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SITE SUITABILITY ANALYSIS FOR WASTE DISPOSAL USING GIS AND RS: A CASE STUDY OF BLANTYRE CITY, MALAWI

BY

THOKOZANI TAUZI
Thyolo, Malawi

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DISSERTATION APPROVED BY:

SUPERVISOR: Dr. Emmanuel Chinkaka Signature: _____

ASSESSOR: Title, Initials, Name Signature: _____

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ABSTRACT

In the face of rising population and urbanization, several countries are striving to build proper waste management systems. A solid waste management system is required for urban solid waste management, and the presence of a sanitary landfill is essential. Finding adequate places for a sanitary landfill is one of the most critical issues. The major goal of this study was to use Remote Sensing and Geographic Information System techniques to find suitable solid waste disposal locations in Blantyre, Malawi, that are economically viable, environmentally sound, and socially acceptable. Slope, road network, river, land-use/land-cover, faults, and soil maps were used in this study. The weights of factor parameters were calculated using the Analytical Hierarchy Process pair-wise comparison model. Overlay analyses were used to create a suitability map that was categorized as extremely suited, suitable, moderately acceptable, less appropriate, and unsuitable. According to the findings, 5.93 percent of the study area is extremely ideal for solid waste dumping in Blantyre city, 6.5 percent is suitable, 3.23 percent is moderately acceptable, 1.02 percent is less suitable, and 83.32 percent is unsuitable. Field observations further confirmed the acceptability of the selected sites, indicating that this method can be utilized to choose garbage dumping locations in urban settings. To reduce environmental risk and human health issues, certain areas are considered ideal for landfilling.

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ACRONYMS/ABBREVIATIONS

BCC:	Blantyre City Council
ITG:	Imperial Tobacco Group
LU:	Land use
WLC:	Weighted Linear Combination
AHP:	Analytic Hierarchy Process
MCE:	Multi-Criteria Evaluation
MCDA:	Multi-Criteria Decision-making Approach
RBF:	Radial Basis Functions

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1. INTRODUCTION

Solid waste refers to leaves/twinges, food residues, paper/cartons, textile materials, bones, ash/dust/stones, dead animals, human and animal excreta, construction and demolishing debris, pharmaceutical debris, etc. Waste is a material discharged and discarded from each step of daily human life activities, which has adverse implications on human health and the environment (Bringi, 2007); conversely, waste is a substance discharged and discarded from each stage of daily human, (Sha'Ato et al., 2007; Babatunde et al., 2013) Household hardware (electrical appliances, furniture, etc.) In today's world, solid waste is a global environmental issue that impacts both developing and developed countries. Solid waste generation is being expedited around the world due to rising population, rapid economic growth, and rising community living standards (Elmira et al., 2010). dumping of solid trash. However, the plurality of solid waste disposal sites is located in the vicinity of urban centers, near water bodies, farming fields, settlements, and roads, among other things. Flies, mosquitoes, and rodents will be able to incubate and proliferate in these areas. They disseminate diseases that are detrimental to people's health (Abul, 2010). Contamination of the surface can occur as a result of improper solid waste disposal. And contamination of ground water by leachate, soil contamination by direct waste contact, air pollution by trash burning, disease transmission by various vectors such as birds, insects, and rodents, or uncontrolled methane emission by anaerobic decomposition of waste (Visvanathan and Glawe, 2006). Solid waste dumped indiscriminately caused aesthetic issues, nuisance, and degradation of the area's land and water bodies (Hammer, 2003). As a result, the main limitation for solid waste management is locating optimal places for solid waste disposal and selecting appropriate landfill sites far from residential areas, environmental resources, and settlement. Solid waste can be safely stored in landfills that have been appropriately designed, built, and managed. With the exception of South Africa, African countries had the fewest designed landfills, with most countries relying on open dumping to dispose of

trash. Several researches have shown that a slope of less than 12% is effective for preventing pollutant runoff. The amount of earth moving will be diminished. Construction of landfills entails the use of this material, which lessens prices across the board. Similarly, most studies indicated that the solid waste dumping site be situated within a 1-kilometer buffer from roadways and other modes of movement (Chang et al., 2008). In order to save transportation costs, solid waste disposal locations should not be too far from roadways. The location of a solid waste disposal site should not be too close to residential areas or recreation places. Sener et al. (2011) discovered in Turkey that the distance between disposal sites and settlement areas must be greater than 1000 m, and the haul distance between the solid disposal site and the main city center must be greater than 1000 m. The distance should not exceed 30 kilometers. Grassland, woods, agricultural land, wet land, and bush lands would all be considered and given an appropriate land use suitability index. By reviewing locally undesirable land-use areas, the relevance of limiting the association of conflicting land-use (LU) in solid waste disposal placement can be realized. The public's acceptance of unwelcome facility locations varies depending on the land use (Baban and Flannagan, 1998). Selecting a suitable place for solid waste dumping and managing it in nations like Ethiopia, which have limited financial resources and a high population growth rate, is more difficult. According to Degnet (2008), this is true in many other emerging countries.

1.1.1. BACKGROUND

This research is based on extensive qualitative and participatory fieldwork in and around Blantyre's Mzedi Dump Site, Malawi's only municipal-run waste disposal facility. For the over 100 informal trash pickers (IWPs) that work there, as well as the scattered populations living on its outskirts, Mzedi represents both opportunity and adversity. Mzedi, which is cut like a gash from the rolling peri-urban patchwork of residences, maize fields, and stores that hug the main M3 Highway to Zomba, is located about 12 kilometers northeast of central Blantyre, just beyond the edges of the huge Kachere slum

community, and metaphorically splitting the urban sprawl of the city from rural Malawi's agricultural landscapes. The site dates back to the mid-1990s, when the Blantyre City Council (BCC) 5 bought the land on which Mzedi presently stands from the Imperial Tobacco Group (ITG) and turned a shallow valley into a waste site with minimum excavation. However, as Kalina et al. (2019) point out, land tenure in the Mzedi area is problematic. Despite the fact that the BCC owns the majority of the property surrounding Mzedi, people from nearby Moto Village have had the de facto right to use the space for agricultural reasons for many years—a privilege that the city has not aggressively challenged. The city, on the other hand, has always maintained that this arrangement is valid is only temporary and subject to change.

