiveness can be impacted by a number of technical, economic, and environmental issues. The purpose of this study is to develop a site suitability model to determine the best locations in Saudi Arabia for solar PV project implementation. To properly assess the acceptable locations, a combination of the Preference Ranking Organisation approach for Enrichment Evaluations (PROMETHEE II) approach and the fuzzy analytical hierarchy process (AHP) is used as a weighting mechanism. To guarantee that building costs were kept to a minimum while PV power plant production was maximised, 12 elements split into two categories (technical and economical) were taken into account. The generated suitability map demonstrates how much potential Saudi Arabia has Approximately 376,623 km2 (65.1 percent) of the entire study area was deemed "most to highly suitable" for the implementation of solar PV plants. Additionally, the suitability map was assessed in relation to the upcoming solar PV projects Saudi Arabia is creating as part of the validation of the model's predictability. The findings revealed that 90.6 percent of the upcoming projects were located in the "most and highly suitable" PROMETHEE II suitability map zones. In addition, a sensitivity analysis was conducted to investigate the impact of economic considerations on the appropriateness outcomes using other preference functions and greater weights for the economic criterion[10].

To meet the nation's present need for electricity, the Ethiopian government turned to renewable energy sources. Around 85 percent of the nation's population resides in rural regions and consumes fossil fuels for domestic purposes. Users and the environment are put in peril when fossil fuels are used. And the Ethiopian government intended to electrify 85 percent of the rural population using the plentiful renewable resources nearby. As a result, using GIS to locate possible solar PV sites is a decision-support tool for suggesting appropriate locations to the government. The solar PV suitability study recommends the best sites for the construction of solar PV power plants. Analytical hierarchy procedures were used to identify elements that impact suitability and weight them in order to determine the best locations for solar PV. The final suitability map for solar PV was created by multiplying the weighted values and classed values together. Solar PV generating efficiency decreases and may malfunction due to an unsuitable placement. An ideal placement for a solar PV power plant is found by determining the best spots. Finding the best locations in the South Gondar Zone for solar PV power generation was the goal of this study. 86.5 percent of the research area is suitable for a solar PV power plant. In the research region, 86 percent of the factors taken into account were determined to be acceptable for solar PV power plant installation. The westernmost portion of the zone had the majority of acceptable locations[11].

A reliable tool for site-suitability assessment of solar power plants capable to account for the protection of cultural, natural, and ecological conservation areas is proposed. The tool integrates an Analytic Hierarchy Process (AHP) based Multi Criteria Decision Analysis (MCDA) algorithm into a Geographical Information System (GIS) package, which consists of layers of satellite-derived data for energy resources and locally obtained data such as land usage, topography, community settlement, road lines, and electrical network, considered as the criteria layers for the assessment of site suitability[12].

The most accessible and scalable renewable energy source, solar energy, offers enormous potential to meet the rising need for power. Therefore, choosing the right location to install solar PV systems is essential. This article describes how a solar suitability map was created to show suitable locations for solar PV systems in the Rinconada District in the Philippine province of Camarines Sur. To determine the weights of the nine parameters for appropriate site selection, ArcGIS examined the yearly average solar radiation, meteorological information, and geographic circumstances. Suitability mapping was then coupled with the Analytic Hierarchy Process (AHP). Twenty-seven (27) barangays were determined to be appropriate based on these considerations, including the centre and eastern portions of Barangay Malawag in Nabua and a significant portion of Barangay[13].

Due to a lack of upkeep and finance after the civil war, the power industry in Lebanon experienced various difficulties. To make up for this electrical shortfall, rationing hours were drastically expanded, which caused residents to turn to the private sector. The majority of the power generated is reliant on burning fuel, which causes significant pollution. This article investigated the viability of solar energy as a supplementary approach to address both the environmental and the electrical deficit problems. The example study used is the North Lebanon district. Using a Geographic Information System (GIS), the best place to build a solar plant is determined scientifically while taking all of the requirements and criteria into account. The weighted average sum overlay approach for raster analysis was used.The investigation was successful in identifying a suitable location that can make up for the North region's power deficit[14].

To find and apply to programmes. The best locations to gather solar energy in the Samawah desert and that fall in the western half of Al-Muthanna governorate are determined using geographic information systems. Additionally, solar energy is utilised in renewable energy initiatives like (electric power generating). Encourage investment and agriculture in Samawah, a desert region. where it is thought of The primary source of environmentally friendly and renewable energy is solar radiation. The study's findings revealed that the Samawah desert receives an exceptional quantity of solar radiation, ranging from 5751.1 to 5953.2 watt-hours per square metre. And the usage of geographic information systems software allowed for the achievement of this objective.

as that technique The incident solar irradiation should be calculated.Depending on the digital model's geographic resolution and time period utilised to calculate radiation because June and July 2019 mark the height of solar radiation in the Samawah desert, those months were chosen for the readings. Given that temperatures are high at this time, measurements are obtained every two hours. The search results reveal that the Samawah desert is seeing a lot of sun radiation[15].

Chapter 3

Proposed Methodology

3.1 Study Area

Pune is a district in the state of Maharashtra, India. Pune City Central is the District Headquarters. Temperatures are moderate and rainfall is unpredictable, in tune with the Indian monsoon. Summers, from early March to July, are dry and hot. Also solar radiation , digital elevation model, transmission line, water line, water bodies, railway, road as such many factors that comes into consideration when we have to plant solar power plant. Thus we have collected the satellite images, sentinel 2A data set of solar radiation, digital elevation model, transmission line, water line, water bodies.

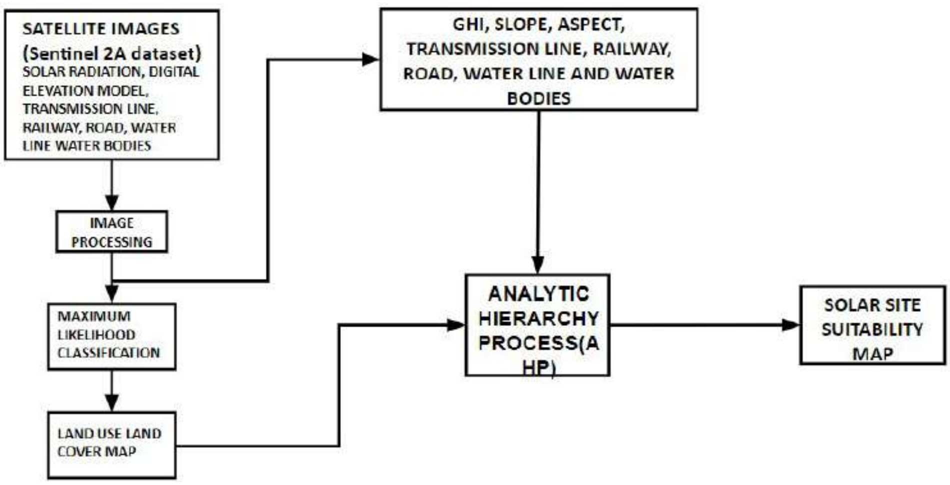

Figure 3.1: Block Diagram for Solar Suitability Map

Sentinel-2A is a European optical imaging satellite, which provide key information on the vegetation state. Sentinel-2A support to four Copernicus core services such as land monitoring, emergency management, security and climate change, and associated thematic applications. Afterwards image processing involve numerous procedures including formatting and correcting the data to process those images into maximum likelihood classification.Which involves scales, patterns, shapes and textures.The maps of GHI clip, slope, aspect, transmission line, water line, water bodies of pune are processed though it.

Maximum likelihood classification assumes that the statistics for each class band are normally distributed and calculates the probability that a given pixel belongs to a specific class. the main advantage of this process is it provides a consistent approach to parameter estimation problems.

Further with help of land use land cover map we actually find classification of distributing factors of solar power plant.The LULC map tells about the percentage of built up area, barren land, water bodies, agriculture and vegetation covered in the Pune district.

Using the AHP, we get the weighted values for each map, used to produce the suitability map. At the beginning of each AHP process we defined a goal and selected the alternatives and criteria. Using AHP the weighted values such as solar radiation, land use land cover, slope, aspect, distance from transmission line, distance from road, distance from railway, distance from water lines, distance from water bodies are calculated to find the exact solar suitability map of pune district.

Gather Data: Solar radiation data: Obtain solar radiation data for the study area. This data represents the amount of solar energy received in different locations. It can be obtained from satellite-based sources, ground-based measurements, online databases. Terrain data: Collect digital elevation models (DEMs) or topographic data for the study area. This information is used to analyze shading effects caused by surrounding terrain features like hills, mountains, and buildings. Land use/land cover data: Obtain land use/land cover data to identify areas with different land uses, such as residential, commercial, industrial, or agricultural.

Preprocess the Data: Ensure all data layers are in the same coordinate system and projection. Remove any data anomalies or errors that may affect the analysis. Resample or interpolate data to a consistent spatial resolution if necessary.

Analyze Solar Radiation: Use GIS tools to process the solar radiation data. Calculate solar radiation values for each location within the study area, considering factors like latitude, longitude, slope, aspect, and shading. Consider the time of the year and time of the day to account for seasonal and diurnal variations in solar radiation.

Assess Terrain and Shading Effects: Analyze the terrain data to identify areas that may experience shading from hills, mountains, or other tall structures. Use tools like line of sight analysis or analysis to determine areas where direct sunlight is obstructed. Identify slope and aspect information to understand how it affects solar exposure.

Consider Land Use/Land Cover: Incorporate land use/land cover data to identify areas with different land uses and prioritize suitable locations for solar installations. Some land uses, such as open fields or rooftops, may be more favorable for solar energy generation.

Combine and Weight Factors: Combine the analyzed data layers using GIS overlay operations, such as weighted summation or suitability index approaches. Assign weights to different factors based on their relative importance. For example, solar radiation may have a higher weight compared to terrain or land use.

Generate Suitability Map: Generate a final suitability map based on the combined factors and weights. This map will highlight areas with the highest potential for solar energy generation, considering solar radiation, terrain, and land use characteristics. Use color ramps or classification techniques to visualize the suitability levels, ranging from high to low suitability.

3.2 AHP

AHP stands for Analytic Hierarchy Process. It is a decision-making methodology developed by Thomas Saaty in the 1970s. AHP is widely used in various fields, including business, engineering, and social sciences, to assist in complex decision-making processes.

The basic steps involved in using the Analytic Hierarchy Process are as follows:

- Define the decision problem: Clearly identify the decision to be made and the alternatives available.

- Create a hierarchical structure: Break down the decision problem into a hierarchy of criteria and sub-criteria. The top-level criteria represent the main objectives or goals, while the lower-level criteria represent the factors that contribute to those objectives.

- Pairwise comparisons: Evaluate the relative importance of each criterion and sub-criterion by making pairwise comparisons. Decision-makers compare each element against every other element in the same level and assign a numerical value to express their preference.

- Construct the preference matrix: Based on the pairwise comparisons, a square matrix called the preference matrix is constructed. The values in the matrix represent the relative importance or preference of each element compared to others.

- Calculate priority weights: Analyze the preference matrix to calculate the priority weights for each criterion and sub-criterion. This is typically done using mathematical calculations such as the eigenvector method.

- Check consistency: Assess the consistency of the judgments made during the pairwise comparisons. Inconsistency can arise when decision-makers provide conflicting or inconsistent assessments. Various consistency measures can be used to evaluate the judgments.

