PROJECT REPORT

ON

Solid Waste Dumping Site Suitability Selection using Remote Sensing & GIS : A study of Kota City

Submitted in Fulfillment for the Degree of

Masters in Remote Sensing & GIS

Submitted To

Geography Department

Panjab University

Submitted By

Mayank Doi

Masters in RS & GIS (Sem-4)

Contents

List Of Tables

List Of Figures

ACKNOWLEDGEMENTS

Firstly, I would like to express my utmost gratitude to GOD .The Almighty who gave his blessings and gave me the best health of mine to do my internship and make it progressed smoothly with a lot of meaningful experiences and new knowledge hiding behind.

I would also like to express my gratitude for a lot of helps and guidance given by my Final Year Project Supervisor Mr. Negi (Reseacrh Scholar). Thousand thanks for your support and understandings and also for your blessings throughout the semester period of implementing the project. Without your guidance I might not be able to complete or to even do the project on my own.

I would also like to express my gratitude for a lot of guidance and support from Chairperson Simrit Kahlon .She went to all depths to make me understand the research methodology for the project and even guided me in the duration.

A very huge gratitude for Subject incharge Asst. Prof Vishwa Bandhu Singh for his support and help in order to help me achieved the objectives of the project.

Last but not least, thanks to all the Faculty (Prof. Karanjot Kaur Brar , Prof. Dhian Kaur , Prof. Krishna Mohan , Prof. Ravinder Kaur , Prof. Smita Bhutani ,Asst. Prof. Gaurav Kalotra , Asst. Prof Navneet Kaur ,) and the staff for giving me information & specification .Without all of you, I would not be able to complete the project within given time. Again, thanks a lot.

Abstract

Solid waste dumping site is a serious problem in Kota city as most solid wastes are not dumped in suitable sites. The main objective of this study was to select suitable solid waste disposal sites that are economically feasible, environmentally sound, and socially acceptable in Kota city by applying Geographic Information System and Remote Sensing technologies. For this research, data were gathered from different sources. Sources include DEM from USGS with a spatial resolution of 30×30 m for slope, Open Street Data, land-use/land-cover maps generated from Sentinel 2A image with a spatial resolution of 10×10 m. To accomplish the objectives, the present study used factor maps as, slope, area, road network, river, land-use/land-cover, , which were reclassified in GIS environment followed by preparation of the restriction map and suitability map. Even if the degree of weight to each factor varies, factors were considered important and mandatory in the selection of suitable sites for solid waste disposal. Analytical Hierarchy Process pair-wise comparison module was used to accomplish weights of factor parameters, and finally suitability map was prepared by overlay analyses and assigned as highly suitable, suitable, moderately suitable, less suitable and unsuitable. The final result shows that from total area 5355.9 sq km , 20.36 % (1090.7 sq km) is highly suitable, 19.7 % (1057.2 sq km) is suitable, 19.90 % (1066 sq km) is moderately suitable, 19.6 % (1051 sq km) is less suitable and 20.37 % (1091 sq km) is unsuitable for solid waste dumping in Kota District. In general, the selection of highly suitable sites requires further geotechnical and hydro-geological analyses to ensure conformity with serious standards required for design and construction of the facility.

Keywords: Analytic hierarchy process, Dumping site, Geographic information system, Solid waste, Remote sensing

Chapter 1: Introduction

1.1 Background of the study

Waste is a material discharged from daily human activities, which makes adverse impacts on human health and environment. Solid wastes can be defined as non-liquid and non-gaseous products of human activities, like those from households, municipal, supermarket, construction and industries. Generation of solid waste has become a global environmental and health issue in the contemporary world both in developing and developed countries. Increasing population, rapid economic growth, improved living standards, expansion of urban and industrial activities accelerate solid waste generation.

Fast expansion of urban, agricultural and industrial activities encouraged by rapid population growth has produced vast amounts of solid and liquid wastes that pollute the environment and destroy natural resources. In many countries, with an increase in human population and the rising demand for food and other essentials resources, there has been a rise in the amount of solid waste generated making its management and disposal problematic. Solid waste management has long been a worldwide environmental problem. Common problems associated with systematic management of solid waste include transmission diseases, fire hazards, foul odor, atmospheric and water pollution and economic victims.

There are problems related to solid waste disposal sites in Kota district. Even if most of the solid wastes are collected from sources using vehicles to temporary transfer stations, there is no scientifically approved site for disposal. There is also no standard transfer station in the town. All health institutions and private sectors follow their way of removal of waste and others dispose of it in and around water bodies (Chambal river) .These dumping sites are not well planned and they are open field disposal (no sanitary landfill) close to rivers and not at an appropriate distance from the center of the city. In order to improve these problems, integrating Remote Sensing (RS) and Geographic Information System (GIS) techniques can be used to select the best possible solid wastes dumping as the concurrent technology. Selection of solid waste disposal sites using RS and GIS requires many factors that should be integrated into one system for proper analysis. The selection criteria should consider and combine slope, built-up, land-use/land-cover and road networks.

1.2 Statement of the Problem

Solid waste management has been a big challenge to both the developed and developing countries all over the world. As a result of urbanization development activities and population growth, high amounts of solid wastes are generated every day. People are coming to the town for study, to find jobs in town urban infrastructure and, to open commercial activities like shop, cafes, hotel, and supermarket. The high rate of waste generation is facing the problem of disposal and as a result it has the very high potential effect to pollute environments such as surface water, groundwater, soil, and air. The most common problems associated with unsuitable management of solid waste include diseases transmission, fire hazards, odor atmospheric and water pollution, social and economic losses.

1.3 Objective

The main goal of study is to select suitable solid waste disposal sites that are economically feasible, environmentally sound, and socially acceptable for Kota District by applying Remote Sensing and geographic information system technology.

Following are the objectives of the present study :

1. To investigate and implement a derived scientific methodology for selecting solid waste disposal site selection.
2. To produce factor maps that are used for solid waste dumping site suitability analysis.
3. To produce suitable solid waste dumping site map for Kota City.

1.4 Research Questions

To fulfill the objectives, the following questions were proposed:

1. What factors are used for selecting suitable dumping site selection which are environmentally sound, economically feasible and politically acceptable for Kota District?
2. Which of the areas are suitable for solid waste disposal from the locations after analyzing selected criteria?
3. Is multi-criteria decision making important for selecting solid waste disposal site in Kota District?

1.5 Significance of the study

From this study, the result is suitable solid waste disposal sites and map of suitable solid waste disposal sites to protect the environment and for the economic, political and social safety of Kota District. Unsuitable solid waste disposal sites affect the social and economic activities of the communities as well as it affects the health of the people.

This study is to explore technical aspects of selecting suitable solid waste disposal site in Kota City. It focuses on the study of solid waste dumping suitability for Kota District.

Kota has no municipal solid waste treatment facility and the waste from the city is taken to treatment facility in Sawai Madhopur, 100 km away.

Therefore, the final result of this research is expected to solve problems caused by solid waste related to health, environment, and economy of the local people through the applications of RS and GIS technology.

1.6 Organization of the Thesis

This thesis contains five chapters. The first chapter is the introduction including introduction, statement of the problem, objectives of the study, research questions, significance. The second chapter contains a review of the literature, mainly including, the concept and types of solid waste management systems, solid waste management, solid waste management in developed and developing countries, solid waste management applications of RS and GIS in suitable dumping site selection and Multi-criteria decision analysis for solid waste dumping site selection. The third chapter deals with the description of the study area and the materials and methods. The fourth chapter presents the results of the suitable dumping site selected for the study area. Chapter five presents the conclusions and recommendations.

Chapter 2 : Review of Literature

2.1 Solid Waste

Waste is generated as a direct consequence of human activities. Wastes are generally classified into solid, liquid and gaseous. Solid wastes, the subject of this study, are mainly disposed of to landfill as it is the simplest, cheapest and most cost-effective method of disposing of waste. Such wastes are generated by the full extent of human activities that range from relatively innocuous substances such as food and paper waste to toxic substances such as paint, chemicals used batteries, healthcare waste, and sewage sludge derived from wastewater treatment .

Numerous classifications of solid wastes have been proposed and the following represents a simple classification of waste into broad categories according to its origin and risk to human and environmental health. These include household waste, municipal waste, commercial and non-hazardous industrial wastes, hazardous (toxic) industrial wastes, construction and demolition waste, healthcare wastes generated in health care facilities (e.g. hospitals, medical research, and laboratory), human and animal wastes and incinerator wastes (Sivasankar and Kuppu, 2017). Household waste represents waste generated at home and usually in city and townships collected by municipal waste collection services. Municipal solid waste includes wastes collected from shops, homes and offices, food waste from restaurants, waste derived from street cleaning and green (organic) waste generated in parks and garden (Debishree and Samadder, 2014).

2.2 Types of wastes

Solid waste can be divided into different types of groups based on their source: (Eberchi and Godwill, 2016).

2.2.1 Urban solid waste

The urban solid waste contains construction waste, household and destruction debris, healthcare wastes, and waste from roads. This waste is generated mainly from settlements and profitable complexes. With increasing urban expansion and revolution in life and food habits, the amount of municipal solid waste has been increasing rapidly and varying its composition (Eberchi and Godwill, 2016).

2.2.2. Hazardous waste

Hospital and industrial wastes are considered as harmful as they may also include poisonous substances. Same types of household waste are also hazardous. Dangerous wastes could be extremely toxic to animals, humans and plants. Domestic wastes that can be classified as hazardous waste include used materials like, car batteries, shoe polish, clinical instrument, paint materials, and medical instruments. Human and animal healthcare waste with chemical substances is also dangerous. These chemicals include formaldehyde and phenols, which are used as antiseptics and mercury, which is used in thermometers or instrument that measure blood pressure. In the industrial sector, the major producers of risky waste are the metal, chemical, paper, insecticide, dye, purifying and plastic industries. Direct contact with chemicals such as dangerous such as cyanide and mercury can be fatal (Eberchi and Godwill, 2016).

2.2.3. Hospital waste

Hospital waste is generated during the diagnosis, treatment and injection of human beings or animals or in exploration activities in these fields or in the production or laboratory testing. It may contain wastes like scissors edge material, disposables, dry waste, culture medicinal wastes, anatomical waste, discarded medicines and chemicals. These are in the form of wastes such as syringes, swabs, bandages, body fluids and excreta. These are highly infectious and can be a serious threat to human health if not managed in a scientific and discriminate manner (Eberchi and Godwill, 2016).

2.3 Solid Waste Management System

Solid waste management is the discipline associated with the control of generation, storage, collection, transfer, transport, processing and disposal of solid wastes in a manner that is in agreement with the best principles of public health, engineering, economics, aesthetics, conservation and environmental considerations, and to change the attitude of people (Zhag *et al*., 2010).