1.1.2. PROBLEM STATEMENT

According to Kalina et al. (2019), the attitude is based on the claim that the dumpsite predates the intense farming of the land, a story disputed by local people who see the dumpsite as an encroachment on agricultural land that has historically been considered theirs. Mzedi is located among plots that have been allotted to families for decades, according to inhabitants of Moto Village. This historical link to the site is heightened by acute land pressure in the area—agricultural plots in Malawi are generational, and Mzedi is set inside plots that have been allotted to families for years, according to inhabitants of Moto Village. As a result, planting elsewhere is out of the question, as other land is either unavailable or too far away to be convenient (Kalina et al., 2019). As a result, despite being a landfill, Mzedi continues to be a place of extensive seasonal agricultural production, with many people of Moto Village maintaining their traditional plots within and along the blurred margins of the site to cultivate maize and a variety of other crops like melons, tomatoes, and gourds. During the growing season, the location is lost in a sea of corn, with every available piece of farmable land being used. The current sanitary landfill in Blantyre has nearly reached its capacity limit, necessitating the construction of a new sanitary landfill. If the management fails to provide a sound and reasonable measure

for the disposal of solid waste, it will be a distressing issue for the residents who live around the Mzedi dumb site. However, it is the obligation of Blantyre waste management to offer acceptable places for the disposal of solid waste created in the city in order to promote a clean, neat, and sanitary environment for the community. As a result, this study is being conducted in order to make the selection of optimal solid waste disposal sites easier. The location of the Mzedi dump site is depicted in Figure 1:

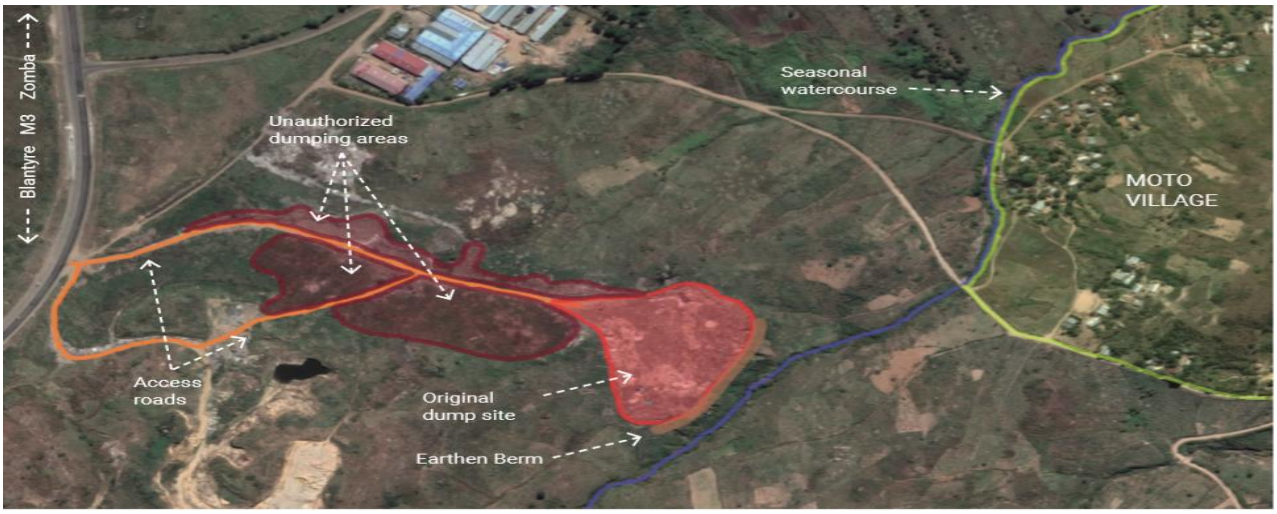


Figure 1: showing Mzedi dump site

1.1.3. AIMS AND OBJECTIVES

AIM: To identify suitable sites for solid wastes disposal in Blantyre city

Objectives:

- Generating thematic map that will be used as factors to be considered in selecting waste disposal site
- Standardize the selection criteria to a common scale and perform weighted analysis
- Produce a landfill site suitability index map showing suitable waste disposal areas

1.1.4. RESEARCH QUESTIONS

- What are some of the best factors to be considered when doing site selection modelling?
- What are some of the standardization selection criteria that will be used in site selection?
- What are some of the main steps to consider when generating the potential model map for the waste disposal sites?
- Which areas in Blantyre city are suitable for categorization as waste disposal sites?

1.1.5. SIGNIFICANCE OF THE STUDY

The main significance of this study is that it provides an assessment of solid waste disposal sites within Blantyre city in terms of current and future capacity, which will help to establish an optimum environment for the city. The cost of bringing solid wastes to town for disposal will also be reduced if a suitable site or land fill can be found within the city. This will lessen pollution's impact and create a facility that will not jeopardize environmentally sensitive places. The once-forested Mzedi dump site is now exposed, with no clear borders separating dumping grounds from surrounding agricultural land. Furthermore, the once-paved entrance road has been heavily rutted and is frequently washed out. As a result, unauthorized dumping has proliferated along the main site's boundaries, with the access road functioning as a secondary dumping field as vehicles illegally unload along it when the main site is inaccessible. Unfortunately, if the city does not find another suitable dumb location, this deterioration is projected to continue. City officials anticipate that the construction of a new location would address many of Mzedi's shortcomings in the future.

1.1.6. STUDY GEOGRAPHICAL AREA

The field of research is Blantyre city, which is nestled in the shire highlands in the country's south. The tropical climate is moderated by Blantyre's elevation of 3409 feet (1039 meters). It has three seasons: a wet season (December to March), a cold season (April to August), and a hot season (September to November) (September to November). Blantyre is Malawi's commercial center, with a population of 661,256 people, 336,234 men and 325,002 women. Figure 2. Map showing the study Area