- Aggregate priorities: Aggregate the priority weights of each alternative based on the criteria weights to determine the overall ranking or preference of the alternatives.

- Sensitivity analysis: Perform sensitivity analysis to assess the robustness of the results and examine how changes in the judgments or criteria weights affect the final outcome.

By following these steps, the Analytic Hierarchy Process helps decision-makers structure their thinking and arrive at a rational and systematic decision. It provides a framework for considering multiple criteria and allows for transparency and traceability in the decision-making process.

	GHI	LULC	SLOPE	ASPECT	TRANSMISSION LINE	RAIL	ROAD	WATER LINE	WATER BODIES
GHI	1	5	2	2	3	2	1	1	1
LULC	0.2	1	2	3	2	2	1	1	1
SLOPE	0.5	0.5	1	2	1	2	2	1	1
ASPECT	0.5	0.33	0.5	1	1	2	2	2	1
TRANSMISSION LINE	0.33	0.5	0.5	0.5	1	2	2	2	3
RAIL	0.5	0.5	0.5	0.5	0.5	1	2	2	1
ROAD	1	1	0.5	0.5	0.5	0.5	1	1	1
WATER LINE	1	1	1	1	0.5	0.5	1	1	1
WATER BODIES	1	1	1	1	0.33	1	1	1	1
						Consistency Ratio = 0.096			

Figure 3.2: AHP Matrix

The above is a AHP matrix that we got as per the weighted values of all maps and got consistency ratio 0.096.

3.3 Requirement analysis

3.3.1 Software Requirement

- GIS Software: ARCGIS

3.3.2 Maps Requirement

Maps Required will be:

- Sentinel 2A Map of Pune district
- Solar Radiation
- LULC
- Slope
- Aspect
- Transmission Line
- Railway
- Road
- Water Line
- Water Bodies

3.3.3 Data Requirement

Table 3.1: Data and its Sources

Sr. No.	Data	Source
1	Country Boundary, State Boundary, District Boundary, Water Bodies	NERL (https://maps.nrel.gov) DIVA-GIS (http://www.diva-gis.org)
2	Road Network, Rails Network, Transmission Lines, Water lines	NERL (https://maps.nrel.gov) DIVA-GIS (http://www.diva-gis.org)
3	Digital Elevation Model (DEM)	CartoDEM – ISRO (https://bhuvan.nrsc.gov.in/bhuvan_links. php)
4	Solar Radiation	Global Solar Atlas (https://globalsolaratlas.info/downloads/india)
5	Sentinel 2A	Copernicus Open Access Hub (https://scihub.copernicus.eu/dhus/#/home)

3.4 Impact analysis

3.4.1 Impact of project on society

Positive Impact of project on society:

Reduced burden on fossil fuels/exhaustible natural resources.

Negative Impact of project on society:

Massive initial investments required.

3.4.2 Impact of project on environment

Positive Impact of project on environment:

Reduced dependency on exhaustible natural resources. Clean energy. Unlimited source of energy.

Negative Impact of project on environment:

Weather Dependent

3.5 Professional ethical practices to be followed

- The study done has not been copied from other sources
- Appropriate credits are provided to the concerned party whose resources are referred in the study
- Conflict of interest was resolved using proper discussions

Chapter 4

Project Implementation

A piece of data that represents a significant state, typically in the context of input and output. Pune district sentinel data and a boundary map are gathered. Sentinel data refers to the Earth observation data collected by the Sentinel satellites, which are part of the European Union's Copernicus program. The Copernicus program aims to provide accurate and up-to-date information about the Earth's environment for various applications, including environmental monitoring, climate change analysis, disaster management, and more.

The Sentinel satellites are equipped with various sensors that capture data across multiple wavelengths of the electromagnetic spectrum. These sensors provide information about land, ocean, atmospheric, and cryospheric parameters, allowing for a comprehensive understanding of Earth's dynamics.

The Sentinel satellite missions include several different types of satellites, such as Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-4, and Sentinel-5. while Sentinel-2 provides high-resolution optical imagery for land monitoring.

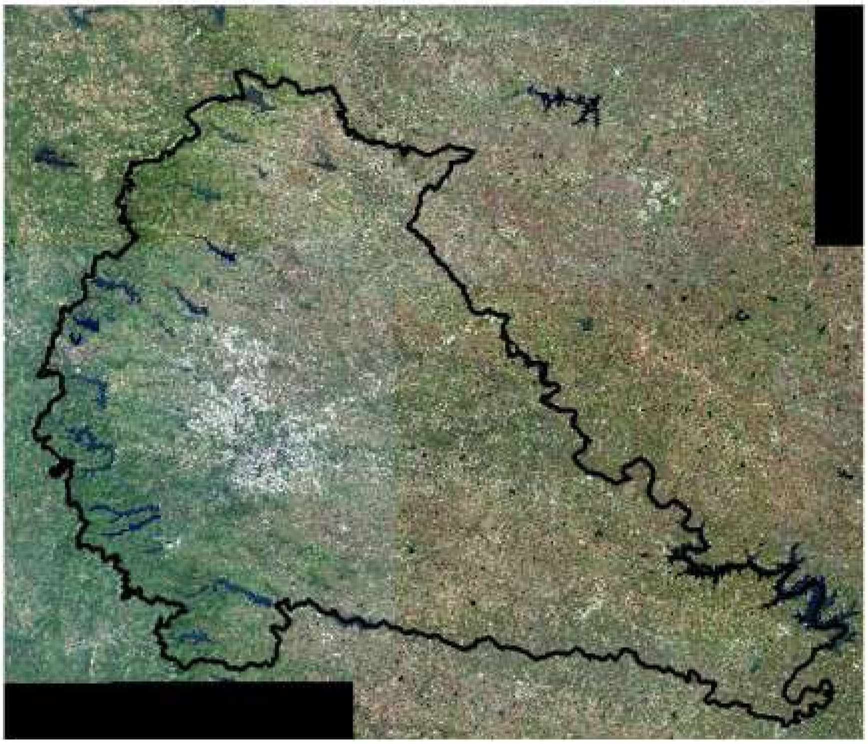

Figure 4.1: Sentinel data of Pune district

The Sentinel satellites are equipped with various sensors that capture data across multiple wavelengths of the electromagnetic spectrum. These sensors provide information about land, ocean, atmospheric, and cryospheric parameters, allowing for a comprehensive understanding of Earth's dynamics. The Sentinel satellite missions include several different types of satellites, such as Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-4, and Sentinel-5. while Sentinel-2 provides high-resolution optical imagery for land monitoring.

The clipped image of Pune from sentinel data collected through Copernicus data hub. Sentinel-2A is a satellite mission developed by the European Space Agency (ESA) as part of the Copernicus program. It is part of a constellation of satellites designed to monitor Earth's environment and provide valuable data for various applications.

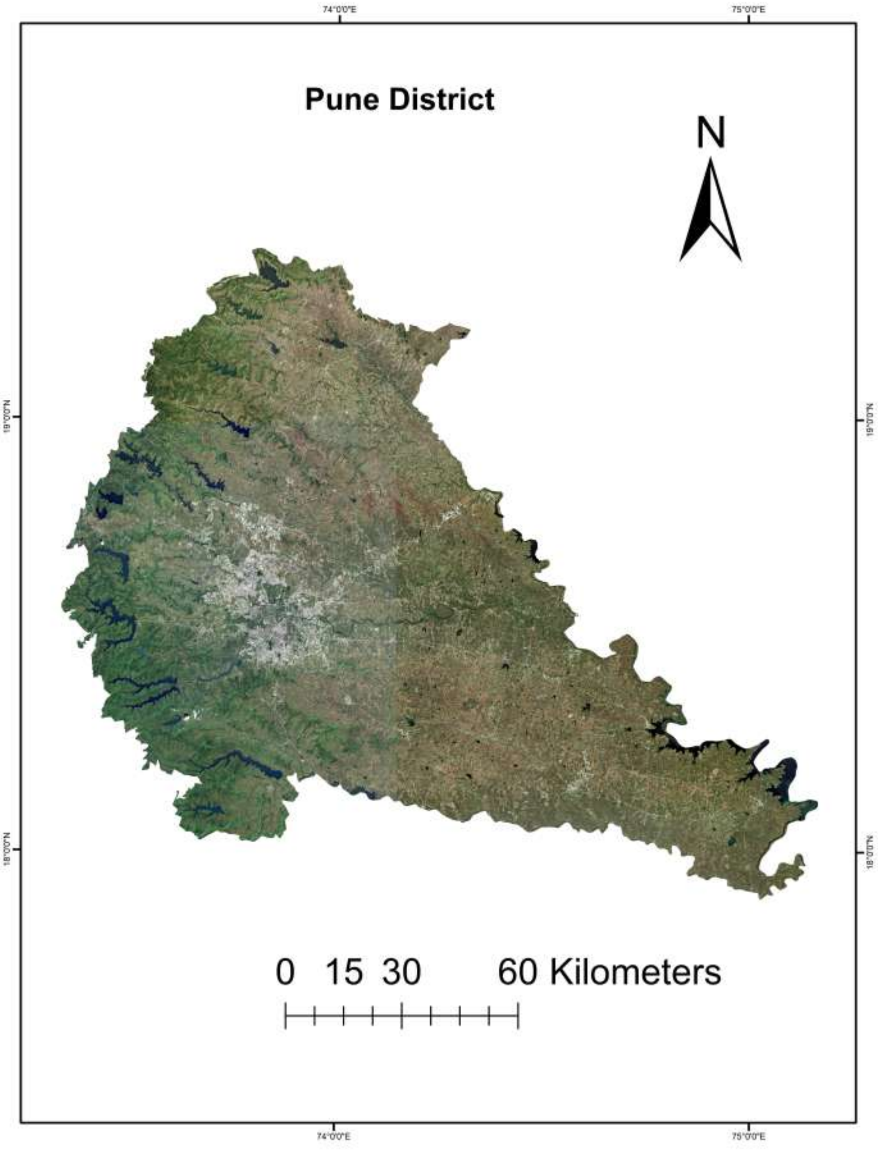

Figure 4.2: Clipped Pune from Sentinel data

Sentinel-2A is one of the satellite missions in the European Union's Copernicus program. It was launched on June 23, 2015, and is designed to provide high-resolution optical imagery of the Earth's surface. Sentinel-2A works in conjunction with its twin satellite.

The land use and land cover (LULC) maps used in this study were grouped into four categories: Barren land, Built-up area, Water bodies and vegetation.
Random Forest is an ensemble learning method that constructs multiple decision trees and combines their predictions to make final predictions. It is known for its ability to handle high-dimensional data, handle missing values, and handle nonlinearity in the data. Random Forests are generally robust, less prone to overfitting, and perform well in a variety of settings.