Scientific management of solid waste around human habitat reduces its adverse impacts on the environment and human health and supports economic development and improved quality of life. The main methods of solid waste management systems are a waste reduction, waste reuse and recycling. There are many environmental benefits that can be derived from the reuse, reduction and recycling methods. They reduce or prevent greenhouse gas emission, conserve resources, reduce the release of pollutants, save energy, and reduce the demand for waste treatment technology and landfill space. Therefore, it is advisable that these methods be incorporated as part of the solid waste management plan (Debishiree, 2014). Poor waste management systems coupled with hot climatic conditions results in increasing environmental problems with significant local as well as global dimensions. In spite of the increasing stress towards the waste reduction at the source, as well as recovery and recycling of the solid waste, disposal of solid waste by land filling remains the most commonly employed method (Debishiree, 2014).

2.4 Solid waste management in developed and developing countries

Developed countries have serious environmental challenges about solid waste management due to fast urban developments. The increased population and improved standard of living in urban areas have led to the generation of varied categories of wastes. Because of urbanization, population growth, industrialization and economic growth, a trend of increase in a municipal solid waste generation has been recorded worldwide (PPCB, 2007). As such, managing solid waste is becoming a challenge for cities in most lower-income countries because of the degree of growing population and quick urbanization and which the increasing municipal solid waste (Zhang *et al*., 2010; Guerrero *et al*., 2013; Eberchi *et al*., 2016). Waste generation has been rising with increasing wealth and economic growth. In developing countries also, the waste generation is rising rapidly and may keep increasing in quantum as a consequence of improvement in the standard of living, economic activities and population growth (UN-HABITAT, 2010b). Lack of waste disposal and inappropriate dumping sites are problems in most of the large urban areas in the world, which has its negative impact on human and environment (Mcfaden, 2003). In most of the urban countries of developing countries municipal solid waste management (MSWM) is highly insufficient and outside the abilities of their economic setup for handling and disposal (WHO, 1996; Henry *et al*., 2006).

Waste disposal in developing countries is the process of collecting removing and relocating it to a place where it can be kept destroyed or recycled. With the rapid growth in urban population (which lead to an expansion of many cities) and industrial revolution result in high production, which in turn lead to the generation of more waste. Waste management becomes the second prominent problem (after water quality), affecting many cities in developing countries (Bartone, 2000).

Based on the World Bank (2012) projection, the global urban waste generation increases to 70%, and developing countries facing the highest consequences. It is expected that the total generation of waste per annum will increase from 1.3 billion tones to 2.2 billion tones by 2025. This will have an effect on the annual global costs of waste management as it will increase from $205 billion to $375 billion. The increase in population coupled with the socioeconomic activities in the metropolis has implications for a solid waste generation, disposal, and management, like all other developing countries (Ogwuche, 2013).

2.5 Dump site selection

Dump site selection is a difficult task to accomplish because the site selection process depends on different factors and regulations and also because it requires data from diverse social and environmental fields such as water supply sources, land-use, sensitive sites, and road network. These data often involve processing of a significant amount of spatial information, which can be used by GIS as an important tool for land-use/land-cover suitability analysis (Zeinhom *et al*., 2010).

Dump site selection is becoming increasingly difficult due to growing environmental awareness, decreased amount of governmental and municipal funding with extreme political and social opposition. Increasing of the human population, public health concerns and a shortage of land available for landfill construction adds more difficulties to the problem to overcome. Environmental factors are very important to be considered in such work due to the fact that landfill might affect the biophysical environment and the ecology of the surrounding area. Several techniques are used in site selection of solid waste disposal. Such site selection techniques combine multiple criteria decision analysis (MCDA) and GIS. The result of these techniques is the evaluation of the suitability for the entire study region based on suitability index, which is useful in order to make an initial ranking of most suitable areas (Mohammad et al., 2014).

Dump site selection in an urban area is a critical issue because of its enormous impacts on the economy and the environmental health of the region, and many site selection factors and criteria should be carefully organized and analyzed. One of the complicated steps is locating of waste dump sites have precise steps including site selection and preparation of waste dump site. If these dump sites are near the individual's workplace or living places, it is considered as a negative outcome and it may cause irreparable consequences to human life (Seiied, 2015).

2.6 Application of RS and GIS for Solid Waste Dumping Site Selection

2.6.1 Application of Remote Sensing

Remote sensing is defined as the science or art of obtaining information about an object, area or phenomenon through the analysis of the data acquired by a device that is not in contact with the object, area or phenomenon under investigation. Remote sensing serves as a tool for environmental resource assessment and monitoring. Nishanth et al. (2010) also describe remote sensing as one of the excellent tools for inventory and analysis of environment and its resources, owing to its unique ability to provide the synoptic view of a large area of the earth’s surface and its capacity of repetitive coverage. With the availability of remotely sensed data from different sensors of various platforms with a wide range of spatiotemporal, radiometric and spectral resolutions have made Remote sensing as one of the best sources of data for large-scale applications and study (Assefa et al., 2007).

Use of remote sensing is becoming frequent in environmental studies. In the recent years, no serious research of the environment performed without advanced image processing and analysis. One of the most important applications of remote sensing can be found in the case of solid waste dump site selection, where remote sensing data (satellite images) are used for extracting most of the site selection criteria used for siting dumping sites (Oštir et al., 2003), (example, mapping land-use/land-cover, geology and surface water). Moreover, remote sensing can provide digital data as an input for GIS.

2.6.2 Application of GIS

The application of GIS in environmental planning has a strong support that can be utilized for materializing sustainable environmental management ways and in sustainable development (Wang et al., 2009). As a management tool, GIS is used in a wide spectrum of disciplines, which include ecological management, fishery, water management, wildlife management, tourism, waste management, natural hazards prediction and management, agriculture and fire management, to mention (Wang et al., 2009). The application of GIS in environmental management has been in diverse forms for it covers all environmental aspects due to its proven power through its application in environmental management; it has come to be every nation's ambition to adopt this powerful technological entity in order to achieve the best out of environmental management as well as saving time and having long-lasting data storage facility all aimed at sustainable development as it has come to be the major environmental concern, globally.

One of the benefits of GIS is its capability for dumping site selection, dumping siting is complex, tedious and costly as it requires multiple criteria from environment, social and economic point of view. Moreover, landfill siting is a complicated process requiring detailed assessment over a vast area to identify a suitable location for constructing a dump selection subject to many different criteria Geographic information system application can help in determining the dump location in accordance with technical requirements, with an overlay thematic map to get appropriate landfill

.

A geographic information system is a tool that not only reduces time and cost of the site selection, but also provides digital data bank for future monitoring program of the site. The procedure followed under the GIS framework rejects unacceptable sites considering environmental factors exclusively, other than economic and political issues, contained in the form of multiple layers of attribute information. Therefore, GIS offers the spatial analytical capabilities to quickly eliminate parcel of land unsuitable for dump site and hence reduce cost and time of dumping site processes

The multi-criteria decision analysis is a set of mathematical tools and methods allowing the comparison of different alternatives according to many criteria, often conflicting, to guide the decision maker towards a careful choice (Chakhar and Mousseau, 2008).

Multi-Criteria Decision Analysis consists of a series of techniques such as weighted summation that permit a range of criteria relating to a particular issue to be scored, weighted and then ranked, for example experts, interest groups and stakeholders according to their degree of suitability or importance for locating a particular facility/service (Malczewski, 2004) like dump site. Analytic Hierarchy Process (AHP) is one of the most commonly used MCDA tools. This tool is applied in site selection processes as it assists the decision-makers to organize the criteria and alternative solutions of a decision problem in a hierarchical decision model (Eldrandaly *et al*., 2005). Furthermore, Multi-criteria approaches have the potential to reduce the costs and time involved in selecting facilities by narrowing down the potential choices based on predefined criteria and weights while also permitting sensitivity analysis of the results from these procedures (Higgs, 2006). Hence, multi-criteria techniques could be particularly useful in situations where there are a large number of alternative sites for a development, where there are a large number of potential criteria to be taken into consideration or where subjective judgments by different stakeholders of the different alternatives is needed to try to reach an objective consensus in the final decision- making (Michael *et al*., 2005).

Management of solid waste program often involves incompatible environmental, economic and socio ecological influences. For example, selecting a new site for dump development at minimal cost is feasible, but the compromise could be the likelihood of groundwater pollution. The dumping site selection problems have often been tackled using Multi-Criteria Decision Analysis through defining the criteria for the dump site. According to Moeinaddini *et al*. (2010), selecting municipal solid waste dump site is a Spatial Multi-Criteria Decision Analysis (SMCDA) for which both GIS and Multi-Criteria Decision Analysis methods should be used. Moreover, dump site selection by GIS is a Multi-Criteria Evaluation (MCE) having four steps such as criterion establishment, standardization of factors, the establishment of factors weight and weighted linear combination. With a weighted linear combination, factors are combined by applying a weight to each followed by a summation of results to yield a suitability map (Hasan *et al*., 2009). Therefore, the role of Multi-Criteria Decision Analysis in dump site selection can be completed by integrating it with GIS. Based on Eldrandaly *et al*. (2005) emphasize, integrating GIS can solve the challenges of dump site selection, which involves highly complex spatial decision-making processes.

Chapter 3 : Materials and Methods

3.1 Description of the Study Area

Kota is the 25th largest district in the northern Indian state of Rajasthan. Kota is located in the South East of the Rajasthan state. Geographically, it is located between 24°32’ & 25°50 N Latitude and 75°37’ & 76°34’ E Longitude. Kota is famous for its coaching institutes for engineering and medical entrance exams and have a population of 29 Lakhs. It is also called "Education City of India". The town of Kota was once the part of the erstwhile Rajput kingdom of Bundi. It became a separate princely state in the 17th century. Apart from the several monuments that reflect the glory of the town, Kota is also known for its palaces and gardens.