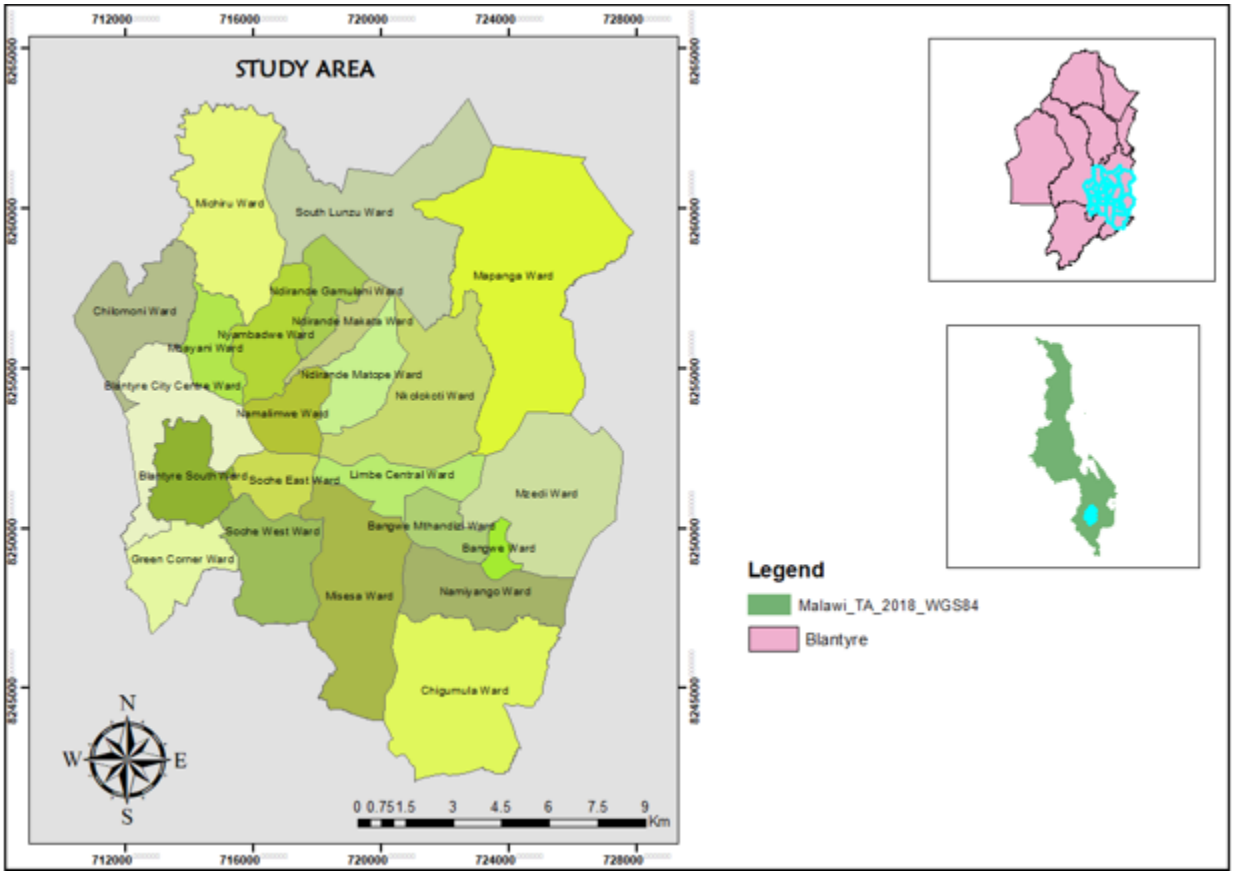


Figure 2: Showing study area map

2. LITERATURE REVIEW

Waste disposal, collection, treatment, recycling, composting, incineration, and dumping are only few of the operations that waste management entails. The research outlined how waste may be effectively handled through the use of computerization. Solid waste (household, industrial, and hospital trash), academic and research institution trash, liquid waste, and trans-boundary waste are the four types of trash that have been classified. Air pollution, contamination of drinking water supplies, and the development of human disease are the most serious consequences of incorrect solid waste management, according to the research. Most site selection approaches, according to reports, lack practical application due to the large number of variables and complexity of mathematical models that comprise the aspects and limitations that must be considered when making a decision. The problem of trash management, collection, and disposal has been described as universal (A.T. Adewole, Waste Management towards Sustainable Development in Nigeria). (H. A. Hamad, 2010. Application of Geographic Information Systems in the Selection of a Suitable Site for Hazardous Waste Landfills.) Hazardous waste management was investigated: He identified it as a global environmental issue that is currently affecting the ecosystem negatively. One of the most important environmental issues facing municipal authorities in emerging countries is hazardous solid waste management. Several ways have been used by various persons to select sites for proper waste disposal; this is owing to the many aspects or criteria that are taken into account throughout the selection process. It has been documented and stated that when selecting land fill locations, several studies took into account the following elements: site capacity, nearby land uses or land cover, airports, surface water, ground water, and other

environmental considerations, geography, soils, climate, insecure areas, infrastructure, local flora and fauna, distance from environmentally sensitive areas, distance from urban regions, and people for site selection, a GIS methodology was used, which was prepared using a map overlay methodology based on the criteria and sub-criteria that were chosen. Kennedy's (2007) writings predate Discard Studies' more current interpretive approach in waste management discourse. Kennedy looks at the history of throwaway goods, echoing but deviating from Heidegger's ontological objective. According to Kennedy (2007), trash symbolizes the collapse of mankind's ontological structure: a fundamental failure of mankind. Waste is a reflection of our own shortcomings, of our incapacity to retain the value originally invested in objects—as machine-minded, uncaring consumers, all we can do is buy, eat, trash, and buy again (Kennedy, 2007, pp. 181-182). Both Hird (2012) and Spelman (2011) use Kennedy's conceptualizations of waste to make epistemic criticism on 'knowing' waste. and encourages the reader to question their own unique perceptions of waste. Moore (2012), for example, emphasizes how various perspectives on what garbage "is" produce a variety of kinds of scholarship that have the capacity to disrupt certain widely held beliefs about values, politics, and socio-spatial interactions. Moore advises that waste be viewed as a parallax object—not as a binary good or bad, but as something that ‘interrupts the smooth operation of things.' Reno (2014) responds to Douglas' aphorism by attempting to rethink notions of 'waste.'

3. METHODOLOGY

This chapter goes over the types of data used and their sources, as well as the methodology used to achieve the study's goals, the research methods used, the type of research conducted, the types and sources of data used, field mapping techniques, field data collection tools and instruments, data collection methods, data management and analysis, and the study's limitations.