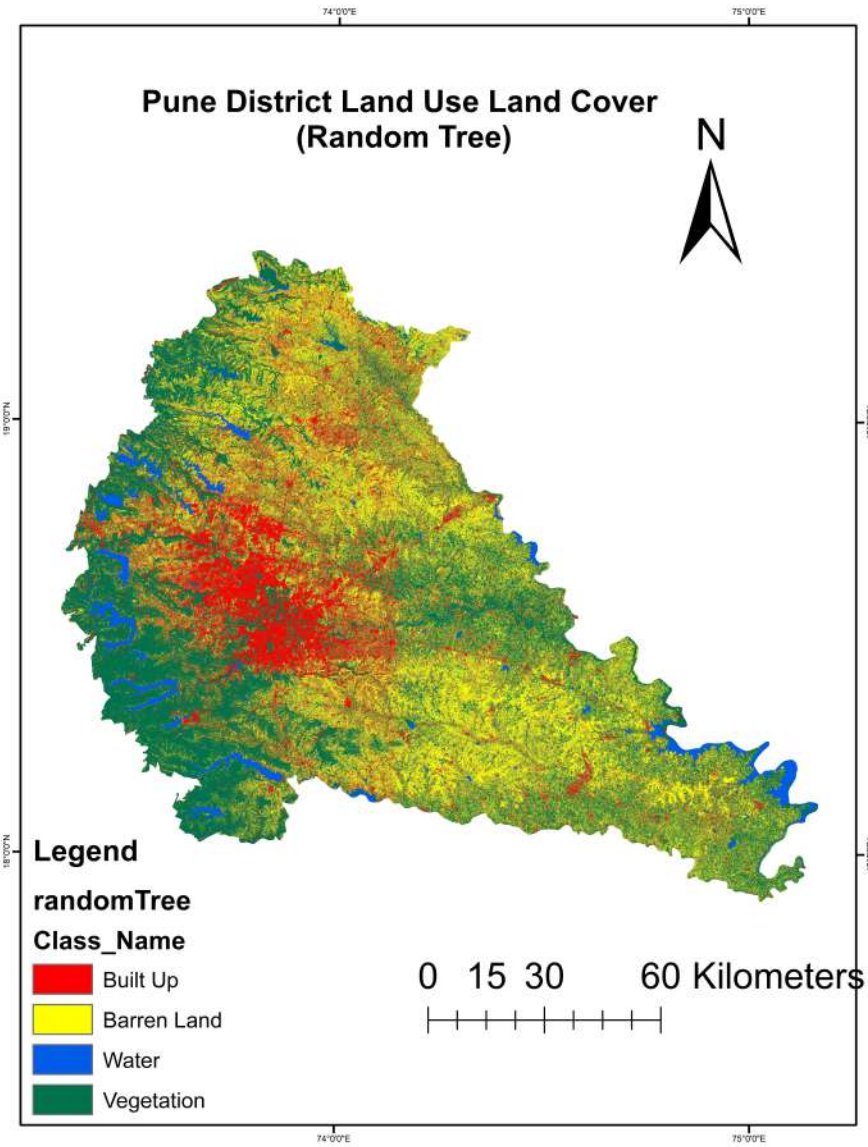

Figure 4.3: LULC using Random Tree

This algorithm is used to extract the data from each multi spectral band and classify the image cells according to a user-defined classification. The LULC map tells about the percentage of built up area, barren land, water bodies, agriculture and vegetation covered in the Pune district.

Table 4.1: Random Tree algorithm pixel counts

Random Tree			
Particulars	**Pixel Count**	**Percentage (%)**	**Area (km2)**
Barrenland	56187806	36.03	5618.78
Water	5281801	3.39	528.18
Vegetation	65409030	41.95	6540.90
Builtup	29051778	18.63	2905.18
Total	**15,59,30,415**	**100**	**15593.04**

The figure shown below depicts the LULC map of Pune using the Support Vector Machine algorithm. LULC (Land Use and Land Cover) classification using SVM (Support Vector Machine) is a common approach in remote sensing and geospatial analysis.Support Vector Machines (SVM) is a powerful supervised learning algorithm used for classification and regression tasks. SVM finds the optimal hyperplane that separates the data into different classes by maximizing the margin between the classes. It is particularly effective when dealing with high-dimensional data or when the decision boundary is nonlinear.

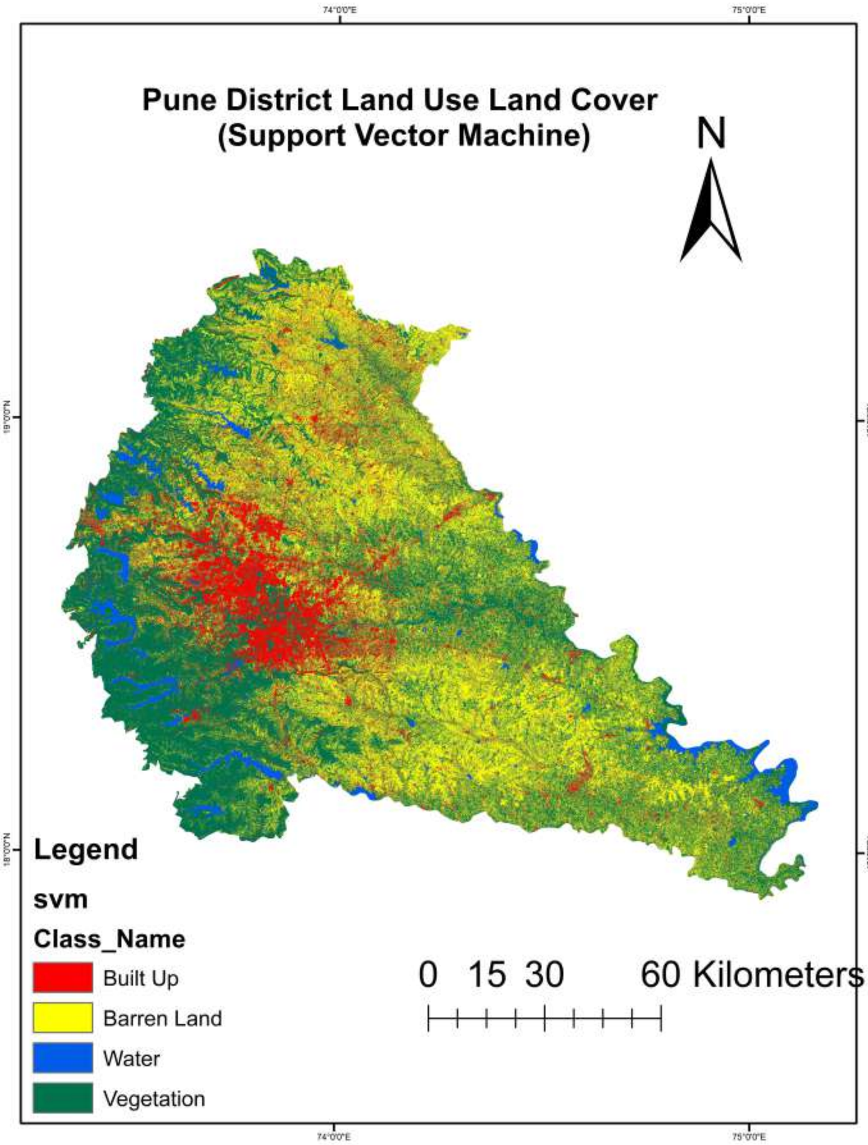

Figure 4.4: LULC using SVM

The pixel count of the support vector machine land use land cover map is provided in the table below.

Table 4.2: Support Vector Machine algorithm pixel counts

Support Vector Machine			
Particulars	**Pixel Count**	**Percentage (%)**	**Area (km2)**
Barrenland	57594914	36.94	5759.49
Water	5601414	3.59	560.14
Vegetation	72493811	46.49	7249.38
Builtup	20240276	12.98	2024.03
Total	**15,59,30,415**	**100**	**15593.04**

The third algorithm used to produce the land use land cover map was the Maximum Likelihood Algorithm. Maximum Likelihood is a statistical method used for parameter estimation in probabilistic models. It is commonly used in techniques such as logistic regression and naive Bayes classifiers. ML is primarily suited for problems where there is a clear probabilistic framework and assumptions about the underlying data distribution. It aims to find the parameter values that maximize the likelihood of the observed data. The basic idea behind maximum likelihood is to find the values of parameters that maximize the likelihood function. This algorithm is used to extract the data from each multi spectral band and classify the image cells according to a user-defined classification.

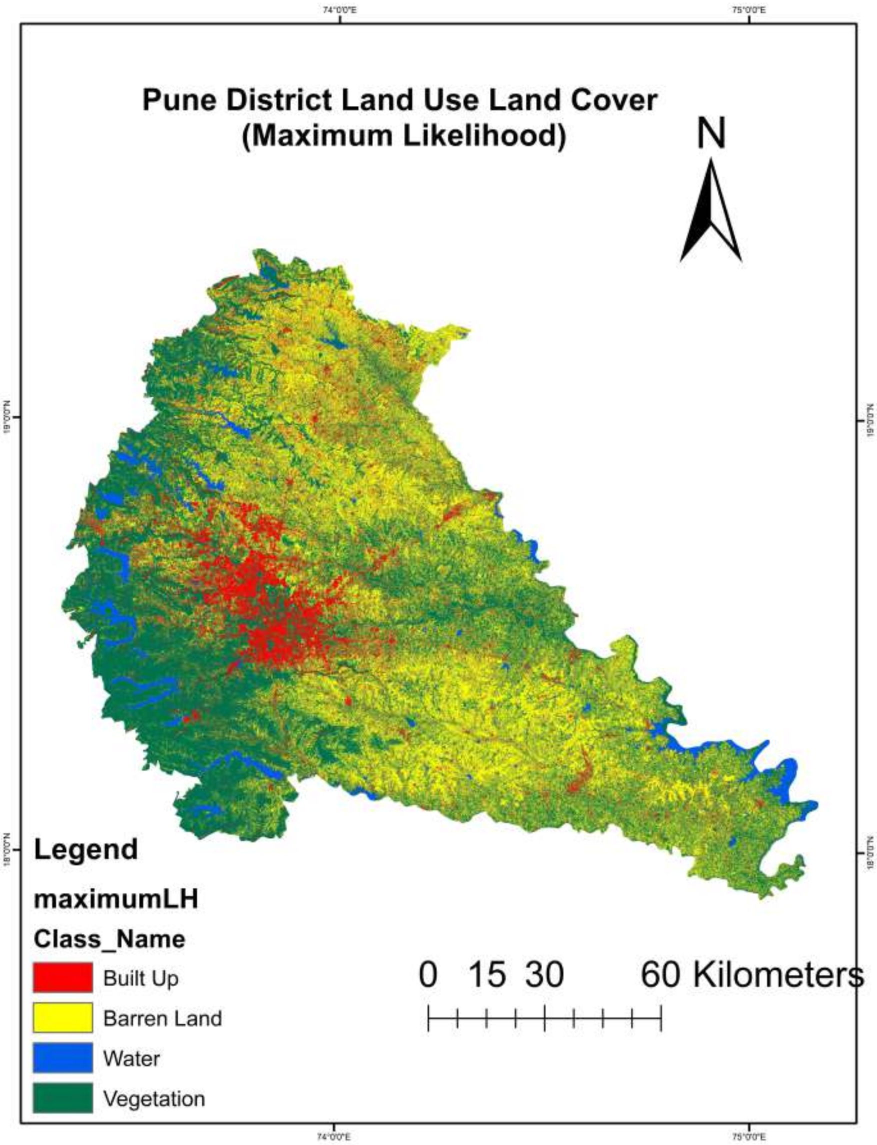

Figure 4.5: LULC using Maximum Likelihood

The pixel count according to the classification for the LULC generated by the maximum likelihood algorithm is presented in the below mentioned table.