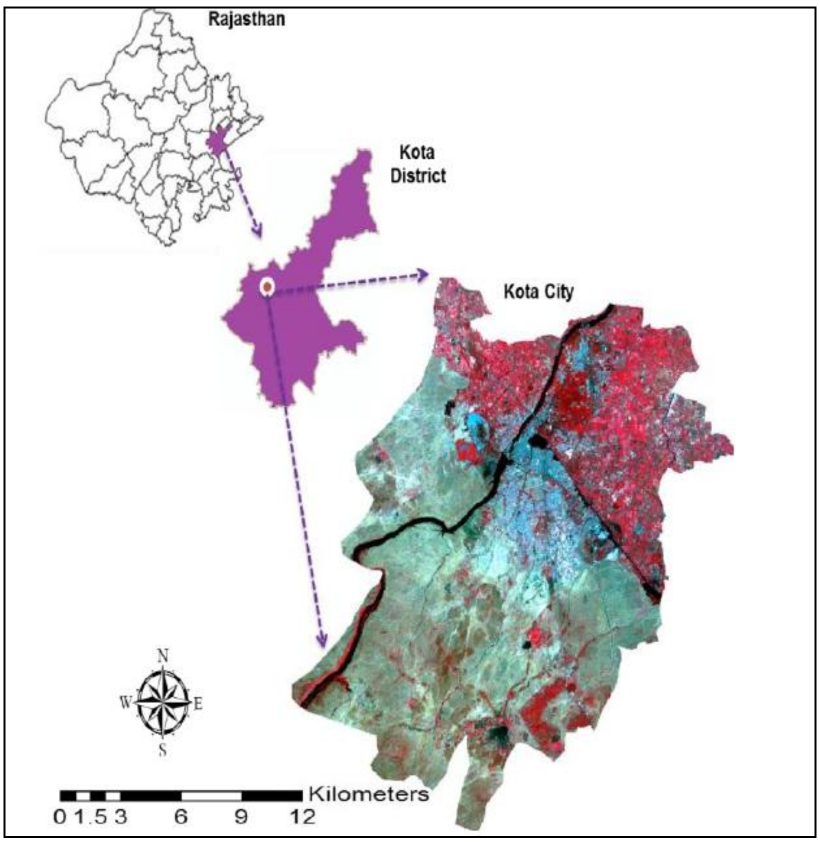


Figure 1 : Location of Kota

Table 3.1: Waste Generation and PerCapita Waste Generation

Year	Waste Generation in TPD	Per Capita Waste Gen in Kgs
2014	510.0	0.471
2016	551.0	0.480
2019	618.9	0.500
2024	751.3	0.540
2029	911.9	0.570

3.2 Methods

3.2.1 Hardware/software used

For data preparation and organization, data analysis and output generation computer hardware and software were used. The hardware includes Personal Computer, hard disk, Printer . The software's used were ERDAS Imagine 2015 for satellite image preprocessing, preparation and land-use/land-cover classifications. ArcGIS 10.4.1 for digitizing, model creation and database creation .

3.2.2 Source of data

To analyze the objectives of this study, two types of data were used. There were secondary data collected from primary and secondary data sources.

3.2.3 Primary data

Satellite images were also some of the primary data types used to show the character of land-use/land-lover classes for this study area.

3.2.4 Secondary data

Different factor maps that help to select suitable dump site were used. These include road network map and land-use/land-cover type of the study area, built-up area extract from land-use/land-cover, DEM of Kota city to derive the slope .. Additionally, secondary data were acquired from reliable internet sources, reports, journals and governmental institutions manuals. All the above data were collected, tabulated and analyzed in remote sensing and GIS environment for further analyses (Table 3.2).

Table 3.2: Source and type of Secondary data

No	Type of Data	Source of Data	Software Used
1	Road network map	Open street Database	ArcGIS 10.4.1
2	Soil map	Bhuvan	ArcGIS 10.4.1
3	Land-use /land-cover type	Sentinel 2A image with 10 m resolution from Copernicus hub	ERDAS Imagine 2015
4	Slope	DEM	ArcGIS 10.4.1
5	Geological map	Bhuvan	ArcGIS 10.4.1
6	River/Stream network	DEM	ArcGIS 10.4.1
7	Fault map	DEM	ArcGIS 10.4.1

3.2.5 Methods used for solid waste dump site selection

This study used primary and secondary data which contain both spatial and non-spatial data, complemented with detailed ground truthing. As observed by different authors (Suman, 2012; Eneche *et al*., 2017), there are numerous criteria used in the mapping of solid waste dumping sites in any geographic area. The present study considered factors such as slope, land-use/land-cover, waterbody, built-up areas, and road. Dump site selection using GIS-based multicriteria generally classified in three phases.

3.2.6 Image pre-processing

Sentinel-2 mission is combinations of two satellite configuration that offers a unique combination of systematic global coverage of land surfaces from 56°South to 84°North, high revisit every 5 days at equator under the same viewing conditions, high spatial resolution 10m, 20m and 60m, multi-spectral information with 13 bands (covering visible, near infrared and shortwave infra-red) and wide field of view 290 km.

The Sentinel-2 Level-1C products takes advantage of the stringent image quality requirements and provide users with ortho-rectified images representing Top of Atmosphere reflectance. Image pre-processing activity is required for obvious reasons that satellite images are subject to various distortions. Activities during image preprocessing are such as layer stacking and resolution merging (B02, B03, B04 and B08). Those are 10 m resolution and B11 and B12 are 20 m, image sub-setting or clipping by the study area, sun angle correction, top of atmospheric correction, geometric rectification and reprojection are performed for all images for better classification and high-quality data. Performances derived from validation activities were estimated for both Top-Of-Atmosphere (TOA) and Bottom-Of-Atmosphere (BOA) products (Baillarin *et al*., 2012).

3.2.7 Image classification

After all the pre-processing activities, one of the actual work of the project was image classification which was the basis for land-use/land-cover map measurement in the spatial metric system. Supervised classification requires the selection of training areas to get accurate classification output. According to Lillesand *et al*. (2004), supervised classification method (maximum likelihood algorism) was used for land-use/land-cover classification. Through, land-use/land-cover classification, training stage, classification stage, and output stage were followed. During the first stage, all numerical data were collected from training areas on spectral response patterns of this land-cover category. This stage is the main activity of supervised classification. The second stage of supervised classification was classification stage when each unknown pixel was compared to spectral patterns and assigned to a most similar category. The final stage was output stage when the final result was presented as Figure and Table forms .

3.2.8 Buffering

Buffering is a well-pronounced way of producing areas or regions of numerically calculated distances from a feature, which can be a point, line or polygon (Lunkapis, 2006). This process was achieved through reclassification of regions from a feature. Using ArcGIS 10.4.1, the considered environmental parameters using respective buffer distances were buffered. The buffered parameters included rivers, roads, built-up but slope is not including because both criteria are not considered as buffer distance. The buffer distances were drawn from literature (Pawandiwa, 2013). The Buffering analysis was executed for roads for a minimum distance 300 m for solid waste dump site selection. The contaminated runoff from the landfill will have an adverse effect on surface water. Accordingly, Tyowuah and Hundu (2017) used 200 m as a minimum buffer distance for river buffer distance criteria for solid waste dump site selection. Therefore, to minimize such pollution, different researchers set minimum buffer distance for solid waste dump site selection, Based on Rafee *et al*. (2011). These values for buffering analysis were assigned and a new value was generated based on the geographical characteristics and clip buffer distance result using Kota district.

3.2.9 Analytic hierarchy process

Analytic Hierarchy Process (AHP) was used as a decision rule to analyze the data for waste disposal site selection using GIS (Sehnaz *et al*., 2011). This process contains the construction of pair-wise comparison matrices and the extraction of weights by using the principal right eigenvector (Theo, 2010; Sehnaz, 2011). Pair-wise comparison matrix was created by setting out one row and one column for each factor in the problem. Therefore, the AHP divides the decision problems based on the factors into understandable parts. Each of these parts was analyzed separately and integrated in a logical manner as suggested by Theo (2010). Analytic hierarchy process also facilitates sound decision applying both empirical data as well as subjective judgments of the decision maker. It assists to establish priorities among the elements within each stratum of the hierarchy. In AHP the 9-point scale, which is ranging from 1(indifference or equal importance) to 9 (extreme preference or absolute importance) (Saaty, 1980) was used in the decision-making process for waste disposal site selection .

3.2.10 Weighted overlay analysis

The weighted overlay is a procedure for applying a common measurement scale of values to different inputs to create an integrated analysis. The weight is given through empirical methods and subjective judgments by the decision maker. For this study, weighted overlay analysis was used for each input layer such as groundwater well points, surface water/river, land-use/land-cover, road network, geology, slope, fault, built up area and soil maps, and suitable site sensitivity index. In this process, weight was assigned to different thematic layers based on their influence in deciding the site suitability. Weighted overlay analysis was employed for deciding the suitable location of solid waste disposal of Kota District .

Phase 1: Restriction model

In the first stage, a model was prepared and named Restriction Model. The formula used in achieving the logic was extracted from the multi-criteria evaluation as;

$s=\Pi^{m}_{j=1} rj$

S= (r road * r waterbody * r park).

Where,
r road; restriction to location related to the road site

r waterbody; restriction related to waterbody location
r park; restriction related to park location
rj = criterion for suitability of constraint j

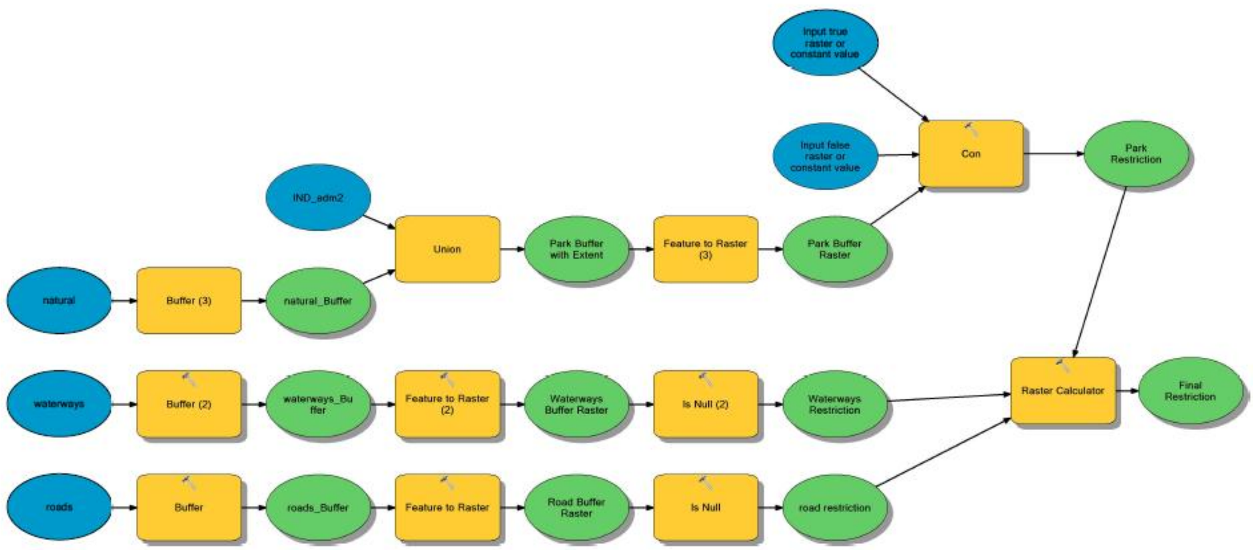


Figure 2 : Restriction Model

Phase 2: Suitability model

The second stage deals with the factor criteria, so a Suitability Model is applied in archiving the task which is Weight Linear Combination (WLC) together with the AHP. The WLC is the most common technique for analyzing multi-scale evaluations. This technique also is called a ‘‘scoring method’’. The AHP was used to capture aspects of the decision. It was used in computing the weights for different criteria used by creating a pair wise comparison matrix. The following equation was used for the model:

$S=\Sigma^{n}_{i=1} WiCi$

S= (WluClu + WslCsl+ WroCro)