3.1. DATA USED

Spatial Data

i. Road network Map
ii. Landsat 8 data (USGS, 30 m resolution)
iii. ASTER DEM (USGS, 30 m resolution)
iv. Geology Map

Non-spatial Data

i. Soil data (NBSS)

3.1.2. METHODS

Landsat 8 data dated 2020, with a resolution of 30 m, was utilized to create primary input thematic maps such as land-use/land-cover. This was accomplished with the help of QGIS software, which employed image processing techniques to remove some distortions following land classification. During the land classification procedure, built-up areas were discovered. The slope map and river map were extracted using the Blantyre city's digital elevation model. Blantyre's geological and soil maps were also used, and these maps

were digitized in ARGIS to create Blantyre's road, fault, and soil erosion maps, respectively. Buffer distances, including built-up area, were determined using these outputs. ARCGIS' buffering function was used to compare rivers and lakes. The Path Distance function was then used to rasterize the map layers, which were vector maps of

polygon, point, and line types. The direct command for polygons was used to rasterize polygon-type maps. Then, using the Reclassify tool, rasterized maps were categorized using the classifications determined. Constrained maps of the road, river, and built-up areas, on the other hand, were created. Following this, the Analytical Hierarchical Process Weight Derivation model was used to compare two criteria at a time using expert judgment and a pair-wise comparison matrix, from which Eigenvectors were derived. The consistency ratios for each of the criteria were also taken into account. The Weighted Linear Combination (WLC) methodology was used to create an overall dump site suitability map that integrated all of the criteria after giving external weights to each layer. Figure 3 depicts the technique flowchart as well as the use of a hierarchical model.

3.1.3. CRITERIA DETERMINING FACTORS

The regulating variables of occurrence of suitability site selection to pick optimal waste dumping sites in the study region were employed as criteria, which suggest the relationships between solid waste dumping site suitability selection and natural elements that determine its occurrence. Six criteria were chosen for analyzing solid waste dump site selection in this study. The analysis took into account factors such as land use/cover, geological formations, slope, distance to river, road, and soil. There are three basic steps in the AHP approach (Saaty & Vargas, 2001). Internally, each layer was weighed depending on buffer minimum and maximum distances as well as requirements. In the first phase, the layers were standardized, and a thematic map of each criterion was created. The preference of each criterion relative to the other criteria on dump site selection was expressed in the second phase by allocating weights. The Analytical Hierarchical Process Weight Derivation model was used to assess two criteria at once,

based on expert judgment and a pair-wise comparison matrix from which a set of weights known as Eigenvectors, as well as consistency ratios for each of the criteria studied, were derived. The Weighted Linear Combination (WLC) methodology was used to create an overall dump site suitability map after giving external weights to each layer. the requirements Factors were integrated using the Weighted Linear Combination method by assigning a weight to each and then summing the results to get a suitability map, as shown in equation 1.

$S= \sum_{i=1}^{n} WiXi$ (1)

where S stands for suitability, wi for factor i's weight, and xi for factor i's criterion score. For Boolean constraints to apply, multiply the compatibility determined from the factors by the product of the constraints, as indicated in equation 2.

$S=\prod^{m}_{j=1} CJ$ (2)

where Cj is the constraint j's criterion score. A series of pair-wise comparisons of relative importance were used to generate the weights. Distinct weights were assigned to all the parameters based on experience and anticipated impacts on the surrounding environment. The weights were calculated using an analytical hierarchy methodology. The restriction was used to narrow down the options that were being considered, which were expressed as a Boolean logical map in 0 and 1. (Mohammad, Kidokoro, &Syed,2009; Eastman, 2012; Shahabi, Keihanfard, Bin Ahmad, Javad, & Amiri, 2013; Olusina & Shyllon, 2014). For Multi-Criteria Evaluation (MCE), apply Equation 3:

$S=\sum^{n}_{i=1} WiCi * \prod^{m}_{j=1} rj$ (3)

S is the suitability of a waste disposal location, Wi is the weight of factor I CI is the criterion for factor I suitability, r j is the criterion for constraint j suitability, and is the product.