Table 4.3: Maximum Likelihood algorithm pixel counts

Maximum Likelihood			
Particulars	**Pixel Count**	**Percentage (%)**	**Area (km2)**
Barrenland	59176623	37.95	5917.66
Water	5225976	3.35	522.60
Vegetation	73536713	47.16	7353.67
Builtup	17991103	11.54	1799.11
Total	**15,59,30,415**	**100**	**15593.04**

The accuracy of maximum likelihood was better than comparatively other two i.e random tree and svm, so went ahead with the LULC map generated from the maximum likelihood algorithm for further solar site suitability map.

4.0.1 System Implementation

The system implementation begins with the use of global solar irradiation map i.e solar map of Pune district. Solar irradiation maps provide valuable information about the amount of solar radiation received in different regions or locations. These maps help assess the solar energy potential and aid in the planning and optimization of solar energy systems.

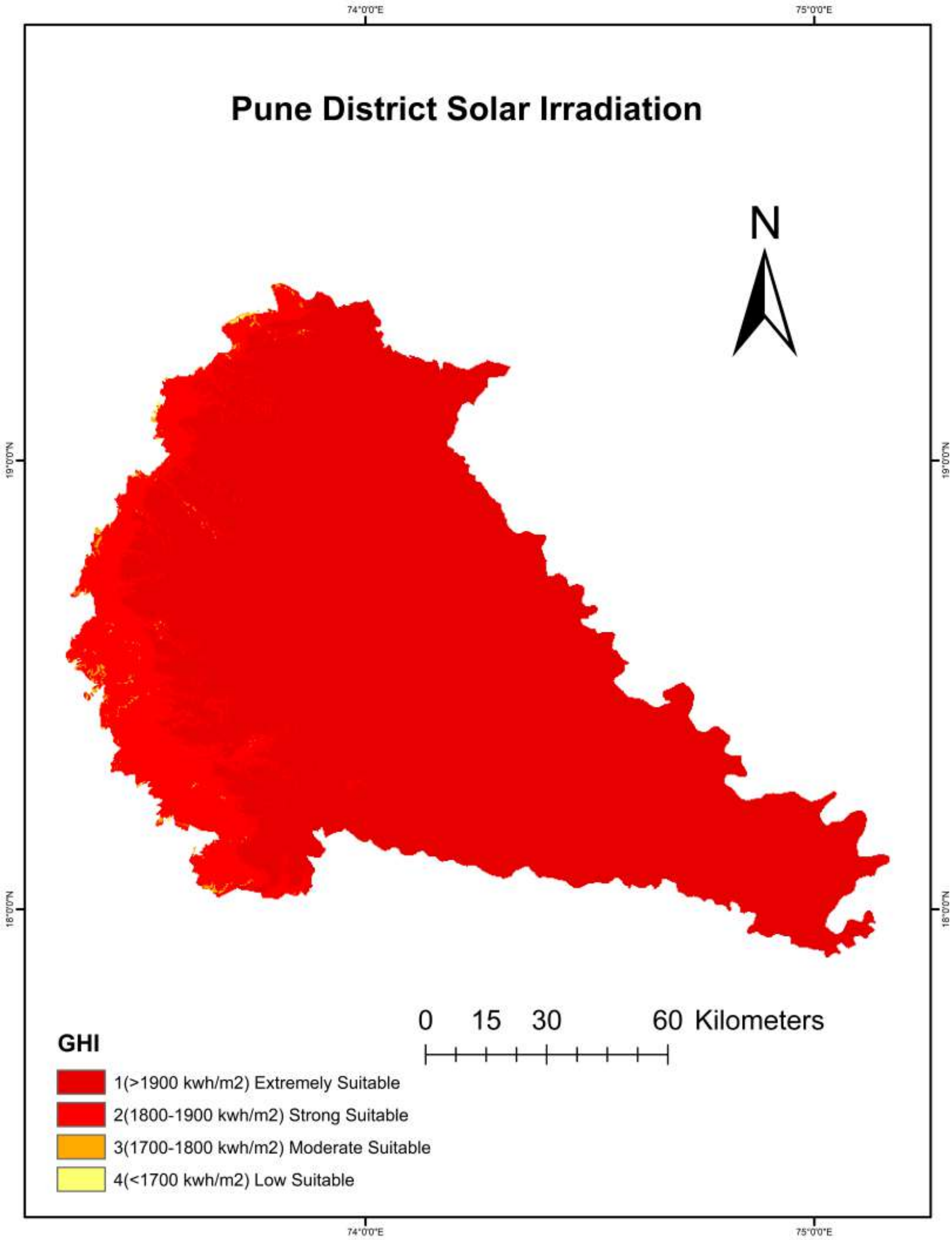

Figure 4.6: Solar Irradiation Map of Pune

The above map classifies the scale of solar radiation as extremely, strong, moderate and low suitability in the above solar irradiation map.

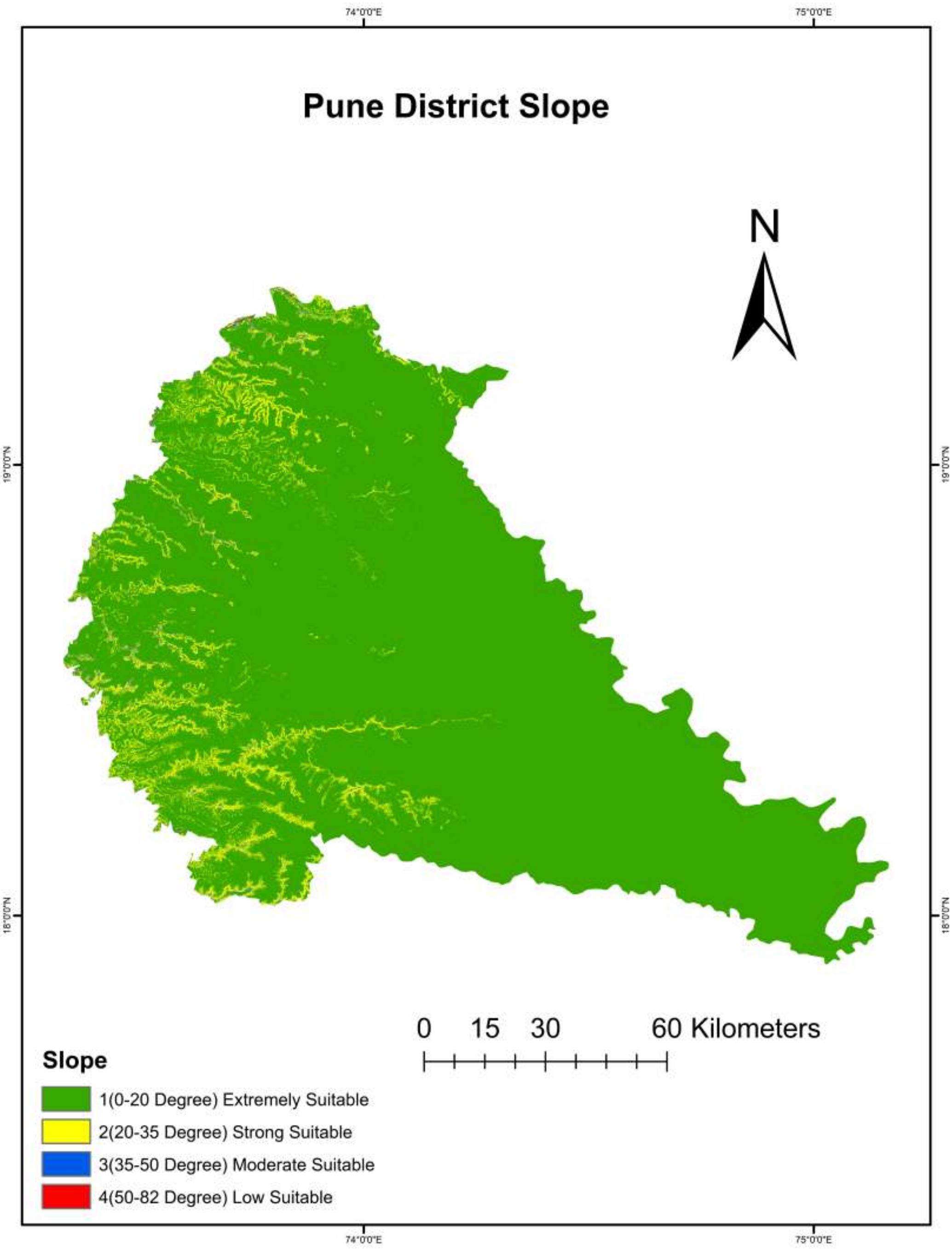

Figure 4.7: Pune Slope map

The above map is about slope map of Pune for which we need elevation data for area of interest. The most common source of elevation data is digital elevation model(DEM), which is representation of earth surface as a grid of elevation values.

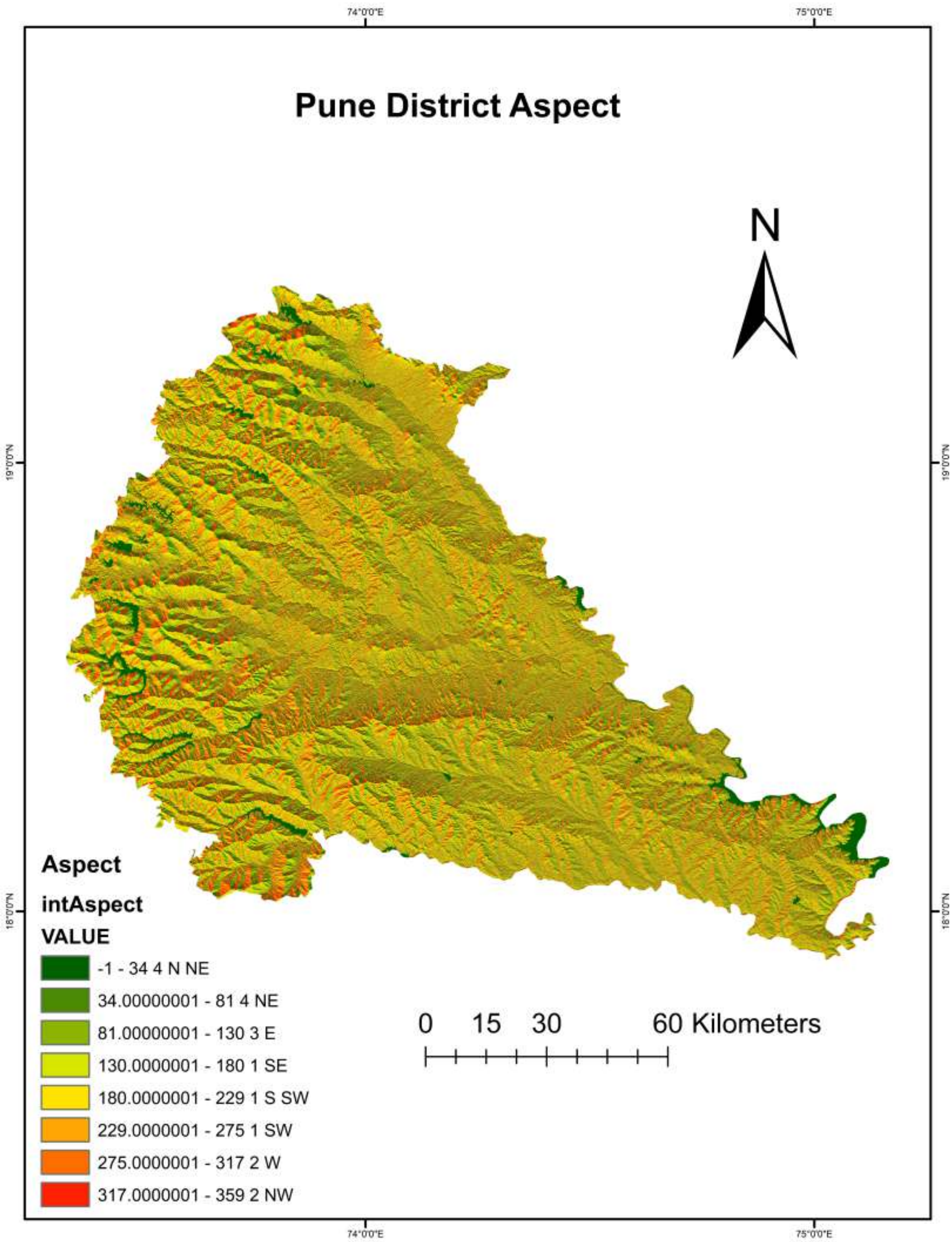

Figure 4.8: Aspect map

The map depicts about the aspect map of Pune for which we need elevation data for area of interest. The most common source of elevation data is digital elevation model(DEM), which is representation of earth surface as a grid of elevation values.The aspect represents the direction in which a slope faces, such as north, south, east or west.