WluWlu: weight and criteria for Land-use

WslCsl: weight and criteria for slope

WroCro: weight and criteria for road

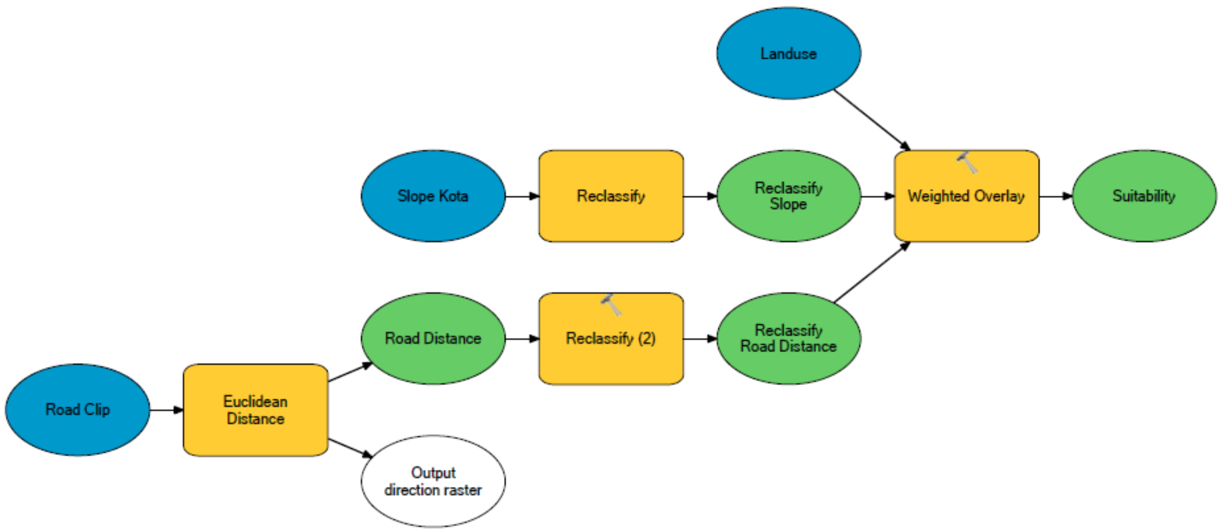


Figure 3 : Suitability Model

Phase 3: Multi-criteria model

The third stage combined both the Boolean and Weight Linear Combination (WLC) which results in a final site using the following equation:

$S=\Sigma W i C i * \Pi^{m}_{j=1} rj$

S= ((r road * r waterbody*r park) * (WlanduseClanduse * WslopeCslope * WroadCroad *).

A number of possible selections were examined for setting a suitable site by taking into consideration multiple criteria and contradictory objectives in a GIS-based MCE technique, using WLC analysis (Chang et al., 2008; Ansari et al., 2012). Data were obtained from different sources and stored in GIS system and used for suitable site selection studies.

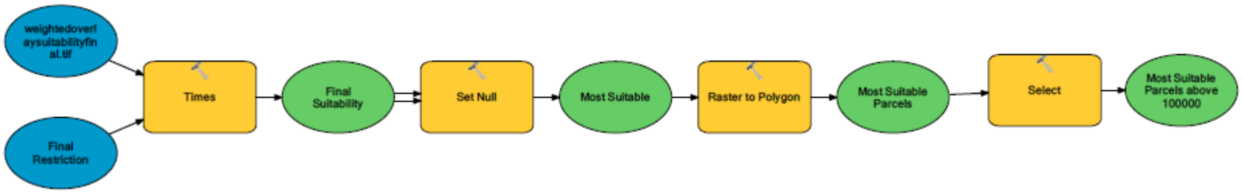
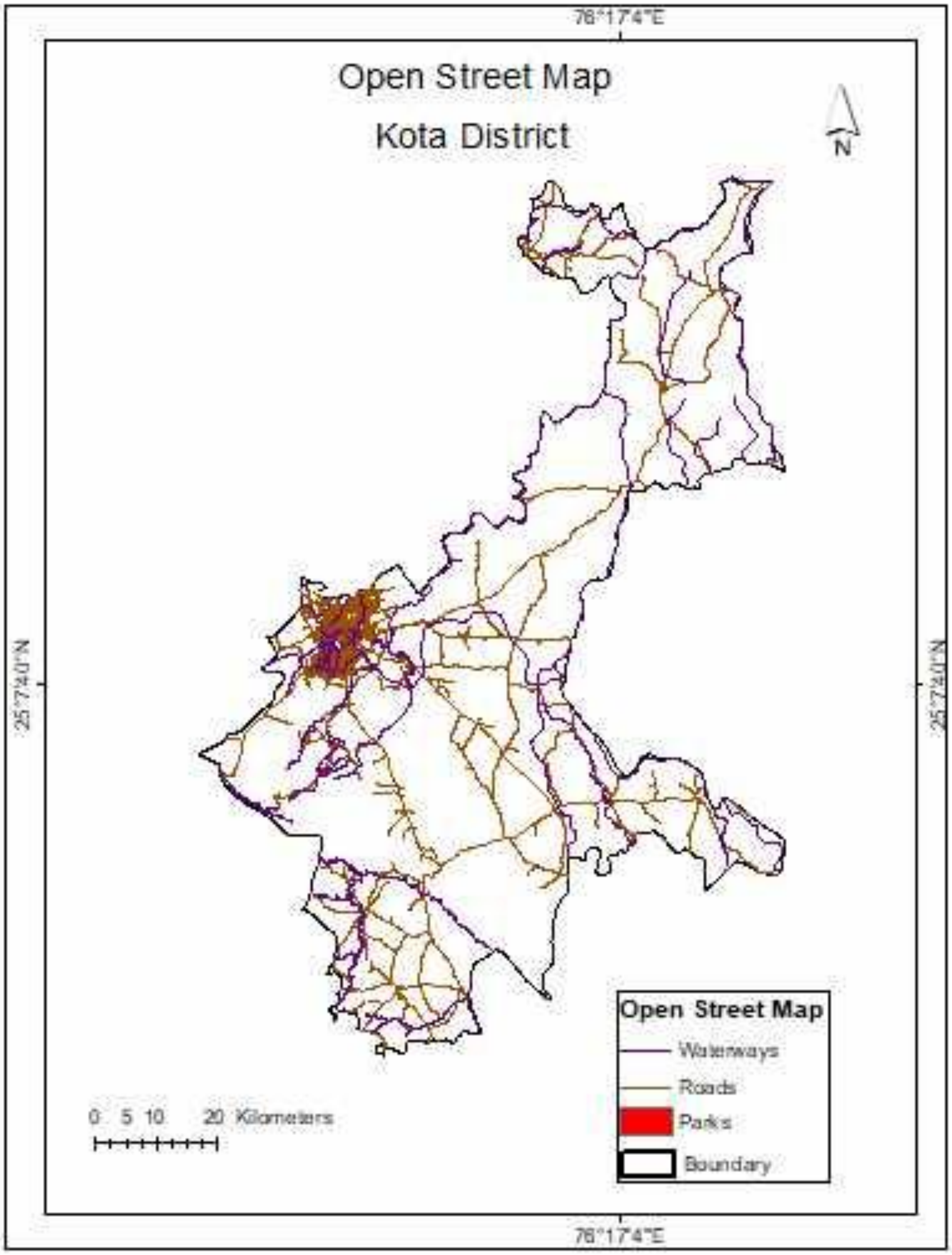