FIGURE 3

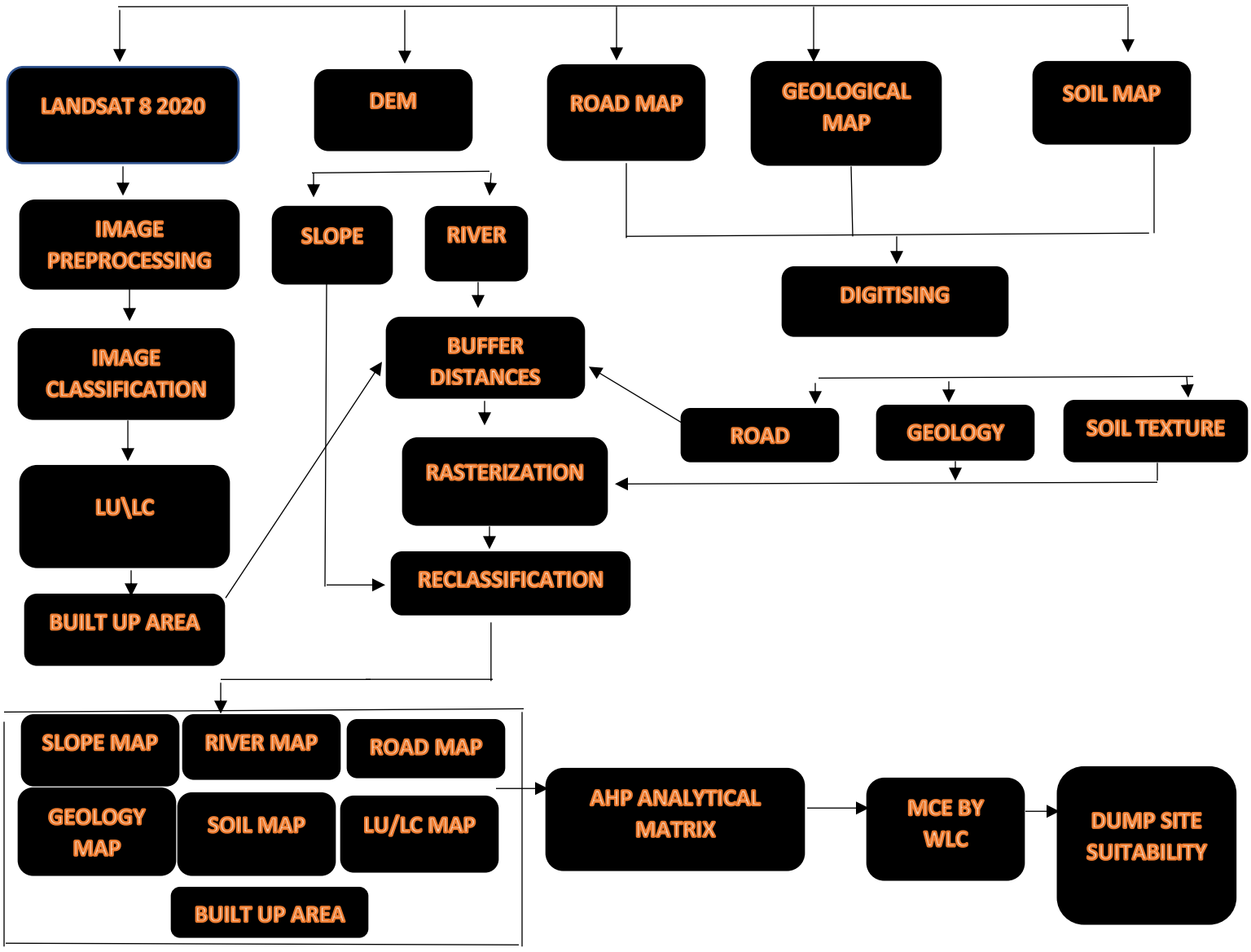


Figure 3: Showing the methodology flowchart

3.1.4. PHASE 1: SUITABILITY MODEL

Decomposing the decision-making problem into a hierarchical framework was the first step in phase one. There are various layers in the structural hierarchy created for the decision problem. Several criteria were devised to determine the hierarchy of the major aims of solid waste disposal site selection, including environmental issues, economic factors, and limits. In order to complete the work, a Suitability Model was used, which included Weight Linear Combination (WLC) and AHP. To capture parts of the choice, an analytical hierarchy technique was adopted. It was used to create a pair-wise comparison matrix and calculate the weights for various criteria (See table 1). The model is based on Equation 4:

$$S=\sum^{n}_{i=1} WiCi \qquad (4)$$

WluClu*WsoCso*WfaCfa*WslCsl*WroCro* WriCri* WbuCbu is (WluClu*WsoCso*WfaCfa*WslCsl*WroCro* WriCri* WbuCbu). WluWlu: land-use weight and criteria, WsoCso: soil weight and criteria, WfaCfa: Fault weight and criteria, WslCsl: slope weight and criteria, WroCro: road weight and criteria, WriCri: river weight and criteria, WbuCbu: built-up area weight and criterion. The Figure 4 below showing the Hierarchical Structure

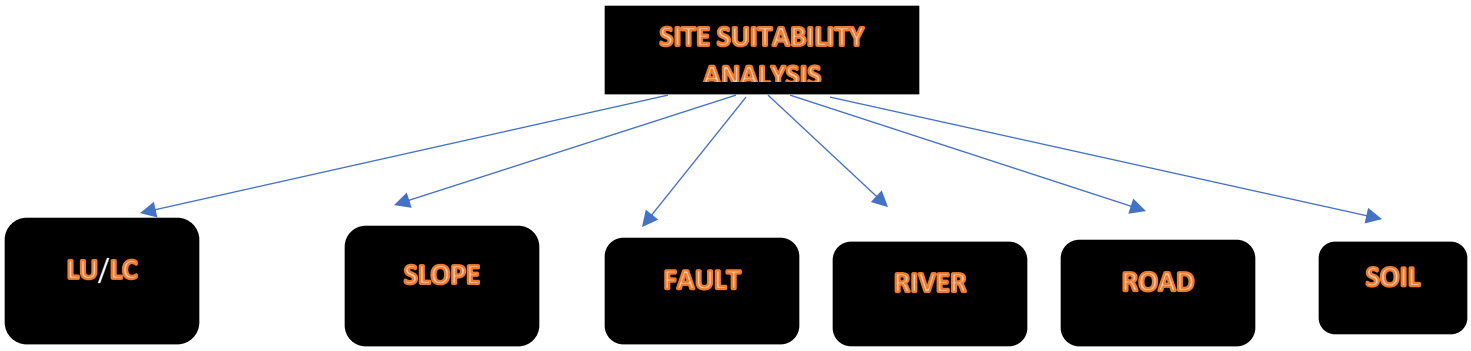


Figure 4: Showing Hierarchical structure

3.1.5. ANALYTIC HIERARCHY PROCESS (AHP)

The Analytic Hierarchy Process (AHP), which was introduced and developed by Saalty, is the most popular and widely utilized MCDA method. Because of its ability to determine the relative weight of many criteria expressed in numerical order of 1 to 9, it is a decision-making tool used in solving multiple criteria problems. Through the scores and weights supplied to each criterion, a pair wise comparison method is used to compare the criteria. When there are a significant number of criteria to examine in the decision-making process, AHP becomes difficult.

3.1.6. WEIGHTING PARAMETERS USING AHP ANALYSIS

Paired comparisons were used to assign weight to the criteria and choices. In the paired comparisons approach, it is necessary to establish which element or criterion is more essential than the other for each pair of criteria. For all parameters, the paired comparisons approach converts qualitative comparisons into quantitative weights. The comparisons were made with the use of the scale in Table 1...

INTENSITY OF IMPORTANCE	DEFINITION	EXPLAINATION
1	Equal importance	Both elements have equal contribution in the objective
3	Moderate importance	Moderate advantage of the one element compared to the other
5	Strong importance	Strong favoring of one element compared to the other
7	Very strong importance	One element is strongly favored and has domination in practice, compared to the other element

9	Extreme importance	One element is favored in comparison with the other based on strongly proved evidences and facts.
2,4,6 &8	Intermediate values	
1/3,1/5,1/7,1/9	Values for inverse comparison	

Table 1: Showing Saalty scale

Table 2: Showing Pair wise comparison matrix of criteria in relation to solid waste dumping site selection in Blantyre city

Criteria	LU/LC	SLOPE	FAULT	RIVER	ROAD	SOIL	BUILT UP AREA
LU/LC	1	5	4	3	5	3	1/7
SLOPE	1/5	1	1/2	1/7	1/3	1/4	1/5
FAULT	¼	2	1	1/9	1/5	2	1/9
RIVER	1/3	7	9	1	9	5	4
ROAD	1/5	3	5	1/9	1	3	1/3
SOIL	1/3	4	1/2	1/5	1/3	1	1/5
BUILT UP AREA	7	5	9	¼	3	5	1

After the pair wise matrix was computed the weight of multiple criteria decisions was calculated as shown in the tables 3, 4,5 respectively.