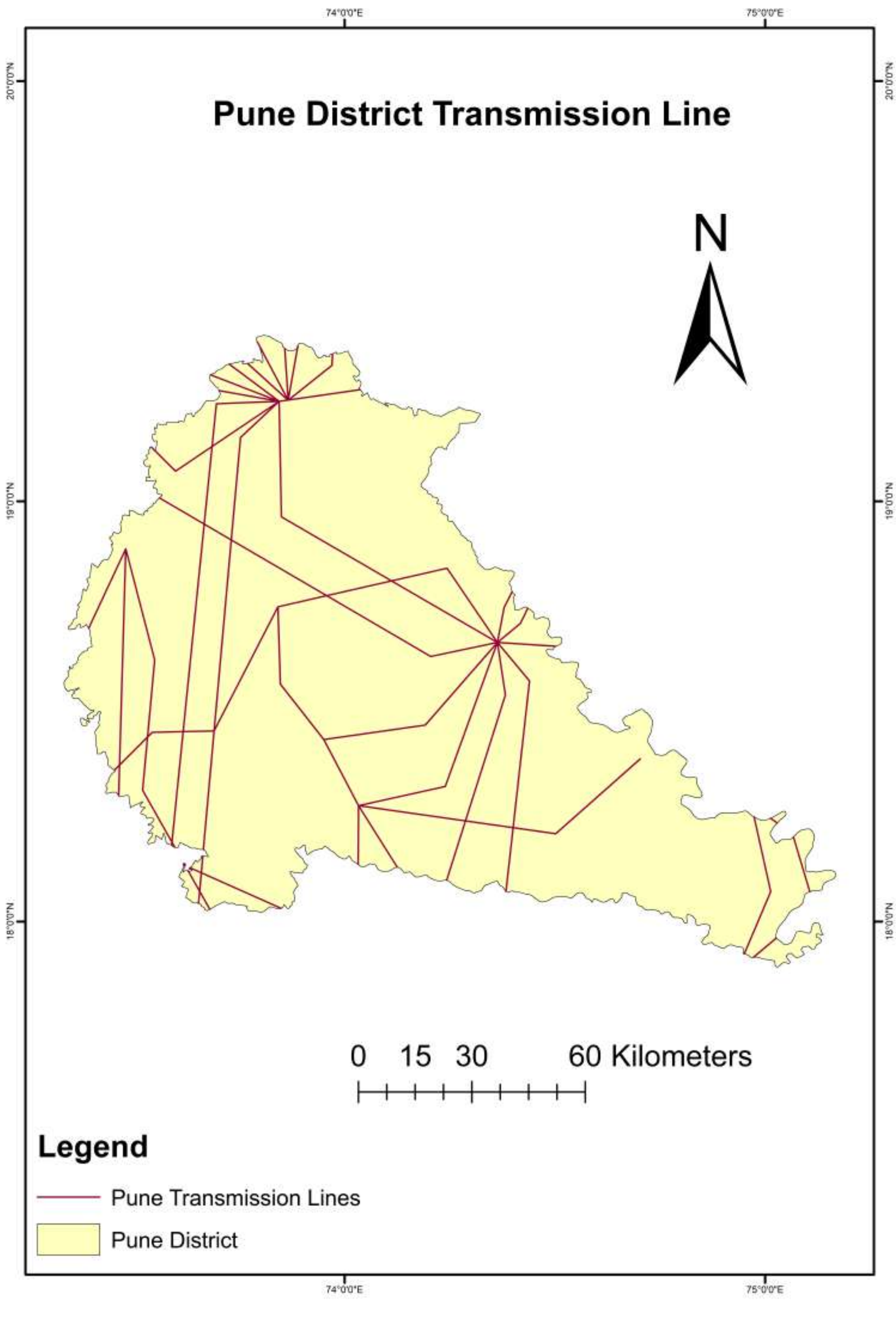

Figure 4.9: Pune transmission line map

The above map is about the transmission line map of Pune which will be used for the solar site suitability analysis map.

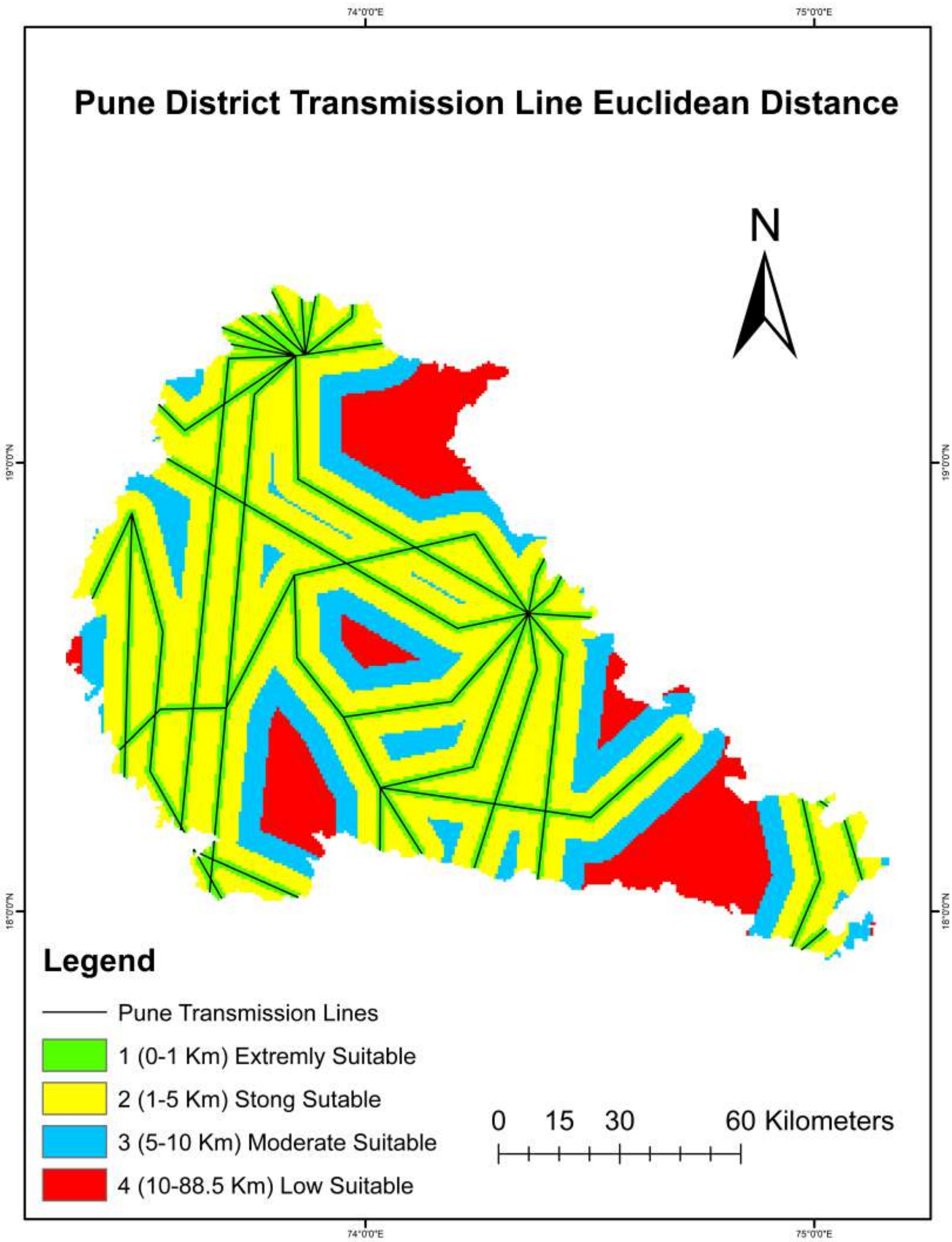

Figure 4.10: Euclidean distance map of transmission line map

The above is euclidean distance map of Pune for which we have to obtain the geographical coordinates or shape file of transmission line, create raster grid, calculate euclidean distance, visualize and analyze euclidean distance map.