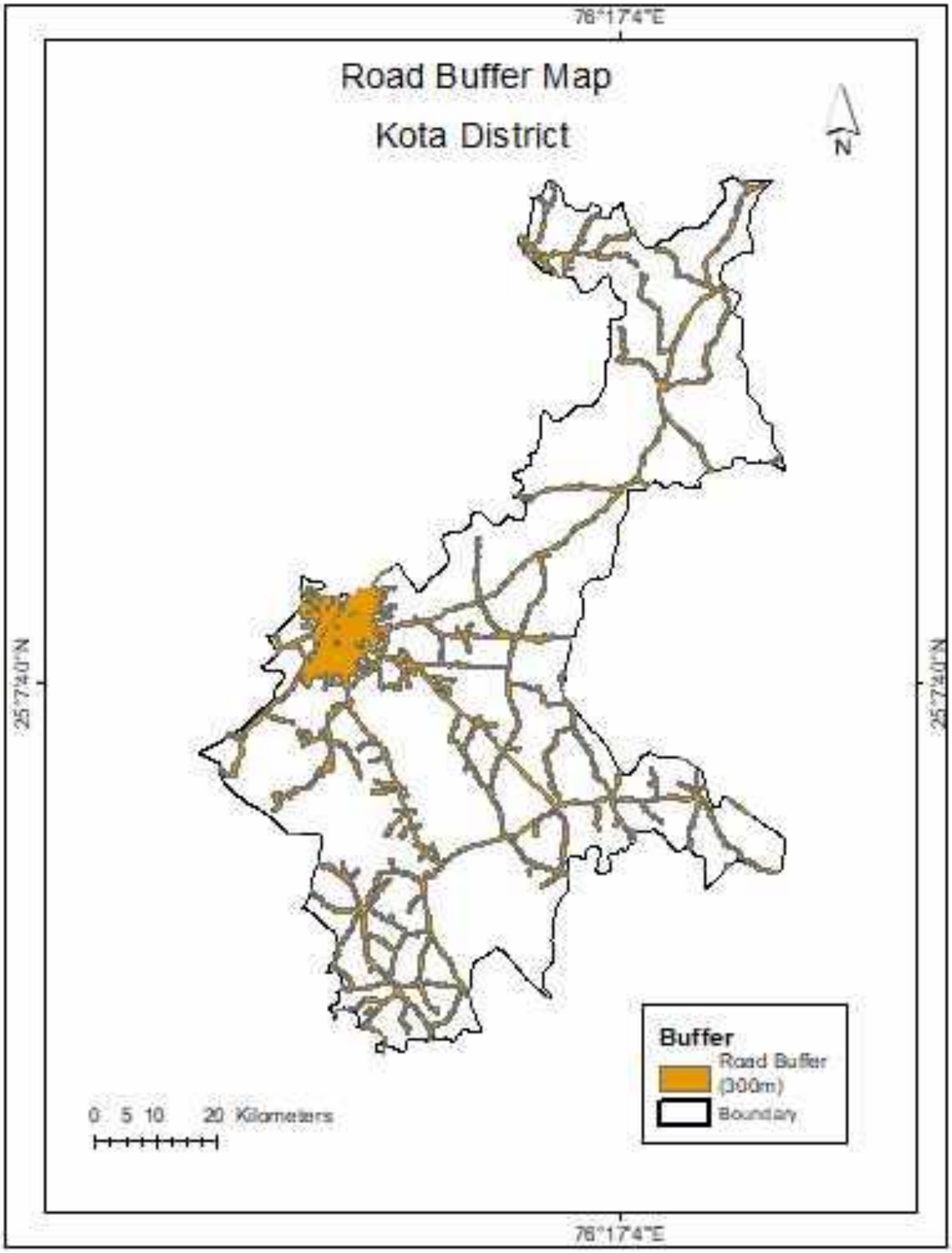
Figure 4 : Multi-Criteria Model

3.2.11 Land use/land cover (LU/LC)

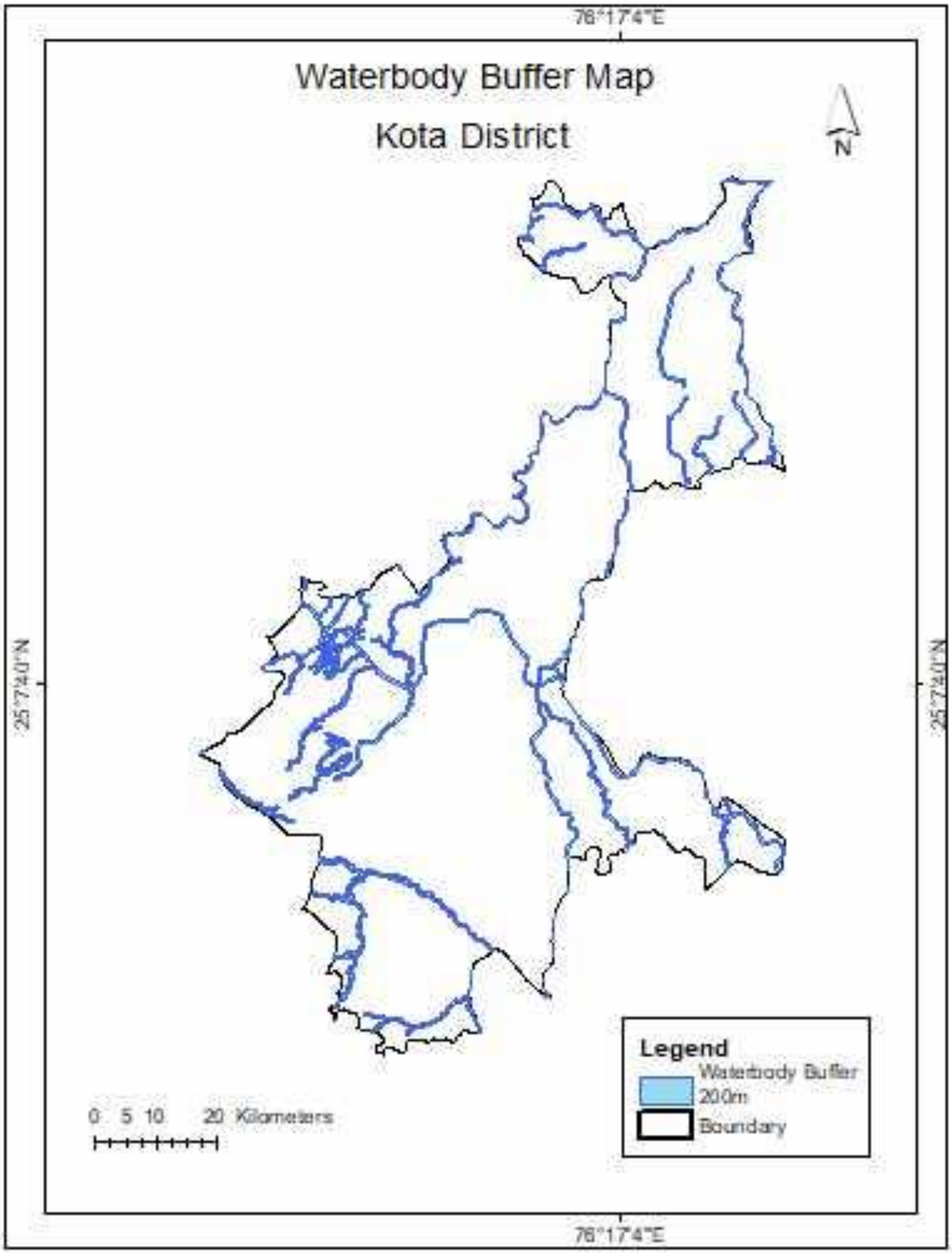
Land-use/land-cover map of the study area was one of the criteria used to select potential sites for solid waste disposal in the town of Logia. For land-use/land-cover classification sentinel 2A image was acquired from Copernicus hub (because Sentinel 2A image is a better resolution than Landsat 8 image) and preprocessed using impact toolbox, like resolution merging, projection transformation, atmospheric correction, geometric correction and clipping by the study area shapefiles. After preprocessing the image was classified using supervised classification method. With the assistance of the Classification toolbar, created training samples to represent the classes using area of interest to extract the same class at the same time from different area and created a signature file from the training samples, which was used by the supervised classification tools to classify the image by using maximum likelihood algorism (parameter rules). Finally, the land-use/land-cover of the study were classified into classes .

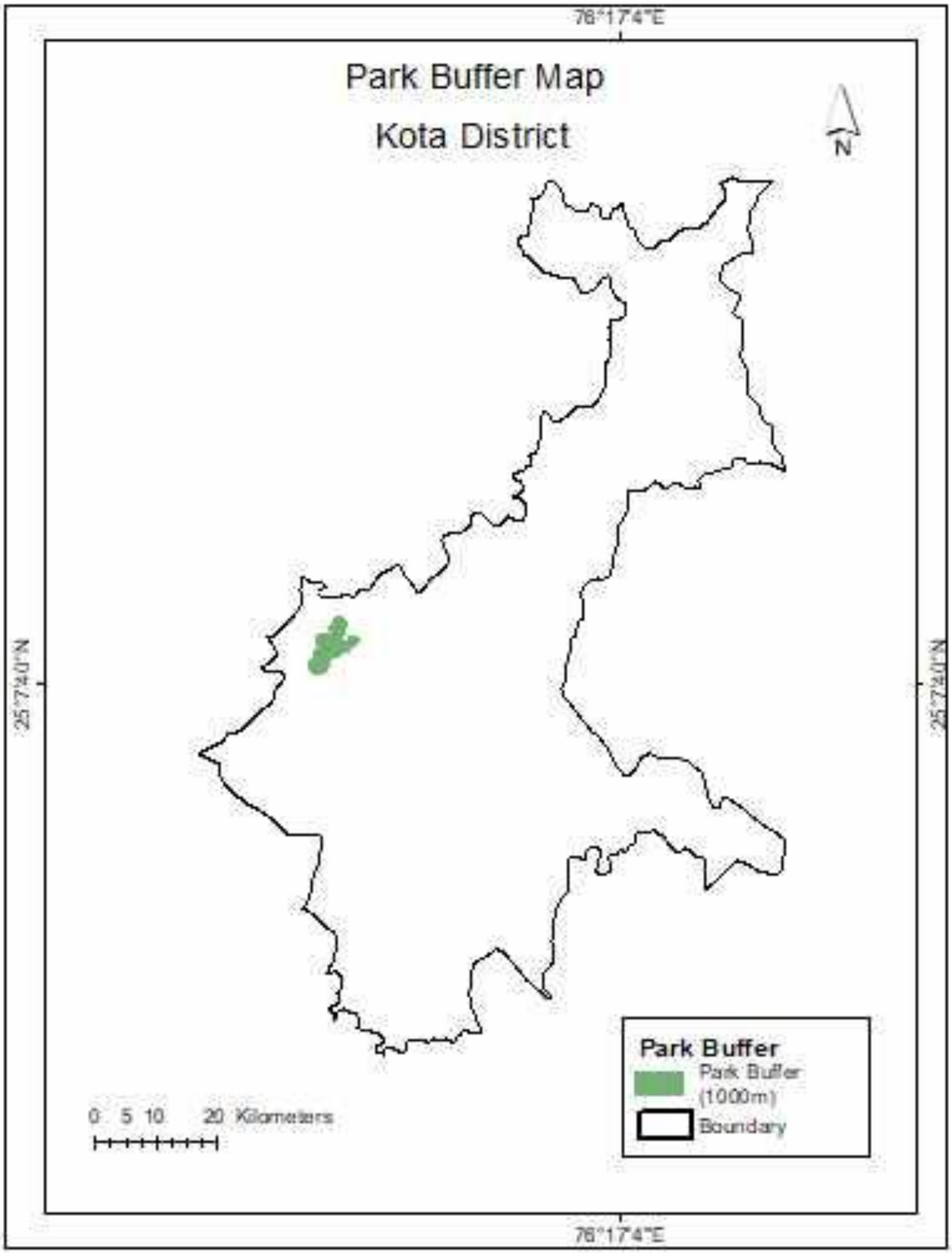


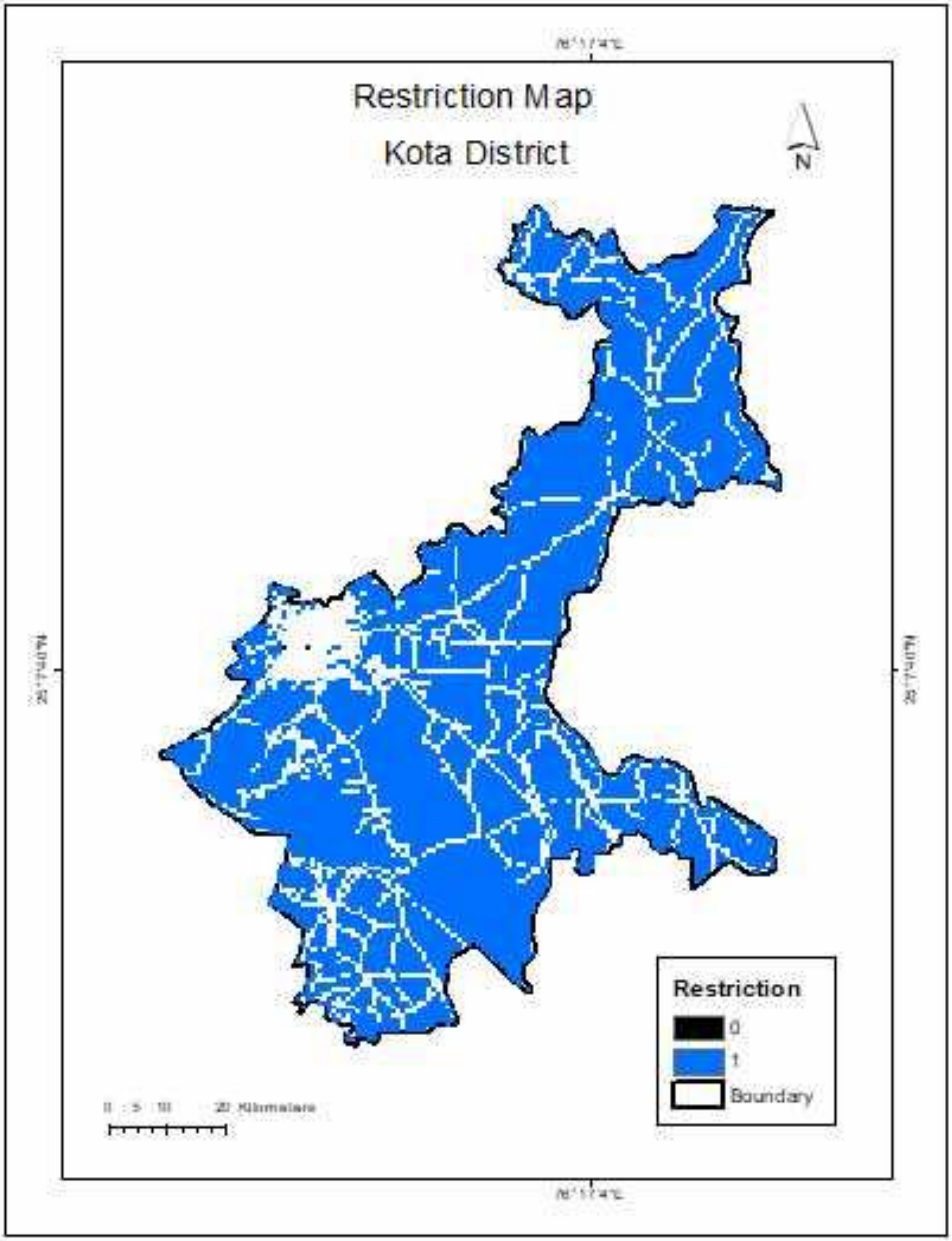
76°17'4"E
Open Street Map
Kota District
N
25°7'40"N
25°7'40"N
0 5 10 20 Kilometers
Open Street Map
Waterways
Roads
Parks
Boundary
76°17'4"E