Table 3: Showing the calculation of criteria weight

Criteria	LU/LC	SLOPE	FAULT	RIVER	ROAD	SOIL	BUILT UP AREA
LU/LC	1	5	4	3	5	3	0.14

SLOPE	0.2	1	0.5	0.14	0.33	0.25	0.2
FAULT	0.25	2	1	0.11	0.2	2	0.11
RIVER	0.33	7	9	1	9	5	4
ROAD	0.2	3	5	0.11	1	3	0.33
SOIL	0.33	4	0.5	0.2	0.33	1	0.2
BUILT UP AREA	7	5	9	0.25	3	5	1
SUM	9.31	27	29	4.81	18.86	19.25	5.98

Each cell was divided by sum of the values of corresponding column

Table 4: Showing the sum of values of each column

CRITERIA	LU/LC	SLOPE	FAULT	RIVER	ROAD	SOIL	BUILT UP AREA
LU/LC	1/9.31	5/27	4/29	3/4.81	5/18.86	3/19.25	0.14/5.98
SLOPE	0.2/9.31	1/27	0.5/29	0.14/4.81	0.33/18.86	0.25/19.25	0.2/5.98
FAULT	0.25/9.31	2/27	1/29	0.11/4.81	0.2/18.86	2/19.25	0.11/5.98
RIVER	0.33/9.31	7/27	9/29	1/4.81	9/18.86	5/19.25	4/5.98
ROAD	0.2/9.31	3/27	5/29	0.11/4.81	1/18.86	3/19.25	0.33/5.98
SOIL	0.33/9.31	4/27	0.5/29	0.2/4.81	0.33/18.86	1/19.25	0.2/5.98
BUILT UP AREA	7/9.31	5/27	9/29	0.25/4.81	3/18.86	5/19.25	1/5.98

In table 5. Showing the criteria weights of each criterion or attribute which was found by adding the row of each criterion and the sum was divided by the total number of criteria used, in this study the total number of criteria used was 6: For example, criteria weight for LU/LC was found by:

0.1074 + 0.1851+ 0.1379 + 0.6237 + 0.2651+ 0.1558 +0.0234/7

1.4984/7 = 0.2140

Table 5: Showing the criteria weights

CRITERIA	LU/LC	SLOPE	FAULT	RIVER	ROAD	SOIL	BUILT UP AREA	CRITERIA WEIGHT	% OF INFLUENCC
LU/LC	0.1074	0.1851	0.1379	0.6237	0.2651	0.1558	0.0234	0.2140	21.4
SLOPE	0.0214	0.0370	0.0172	0.0291	0.0174	0.0129	0.0334	0.0240	2.4
FAULT	0.0268	0.0740	0.0344	0.0228	0.0106	0.1038	0.0183	0.0415	4.1
RIVER	0.0354	0.2592	0.3103	0.2079	0.4772	0.2597	0.6688	0.3169	26.9
ROAD	0.0214	0.1111	0.1724	0.0228	0.0530	0.1558	0.0551	0.0845	8.4
SOIL	0.0354	0.1481	0.0172	0.0415	0.0174	0.0519	0.0334	0.0492	4.9
BUILT UP AREA	0.7518	0.1851	0.3103	0.0519	0.1590	0.2597	0.1672	0.2692	31.6

3.1.7. THE CONSISTENCY RATE

The Inconsistency Rate is a metric that determines how consistent the resulting priorities are; if it is less than 0.1, the comparisons are acceptable; if it is larger than 0.1, the comparisons should be repeated. Across all comparisons in this study, the inconsistency rate was determined to be less than 0.1.

Table 6: Showing the consistency rate.

FACTORS	WEIGHTS	WEIGHTED SUM VALUE	RATIO
LU/LC	0.2140	2.0584	2.0584/0.2140 9.6186
SLOPE	0.0240	0.2257	0.2257/0.0240

			9.4041
FAULT	0.0495	0.3227	0.3227/0.0495 7.7759
RIVER	0.3169	3.0123	3.0123/0.3169 9.5055
ROAD	0.0845	0.678	0.678/0.0845 8.0236
SOIL	0.0492	0.3814	0.3814/0.0492 7.7520
BUILT UP AREA	0.2692	2.8394	2.8394/0.2692 10.5475

Lambda max=9.6186+9.4041+7.7759+9.5055+8.0236+7.7520+10.5475/7

= 62.6272/7

= 8.9467

Consistency Index (CI) =Lambda Max-Number of criteria(n)/Number of criteria(n)-1

= 8.9467-7/7-1

= 0.3244

Therefore, Consistency Ratio = Consistency index/ Random consistency index (RI)

= 0.3244/3.25

=0.099

The importance and value of each component is represented by its weight in relation to other elements. As a result, making an informed and suitable weight selection

substantially aids in determining the desired outcome. The elements of each level are influenced by some or all of the elements on the level above it in this arrangement. By incorporating past studies, AHP matrices were constructed and confirmed by a number of experts knowledgeable with the waste disposal site selection procedure and environmental challenges. These matrices were later integrated into Expert Choice software, and AHP coefficients were calculated (Table 7).

Table 7: Showing AHP coefficients and parameters of each criterion

FACTORS	PARAMETER(m)	SUITABILITY CLASS	RANK	WEIGHT	AREA (ha)	AREA (%)
LU/LC	0-700	Unsuitable	1	0.0344	3704.8	44.3
	701-2100	Less suitable	2	0.0613	2644.2	31.4
	2101 – 3500	Moderately suitable	3	0.1088	1352	16.1
	3501 – 4900	Suitable	4	0.2486	665.5	7.6
	>4900	Highly suitable	5	0.5469	51.5	0.6
SLOPE	>20°	Unsuitable	1	0.1481	3	0.03
	11 20°	Suitable	5	0.2703	68	0.87
	0 10	Highly suitable	4	0.5816	8347	99.1
FAULT	0 – 1000	Unsuitable	1	0.0682	5398	64
	1001 – 2000	Less Suitable	2	0.1664	1984	23.5