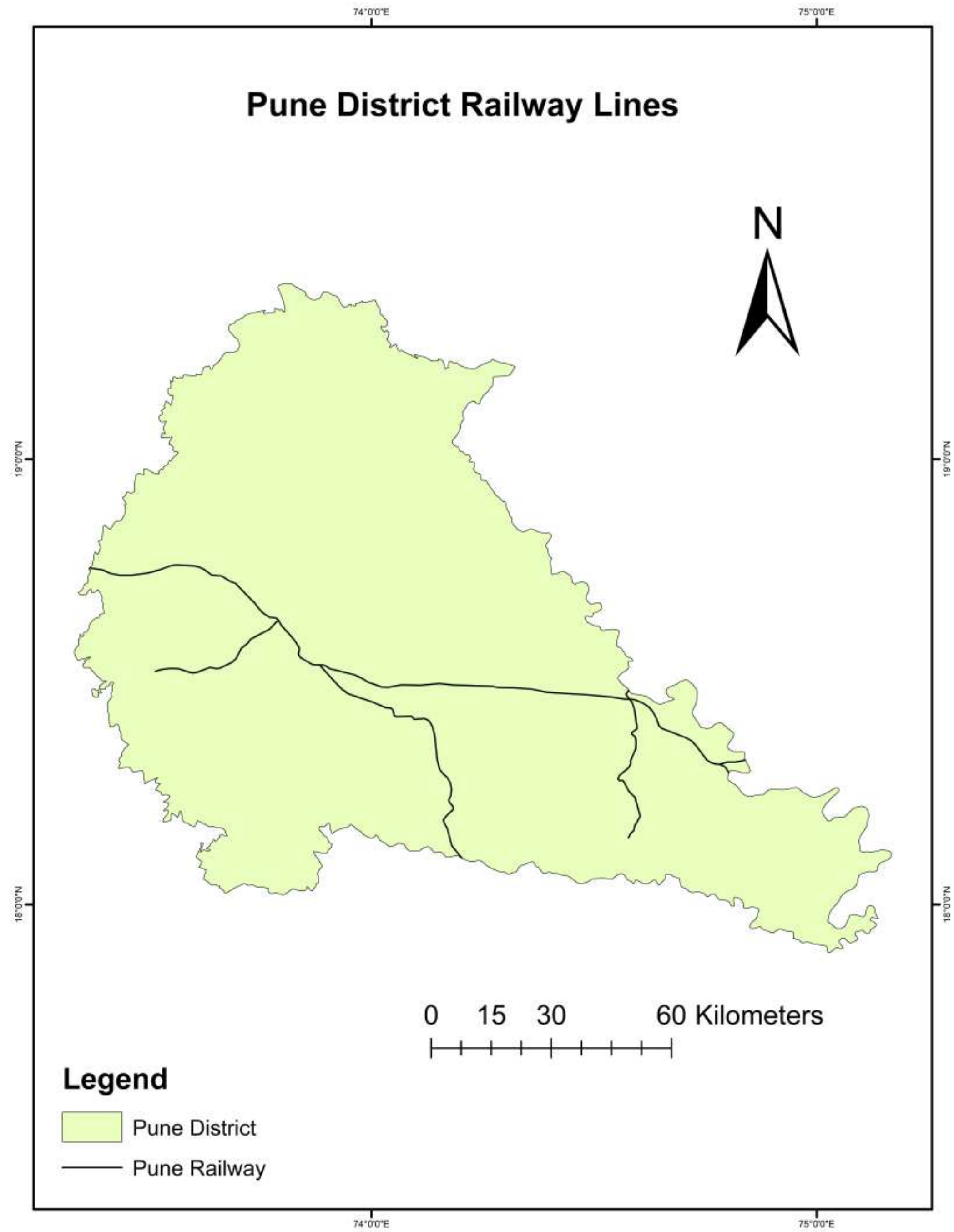

Figure 4.11: Pune railway map

The above is railway map of Pune, to obtain this we need to connect to pune district data sources, data acquisition, symbology and styling, labeling for map output.

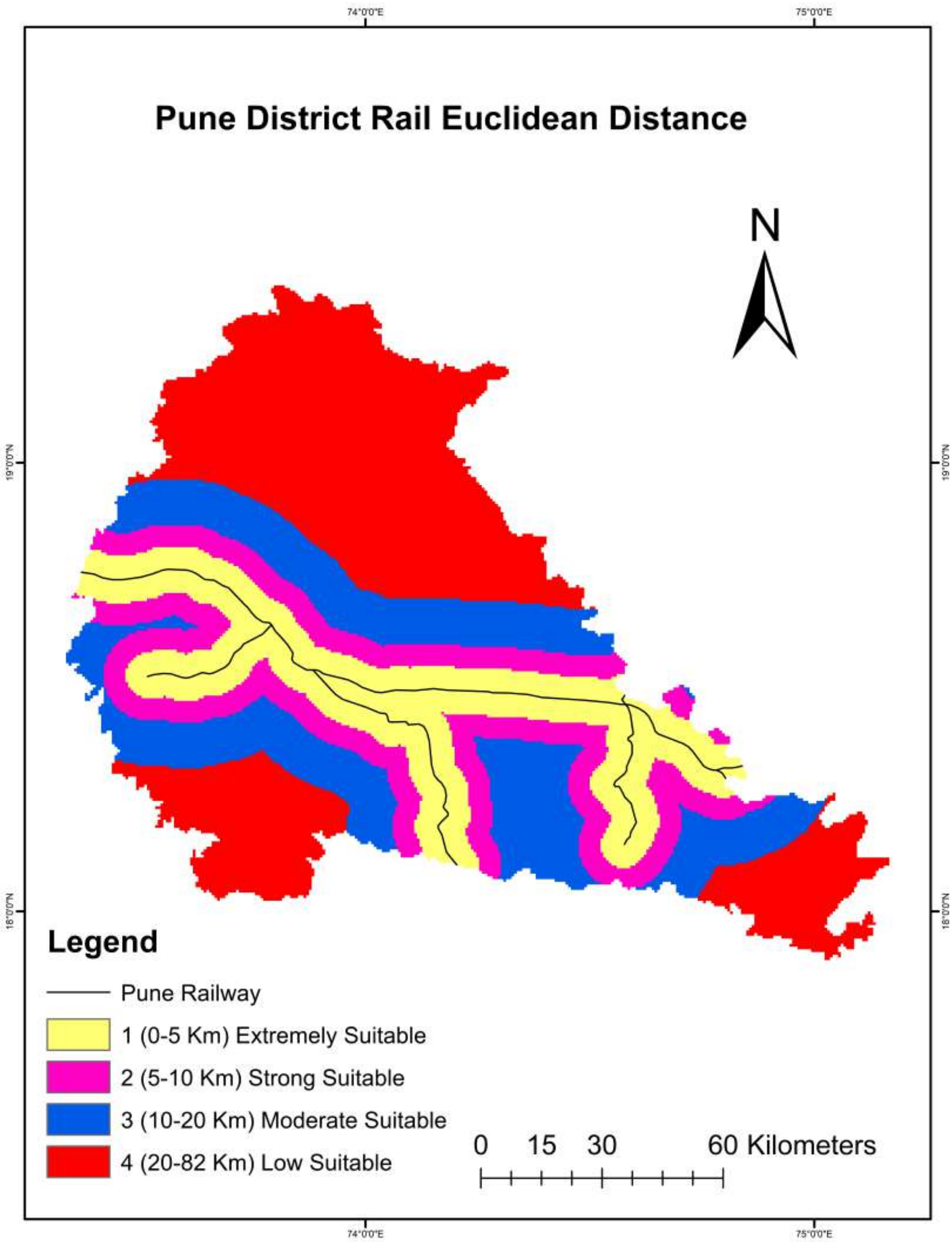

Figure 4.12: Euclidean distance map of railway line map

The above is euclidean distance map of railway line map of Pune to create this we need to obtain railway data of Pune district, data acquisition, load data with GIS, convert vector lines to raster, calculate euclidean distance.

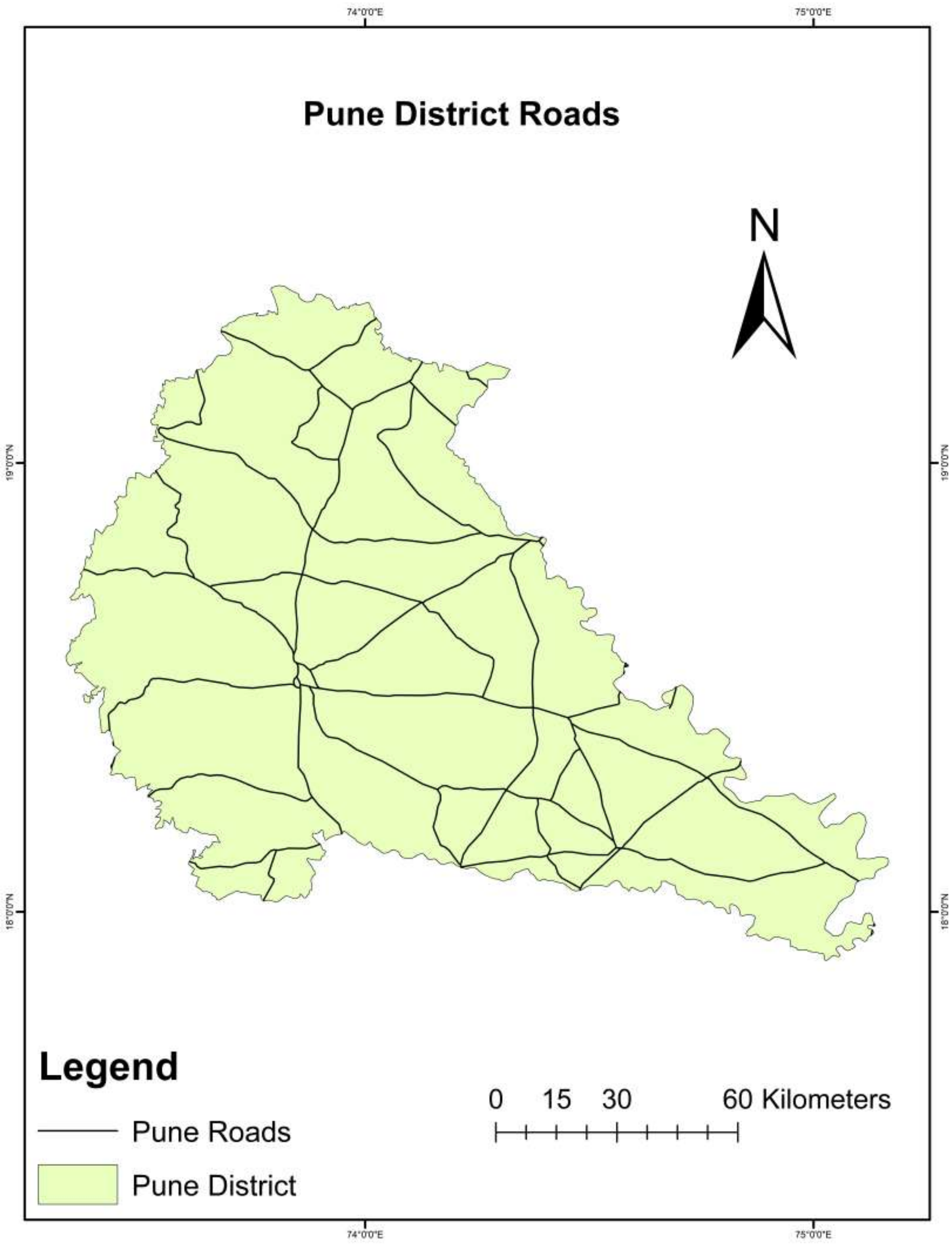

Figure 4.13: Pune road map

The above is road map of Pune, to obtain data sources and acquisition, to calculate distance, labeling is required.