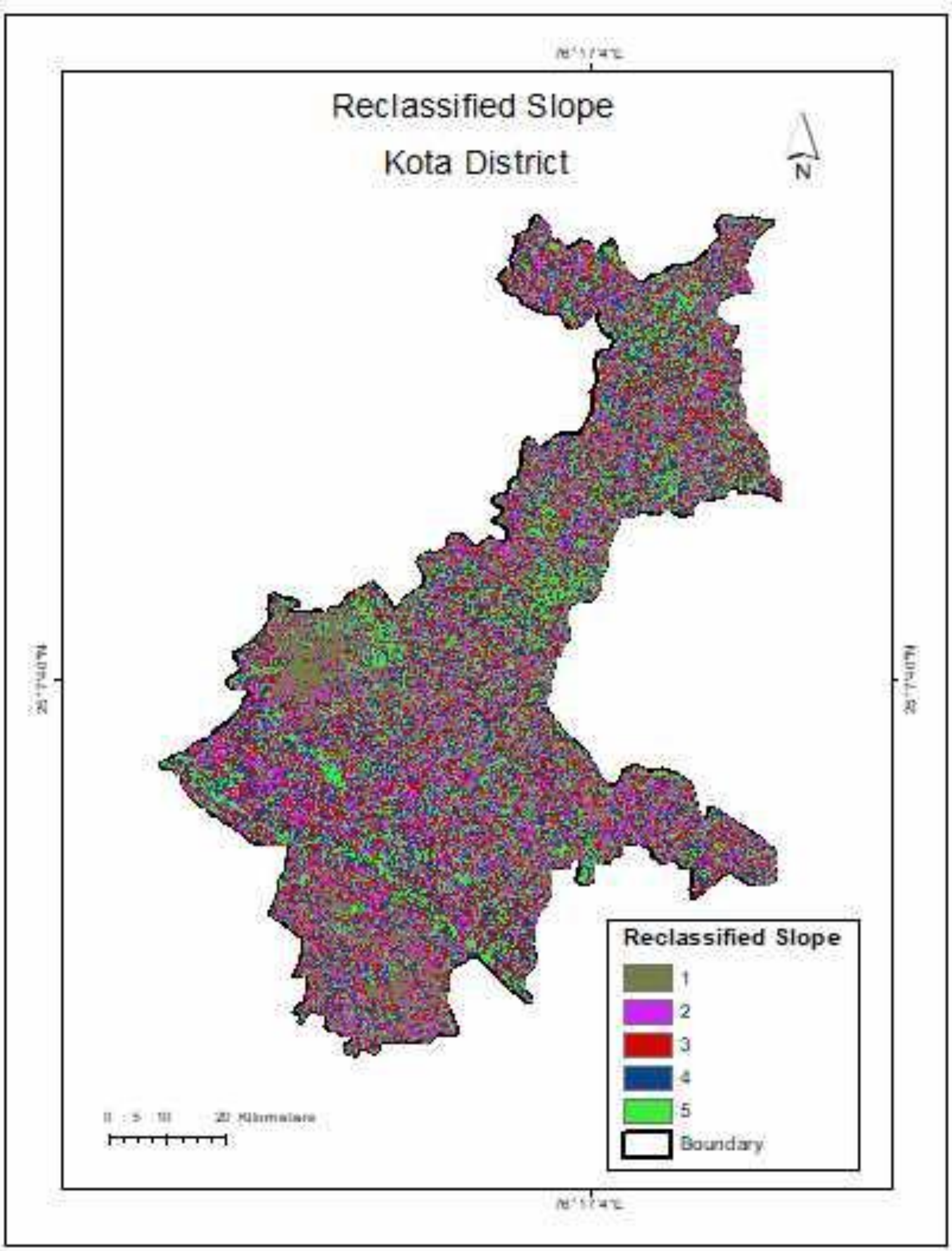


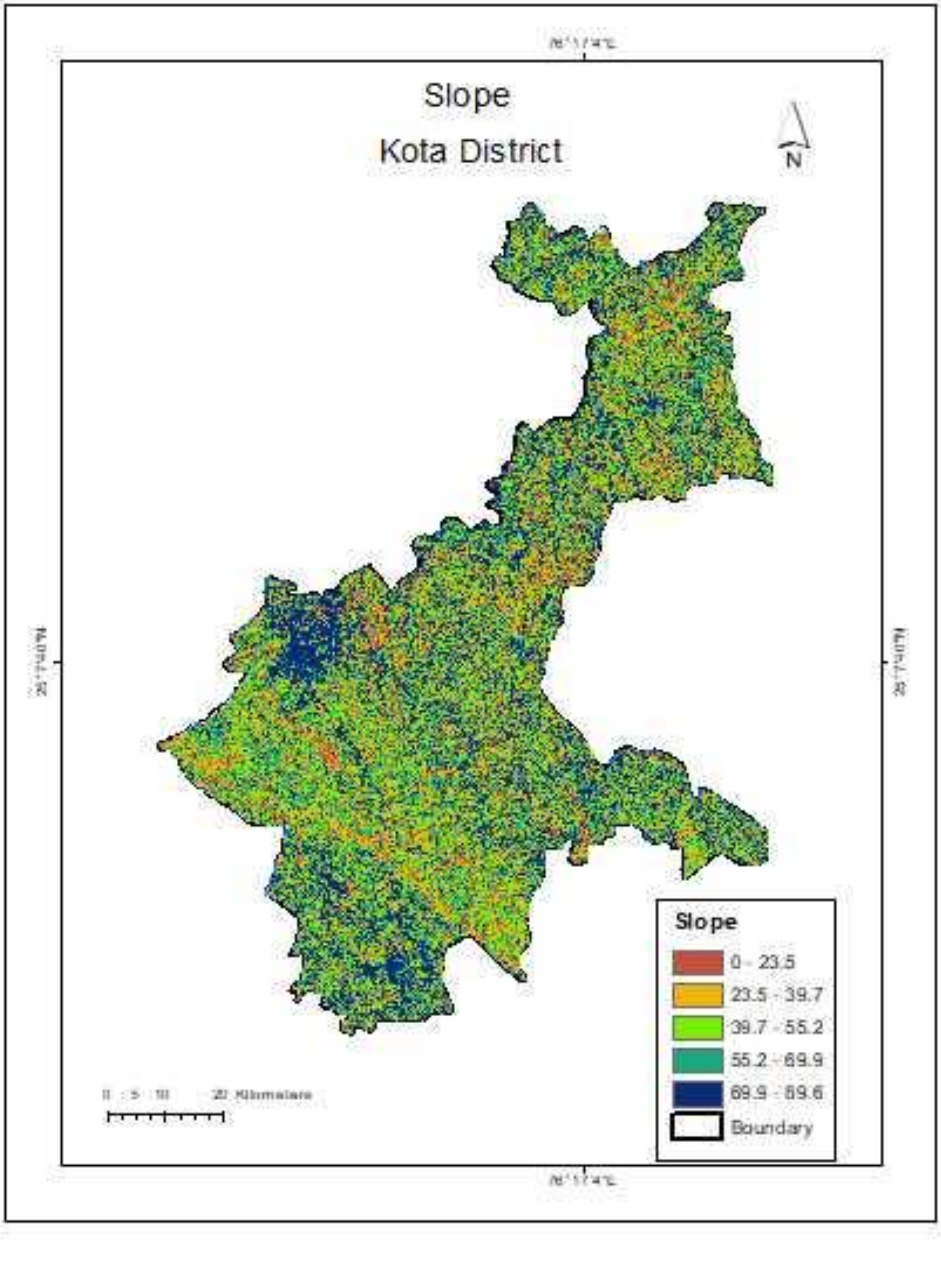
76°17'4"E
Road Buffer Map
Kota District
N
25°7'40"N
25°7'40"N
Buffer
Road Buffer (300m)
Boundary
0 5 10 20 Kilometers
76°17'4"E