	200 – 3000	suitable	4	0.296	871	10.6
	>3000	Highly Suitable	5	0.4686	165	1.9
RIVER	0 – 500	Unsuitable	1	0.0202	3144.1	37.34
	501 – 1000	Less suitable	2	0.1124	1547	18.38
	1001 – 1500	Moderatel y suitable	3	0.1423	2183.3	25.94
	200 – 3000	Suitable	4	0.2968	871	10.6
	>3000	Highly suitable	5	0.4686	165	1.9
ROAD	0 – 700	Unsuitable	1	0.0344	3704.8	44.3
	701 – 2100	Less suitable	2	0.0613	2644.2	31.4
	2101 – 3500	Moderately suitable	3	0.1088	1352	16.1
	3501 – 4900	Suitable	4	0.2486	665.5	7.6
	>4900	Highly suitable	5	0.5469	51.5	0.6
SOIL	Sandy loam	Unsuitable	1	0.4284	2024	35.36
	Loamy sand	Less Suitable	2		0.7	51.08
	Loam	Moderately suitable	3			5.9
	Sandy clay	Suitable	4			6.35

	Clay	Highly Suitable	5	0.5716		1.60
BUILT UP AREA	0 – 700	Unsuitable	1	0.0428	2227.7	26.5
	701 – 2100	Less suitable	2	0.0940	2812.9	33.4
	2101 – 3500	Moderately suitable	3	0.1232	1916.9	22.8
	3501 – 4900	Suitable	4	0.2242	1282.9	15.2
	>4900	Highly suitable	5	0.6158	177.6	2.1

3.1.8. PREPARATION OF FACTOR MAPS

When choosing a dump location, a number of variables should be considered. Map layers comprising effective elements, criteria, and limitations should be processed and analyzed in GIS systems for site selection. The following procedures were used to create factor maps in this study (Figure 5):

1. Using an ARCGIS buffering tool, buffer distances were generated from these input maps, which included built-up areas and waterways. The Path Distance function was used to rasterize the vector maps of polygon, point, and line types. Polygon-type maps, on the other hand, were rasterized using the direct command for polygons.

2. Reclassification: Rasterized maps were classified using the Reclassify tool at this stage, taking into account the classes indicated in Table 7.

3. The slope command was used to create a slope factor map using contour lines. A factor map of groundwater depth was also created using Radial Basis Functions (RBF).

3.1.9. PHASE 2: MULTI-CRITERIA MODEL

In the second phase, decision tables were created at each level of the hierarchical breakdown. The matrices were used to combine a series of pair-wise comparisons based on relative data and Weight Linear Combination (WLC), resulting in a final site selection using the equation:

$$S=\sum^{n}_{i=1} WiCi \ * \prod^{m}_{j=1} rj \qquad (5)$$

(WluClu * WsoCso * WfaCfa * WslCsl* WroCro * WriCriS * WbuCbu) * (WluClu * WsoCso * WfaCfa * WslCsl* WroCro * WriCriS * WbuCbu) Using the GIS-based MCE approach and WLC analysis, a number of prospective site selections were explored for choosing a suitable location, taking into account numerous criteria and opposing objectives (AlAnsari, Hanbali, & Knutsson, 2012; Chang et al., 2008). A square matrix was created using the pair-wise comparisons of several criteria (Table 2). With values ranging from 1 to 9 for whole integers and 1/9 to 1/2 for fractions, the matrix was well-known. Each column's weights were added together, and each element in the matrix was divided by the sum of the relevant column's weights, yielding the first eigen factor. The percentage weight for each element contributed to the solid waste disposal site suitability study was calculated using the second eigenvector.

4. RESULTS AND DISCUSSION

4.1. RESULTS

4.1.1 RIVER SUITABILITY

Waste dumping sites should be located distant from rivers, lakes, and wetlands with high subsurface water levels. Solid trash dumped near rivers causes environmental, agricultural, and health issues. The suitability of a solid waste dump site map was produced in light of these issues (Table 7 and Figure 5). According to the findings, 5.2 percent of the area was unsuitable, 56.8% was less suitable, 17.8% was moderately suitable, 9.3% was suitable, and 10.9 percent was highly suitable for a solid waste disposal site in Blantyre city.

4.1.2 SLOPE SUITABILITY

A slope of 0–10° dominates the terrain of the research region, accounting for 99.1% of the overall research area. The research region's second most prevalent topography is 10 - 20°, which covers 0.87 percent of the total area, while 0.03 percent of the region has a slope greater than 20°. (Table7). The extent of extremely suitable, suitable, and unsuitable sites was delineated and a suitability map was created based on Blantyre's slope suitability coverages (Figure 5).

4.1.3 LAND USE/LAND COVER SUITABILITY

For dumping garbage, a land-use/land-cover map was created with an overall accuracy of 86 percent. The land-use map depicts the area in Blantyre that is used by humans and natural cover. The vegetation, barren ground, built-up area, and water bodies are all depicted on the land-use map. Vegetation covers the vast part of the region. According to land-use/land-cover suitability, the majority of the studied area (21.87 percent) is highly unsuitable for solid waste disposal sites, whereas 52.9 percent and 22.5 percent of the region, respectively, were suitable and less suitable. The remainder of the research area, 2.64 percent, was ideal for a solid waste disposal site.

4.1.4 FAULT SUITABILITY

The more distance from fault, the more suitable the area for waste disposal to minimize negative effects of dump site. Based on fault proximity suitability, only 1.9% of the extent of the study area is highly suitable and 10.6% of the area is suitable, whereas 23.5% and 64% of the study area are less suitable and unsuitable, respectively, for solid waste disposal sites. As per suitability reclassification, the highest rank was assigned to a buffer distance of >3000 m from fault and the lowest rank 1000 m from fault was given to unsuitable areas.

4.1.5 SOIL SUITABILITY

There are five different types of soil textures in Blantyre: clay, sandy loam, loam, sandy clay loam, and loamy sand. According to Table 3, 35.36 percent of the overall area is unsuitable for solid waste disposal sites, 51.08 percent is unsuitable, 5.9 percent is moderately suitable, 6.35 percent is suitable, and 1.60 percent is highly suitable (Figure 5). As per suitability reclassification, the highest rank was assigned to clay soil since it does not allow surface run off during heavy rainfall which is 5 and the lowest rank was given to sandy loam which encourages surface run off during heavy rainfall.

4.1.6 ROAD NETWORK SUITABILITY

Main roads, secondary roads, and pedestrian roads make up the current research area. Figure 5 depicts the calculated road network suitability distance. In the study area, 0.6 percent and 7.6 percent of the area are less and moderately suitable, respectively, for waste disposal sites, while 44.3 percent, 31.4 percent, and 16.1 percent of the area are unsuitable, suitable, and extremely suitable, respectively. The entire research region has moderate to poor road proximity for solid waste disposal locations.