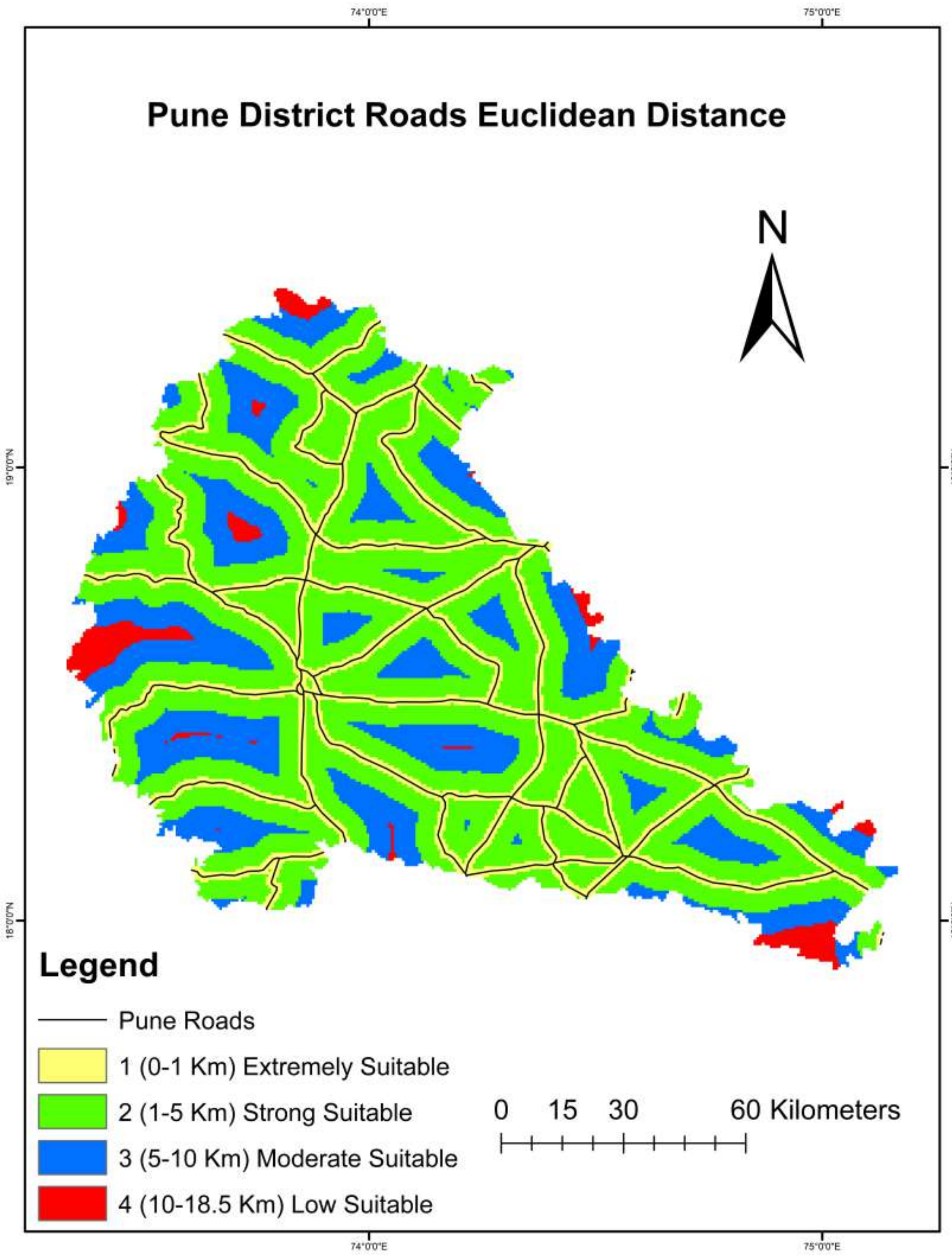

Figure 4.14: Euclidean distance map of road map

The above is euclidean distance map of road map of Pune, to obtain this we need to get help of data sources, data acquisition then visualize it and analysis of data.

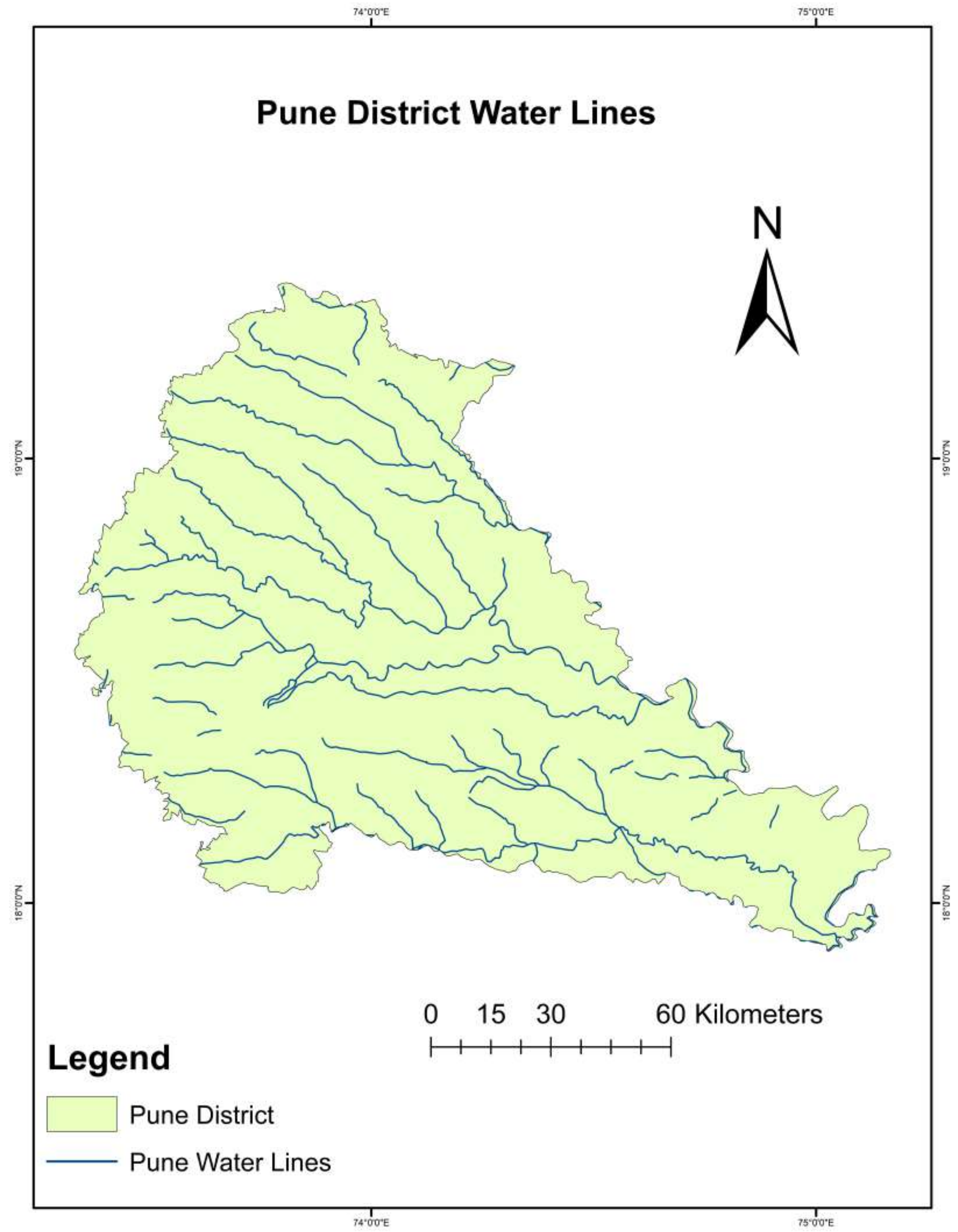

Figure 4.15: Water Line map of Pune

The above is water line map of Pune, to obtain this we need to get data sources from websites, data acquisition, symbology and styling, labeling.

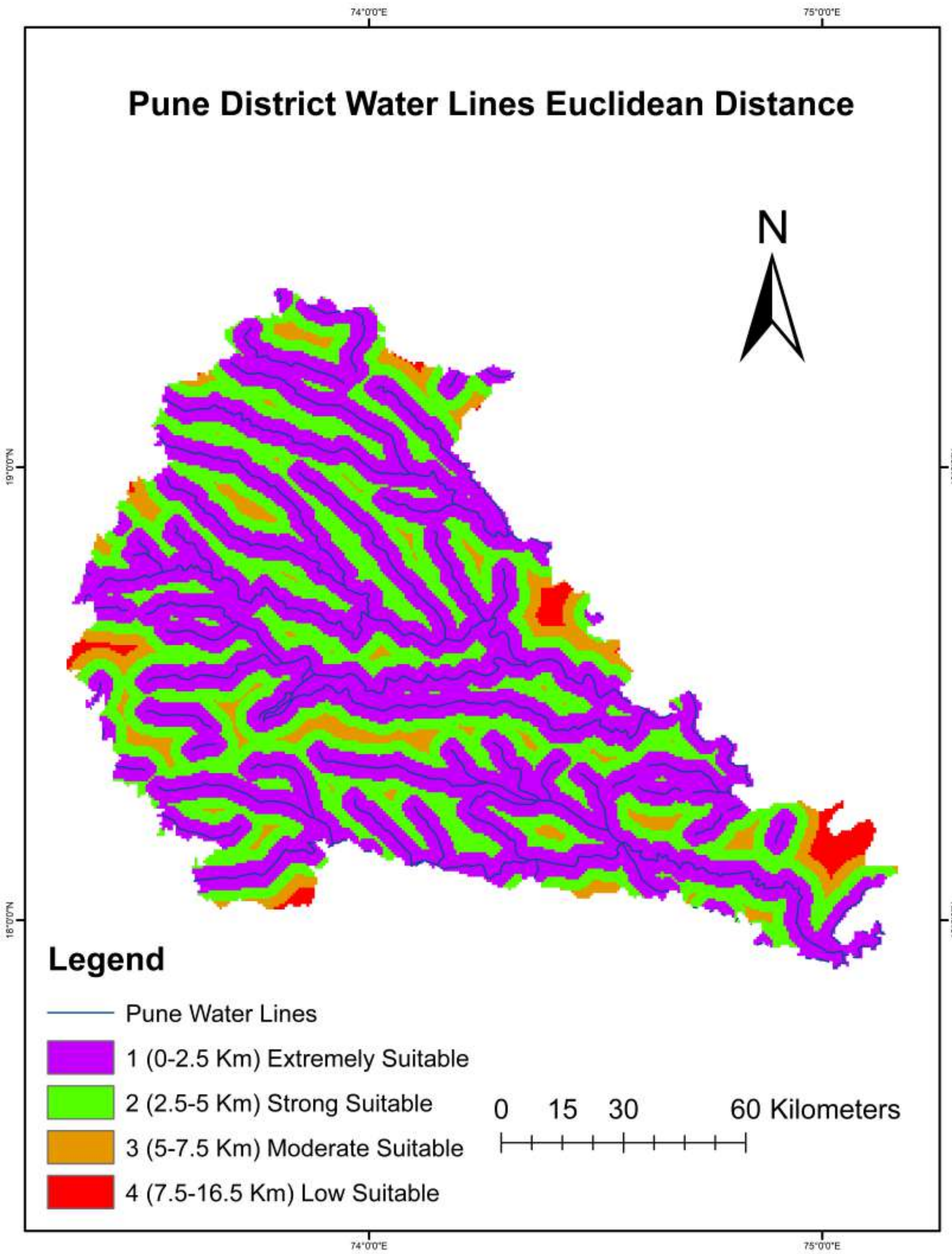

Figure 4.16: Euclidean distance map of water lines

The above is euclidean distance map of water lines of Pune district, to create this we need to obtain water line data, convert vector lines to raster, calculate euclidean distance, visualize and analyze euclidean distance map.