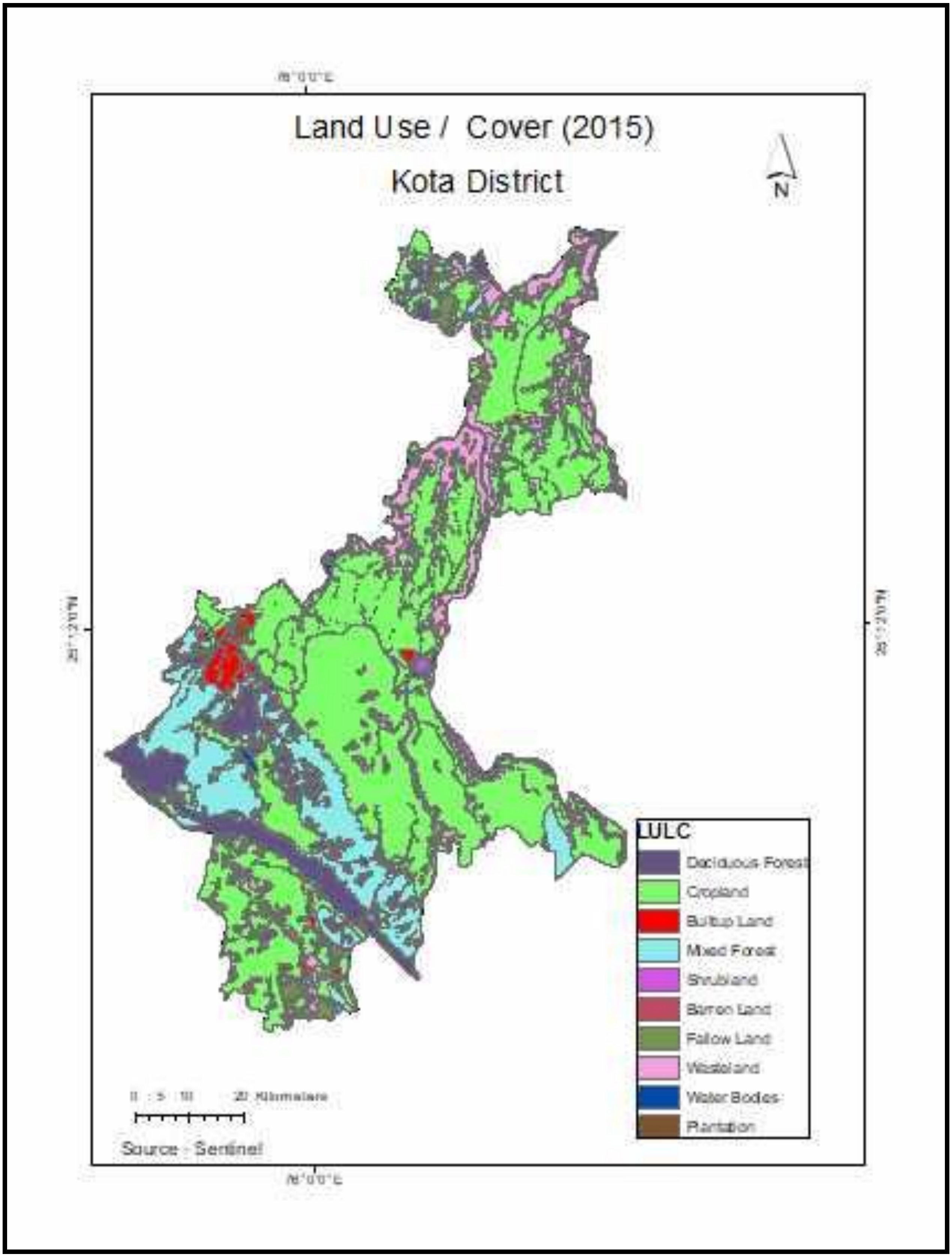

76°17'4"E
Waterbody Buffer Map
Kota District
N
25°7'40"N
25°7'40"N
Legend
Waterbody Buffer 200m
Boundary
0 5 10 20 Kilometers
76°17'4"E

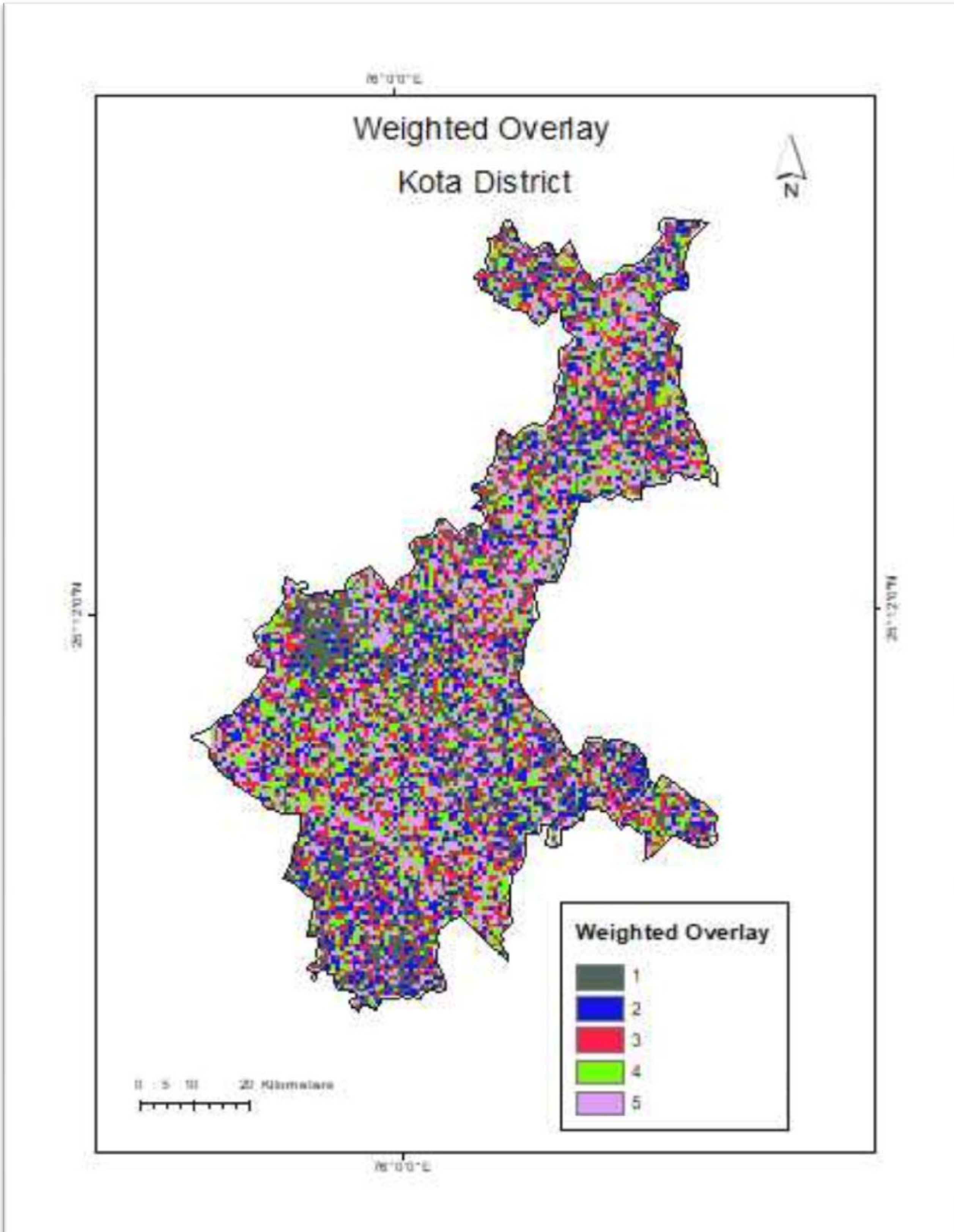

76°17'4"E
Park Buffer Map
Kota District
N
25°7'4.0"N
25°7'4.0"N
Park Buffer
Park Buffer (1000m)
Boundary
0 5 10 20 Kilometers
76°17'4"E

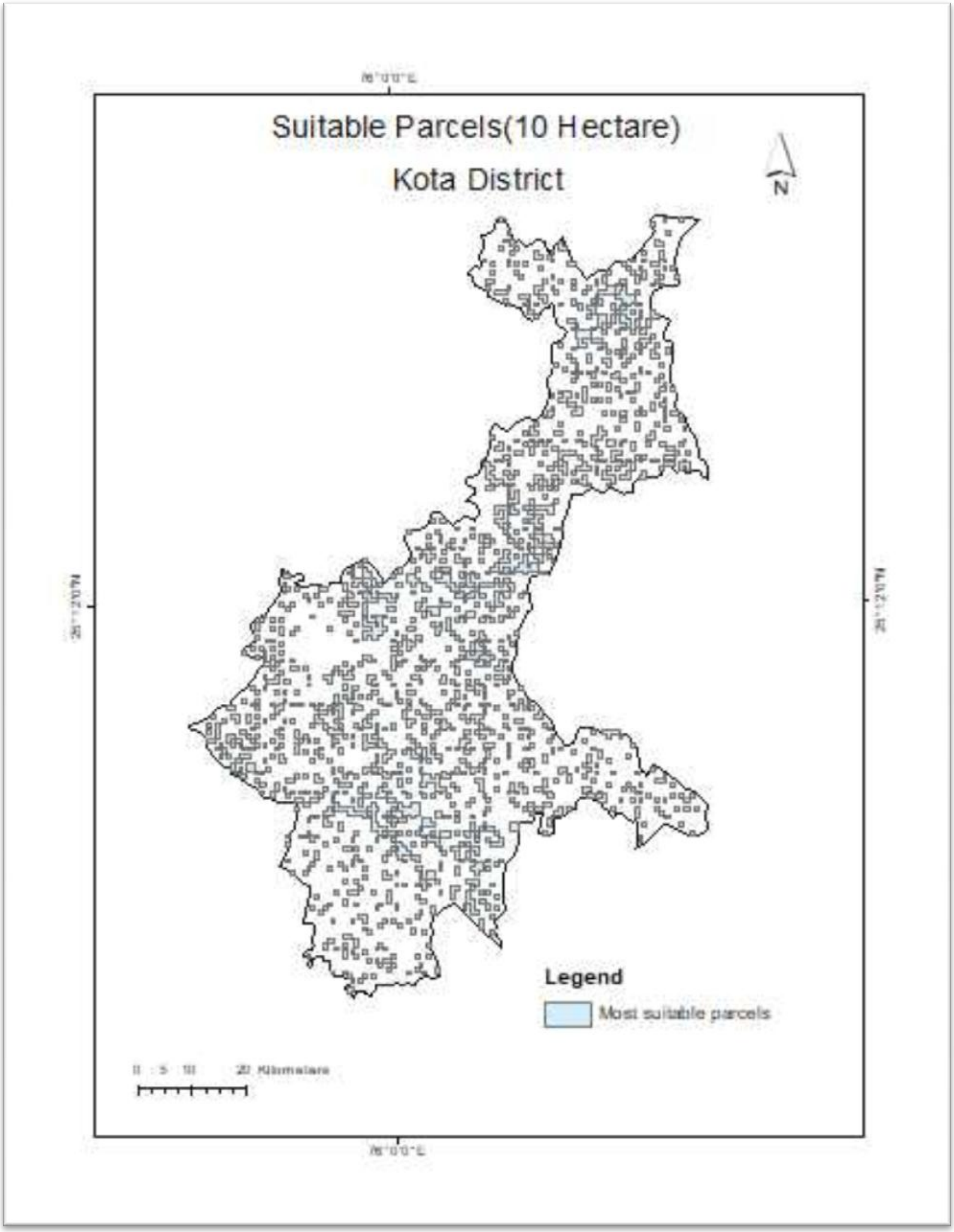

Restriction Map
Kota District
N
Restriction
0
1
Boundary


Reclassified Slope
Kota District
N
Reclassified Slope
1
2
3
4
5
Boundary


Slope
Kota District
N
Slope
0 - 23.5
23.5 - 39.7
39.7 - 55.2
55.2 - 69.9
69.9 - 89.6
Boundary


Land Use / Cover (2015)
Kota District
N
LULC
Deciduous Forest
Cropland
Builtup Land
Mixed Forest
Shrubland
Barren Land
Fallow Land
Wasteland
Water Bodies
Plantation
Source - Sentinel


Weighted Overlay
Kota District
N
Weighted Overlay
1
2
3
4
5


Suitable Parcels(10 Hectare)
Kota District
N
Legend
Most suitable parcels
Kilometers