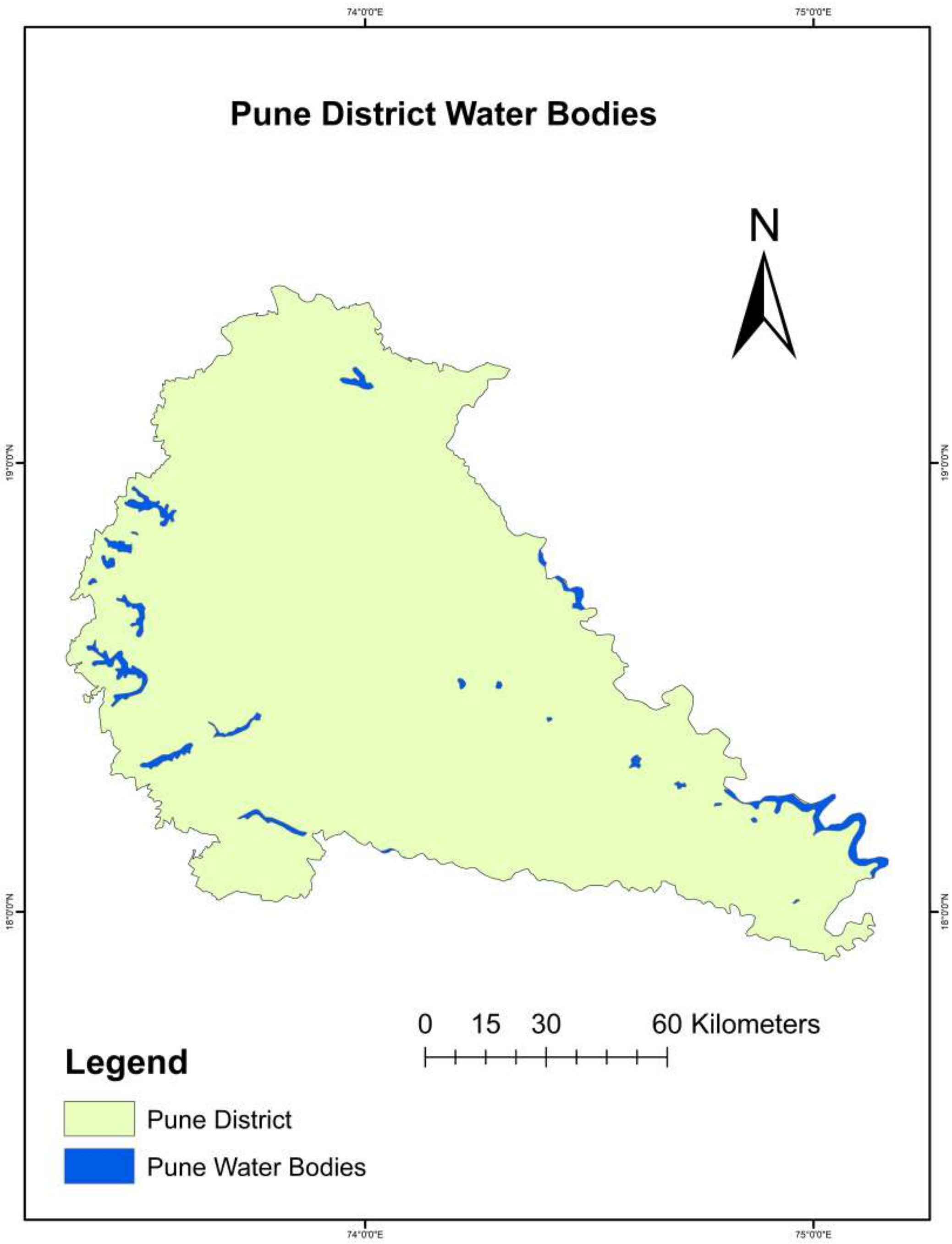

Figure 4.17: water bodies map

The above is water bodies map of Pune district to obtain this we need to get help of satellite imagery, open data source, online mapping platforms, hydrological data.

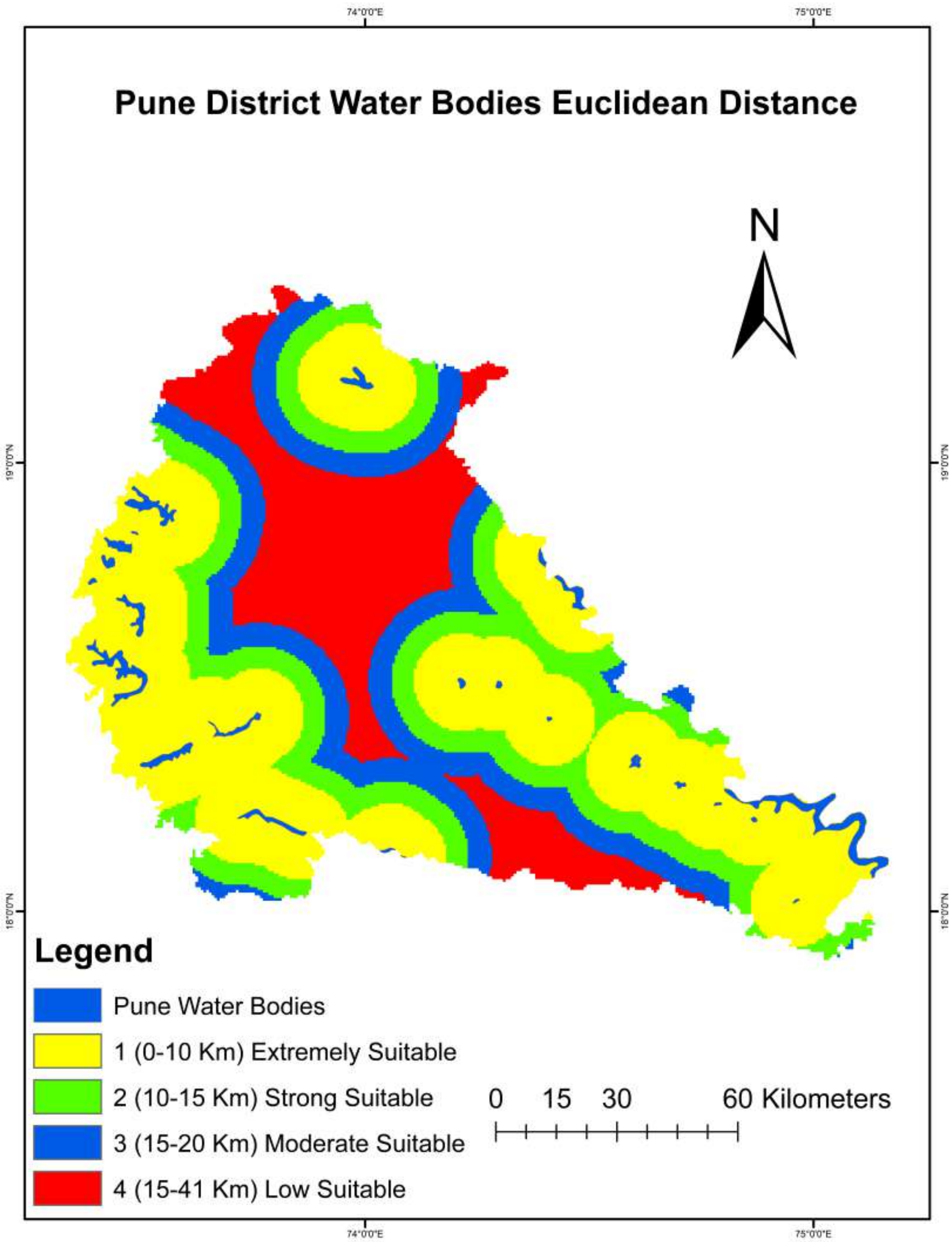

Figure 4.18: Euclidean distance map of water bodies map

The above map is euclidean distance map of water bodies of Pune district, to create this data preparation, to calculate euclidean distance, visualization and analysis is required.

4.0.2 Software Implementations

As per AHP technique, using the AHP, we get the weighted values for each map, used to produce the suitability map.We can see in the above table solar radiation map has the highest value 20.388 and Road map with lowest value of 7.859.

Table 4.4: AHP count for each map

Sr.No	Map	Value
1	Solar Radiation	20.388
2	Land Use Land Cover	13.299
3	Slope	10.785
4	Aspect	9.885
5	Distance From Transmission Line	12.098
6	Distance From Railway	8.206
7	Distance From Road	7.859
8	Distance From Water Line	8.392
9	Distance From Water Bodies	9.088

Chapter 5

Results and Discussion

5.1 Results

The Suitability map generated presents us with the following results that:

- The extremely suitable area was of total 5867.66 Km2.
- The strong suitable area was of total 40704.11 Km2.
- The moderate suitable area was of total 3288.10 Km2.
- The low suitable area was of total 1733.17 Km2.

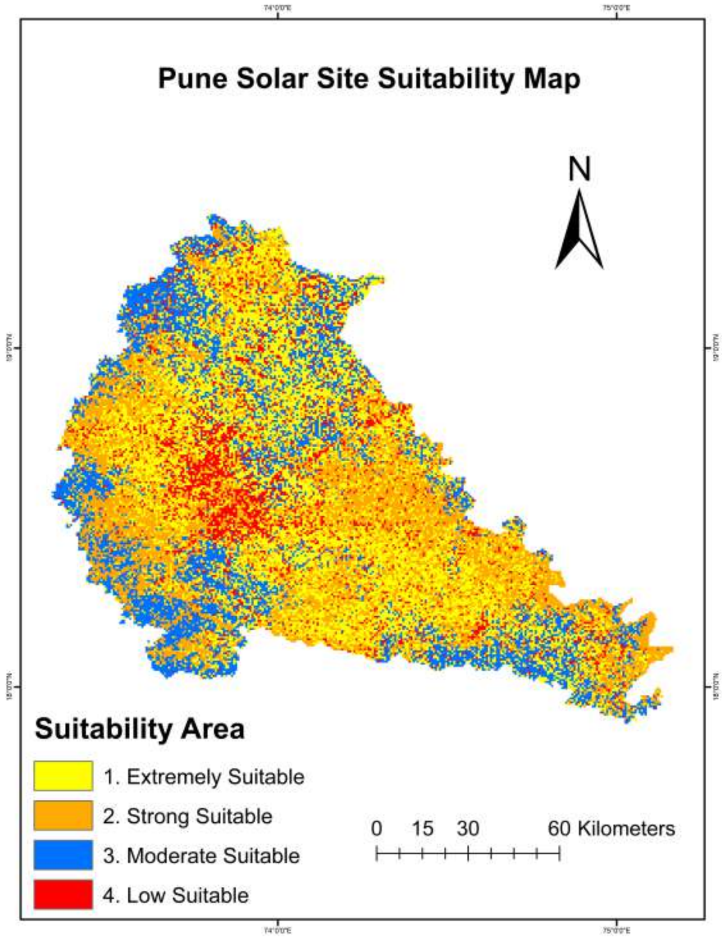

Figure 5.1: Pune District Solar Suitability Map

The values generated might contrast to the actual data present and if needed needs to be re-worked upon.

Table 5.1: Pixel Count of Solar Site Suitability Map

Sr. No.	**Particulars**	**Pixel Count**	**Percentage (%)**	**Area (km2)**
1	Extremely Suitable	13853	37.63	5867.66
2	Strong Suitable	11106	30.17	4704.11
3	Moderate Suitable	7763	21.09	3288.10
4	Low Suitable	4092	11.12	1733.17
	Total	**36814**	**100**	**15593.04**

Chapter 6

Conclusions and Future Scope

6.1 Conclusions

- We conclude the percentage of area which is extremely, strong, moderate,low suitable for setting up solar power plants.
- We conclude that up to 37 percent of Pune district area is highly suitable for setting up solar power plant.
- And approx 11 percent area of Pune district is low suitable for solar power plant.
- he values generated might deviate from the actual values and needs to be cross verified.
- Hence, if needed some re processing needs to be done to get more accurate results.

6.2 Future Scope

- Further more discovery can be done using the satellite images.
- Also, power generated can be calculated at the suitable solar sites when solar power plant is set up at the finalized sites.

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