Chapter 4 : Results

4.1 Constraint criteria

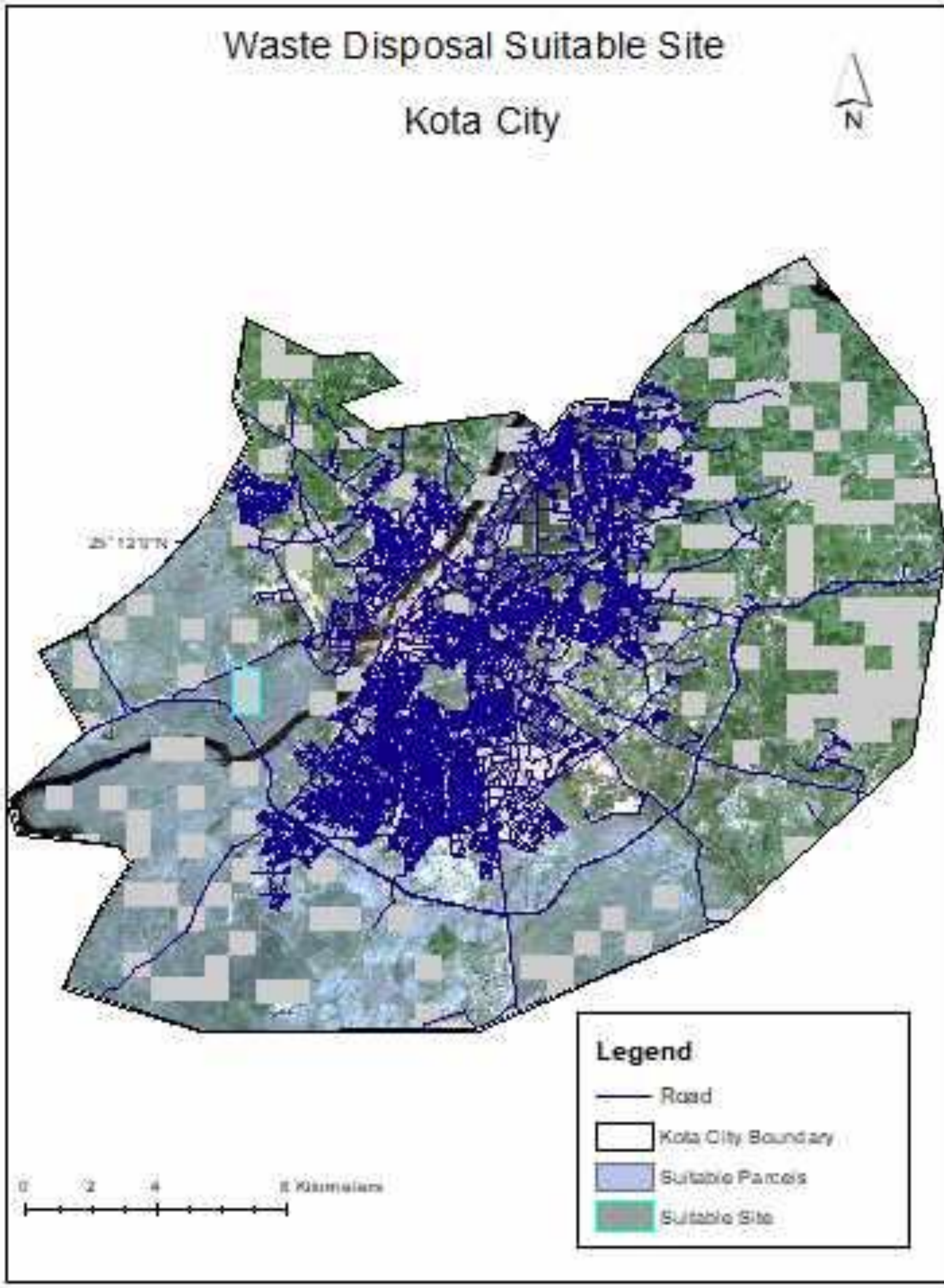
Constraints are limitations or restrictions, which prohibit certain elements to be taken into account. Constraint maps are used to distinguish between lands suitable and restricted for dump sites. A constraint map for each theme contains 1"s for suitable land and 0"s for unsuitable land. Thus, five constraint maps were generated, for factors such as groundwater well points, river, road network, fault and built-up area.

4.2 River and road constraint buffer distance suitability map

To locate waste-based facility, surface water contamination is a major consideration. The river constraint map had a buffer zone less than 200 m as the desired location for the dump site.. Distance from existing roads is an important factor in locating waste conversion facilities. A restricted buffer zone was considered in this study in order to minimize odor and health problems. Beyond this restricted buffer zone, the facility location must be close to a road network in order to reduce transportation costs. Buffer ring were created around the roads. The road constraint map of buffer distance <700 m was made and areas as 0 m (unsuitable) and 1 (suitable) on the road network proximity standard. Locating the dump site not far away from a road would help reduce costs related to transportation .

4.3 Dumpsite Suitability map

In order to select appropriate solid waste disposal site selection for the study area comparison of the different positions based on environmental, social and economic impacts were done. From the weight calculation, the relative importance of each parameter was determined for all criteria land-use/land-cover , river, road, built-up area and slope. Out of the total study area, The final result shows that from total area 5355.9 , 20.36 % (1090.7 sq km) is highly suitable, 19.7 % (1057.2 sq km) is suitable, 19.90 % (1066 sq km) is moderately suitable, 19.6 % (1051 sq km) is less suitable and 20.37 % (1091 sq km) is unsuitable for solid waste dumping in Kota District .


Waste Disposal Suitable Site
Kota City
N
Legend
Road
Kota City Boundary
Suitable Parcels
Suitable Site
0
2
4

Chapter 5 : Concluion

5.1 Conclusion

This study examined problems of solid waste disposal sites in kota District and its implications on the residents of Kota City. The study revealed that the town has grown in population as well as spatial extent over the years. The findings have shown a useful application of GIS and AHP methods as a viable tool for analyzing the criteria for decision making support. The analysis was taken land-use/land-cover, slope, river, road, built-up area as determining factor in order to find an appropriate site for a solid waste dumping site. One area was selected as most suitable. This site is easy to access and manage for disposal of solid waste. The integration of multi-criteria decision analysis is a useful tool in solving solid waste dump site selection problem because it provides efficient spatial data manipulation and presentation. Hence, the capacity to use AHP with GIS and RS technology for identification of suitable solid waste dumping site will minimize the environmental risk and human health problems. The final result shows that from total area 5355.9 sq km, 20.36 % (1090.7 sq km) is highly suitable, 19.7 % (1057.2 sq km) is suitable, 19.90 % (1066 sq km) is moderately suitable, 19.6 % (1051 sq km) is less suitable and 20.37 % (1091 sq km) is unsuitable for solid waste dumping in Kota District .

5.2 Recommendations

For proper solid waste disposal systems and management are to be developed, and maintained in Kota District, for which the following recommendations were suggested.

1. Multi criteria evaluation technique is very important technique for dump site selection, therefore the researcher will use this method to consider different criteria from different points of view.

2. The selected dump sites by this study are only for non-hazardous solid wastes. Since the criteria for hazardous wastes area different from non-hazardous wastes, separate dump site should be selected.

3. According to the results the highly suitable area is far from the built-up area, therefore, the government should put waste collection bins in a different part of the cities and arrange the transportation with appropriate vehicles; also, the system will be developed for recycling wastes as plastics, metals and others.

4. There should be public awareness in different ways like media, school symposium, workshops seminars which explored by the government and participation in the planning and implementation of solid waste management.

5. The concerned body should formulate solid waste disposal sites by considering social, economic and environmental aspects to improve the status of the solid waste management system of the town.

6. Using GIS approach to waste disposal and site selection has proven to be a powerful tool that enhances the sitting process. The GIS is a powerful tool for identifying suitable waste disposal sites. The major benefit of a GIS is that once a GIS database exists, it can be enhanced into a complete waste disposal management GIS package.

7. The selection of the final solid waste dumping sites requires further hydro-geological analyses to ensure conformity with the stringent standards required for design and construction of such facility.

Bibliography

Assefa Melesse, M., Weng, Q., Thenkabail, S.P., and Senay, B.G. (2007). Remote Sensing Sensors and Applications in Environmental Resources Mapping and Modeling. Sensors*,* **7**(12), 3209−3241

Bartone, C. (2000). Strategies for Improving Municipal Solid Waste Management. Workshop on Planning for Sustainable and Integrated Solid Waste Management. Manila: Washington, DC: Urban Management Division, World Bank

Chakhar, S., and Mousseau, V. (2008). GIS-based multi-criteria spatial modeling generic framework, International Journal of Geographic Information Science. **22**:1159−1196.

Debishree, K., and Samadder, S.R. (2014). Application of GIS in Landfill Siting for Municipal Solid Waste, Dhanbad, India. International Journal of Environmental Research and Development. **4**(1): 37–40.

Eberchi, E., and Godwill, T. (2016). Site Selection and Analysis of Solid Waste Dumpsites in Ile-Ife, Nigeria. In FIG Working Week 2016, Christchurch, New Zealand, May 2–6.

Guerrero, L., Maas, G., and Hogland, W. (2013). Solid waste management challenges for cities in developing countries. Waste Management. **33**, 220–232

Higgs, G. (2006). Integrating multi-criteria techniques with geographical information systems in waste facility location to enhance public participation, Waste Management and Research. **24**(2):105–117

Mathur, D. S. (2018). A Study on the Effect of Affluence on Solid Waste Generation in Kota. *IJEMR* , 5.

Mcfaden, G. (2003). Multi Criteria and Landfill Site Selection Using GIS: A Case Study from Palestine, Italian Agency- Palestine, **3**:33-41

Michael, J., Robert, B., Simon, M., Brian G., and Sunil, S. (2005). Multi-criteria decision analysis in spatial decision support: the ASSESS analytic hierarchy process and the role of quantitative methods and spatially explicit analysis. Environmental Modeling and Software. **20**: 955–976

Mohammad, A. A., Nadhir, A., Hadeel, K., and Sven, K. (2014). Modeling Landfill Suitability Based on GIS and Multi-criteria Decision Analysis: Case Study in Al-Mahaweelqadaa, Scientific Research, Iraq, **06**(11):828–851.

Ogwuche, J. A. (2013). Spatial Location of Solid Waste Dumpsites and Collection Scheduling Using the Geographic Information Systems in Bauchi Metropolis, Nigeria. European Scientific Journal. **11**:1857–7881.

Seied, T., Ebrahim, F., Taghi, E., and Mohamad, A. (2015). Site Selection of Sarin's Municipal Solid Waste Landfill Using the GIS Technique and SAW Method, International Journal of Environmental Science and Development. **6**(12):934–937

Setting up of Municipal Solid Waste Processing Plant. (2016). Kota: Nagar Nigam.

Singh, H. (2019). Factual Status of Bio-Medical Waste Management in Kota, Rajasthan, India. *IJEAT* , 8.

Zhang, D., Tan, S., and Gersberg, R. M. (2010). Municipal solid waste management in China: Status, Problems and Challenges, Journal of Environmental Management. **91**:1623–1633