4.1.7 BUILT UP SUITABILITY

Commercial buildings, urban green space, service areas, and industries should all be far away from the waste site. As a result, 26.5 percent of the entire area is unsuitable for solid waste disposal, while 33.4 percent is less suitable. The remaining 22.8 percent, 15.2

percent, and 2.1 percent of the territory in Blantyre city were moderately suitable, suitable, and extremely acceptable for trash disposal, respectively.

4.1.8 CONSTRAINT CRITERIA

Constraints are limitations or constraints that prohibit some aspects from being considered. To construct a waste disposal site, restrictions in the raster are exposed here by Boolean expression, where restricted cells are represented with 0 and viable cells are represented with 1. Constraint maps are used to discriminate between regions that are acceptable for dump sites and those that are not. For each theme, a constraint map contains 1s for acceptable land and 0s for unsuitable land. As a result, five constraint maps covering characteristics such soil, river, road network, built-up area, and geology were created.

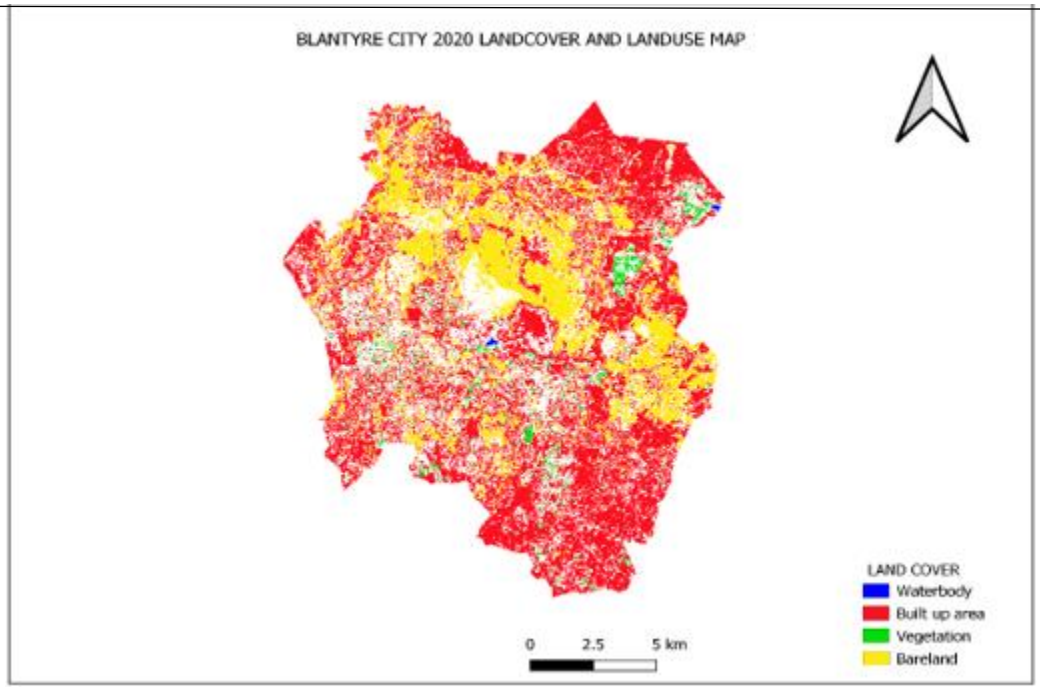
4.1.9 RIVER AND ROAD CONSTRAINT BUFFER DISTANCE SUITABILITY MAP

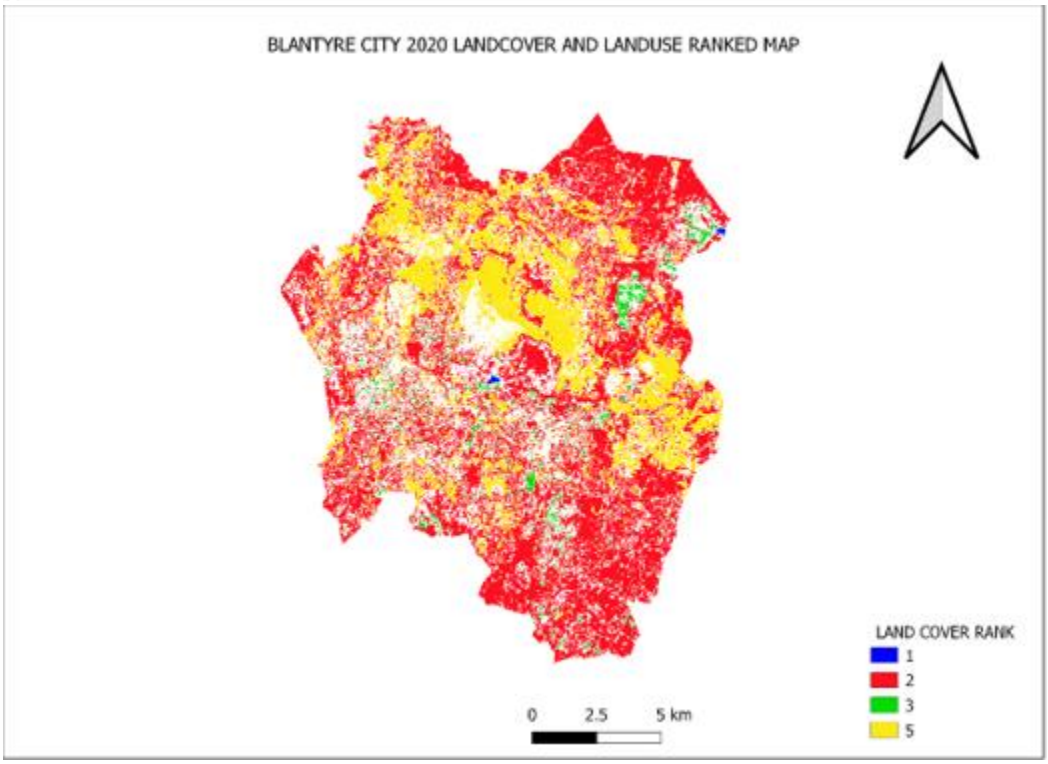
The river constraint map was made using buffer distances of less than 500 meters as unsuitable and greater than 2000 meters as suitable (Figure 5). When it comes to placing waste conversion facilities, distance from existing highways is crucial. The road constraint map with a buffer distance of 700 meters was unsuitable, but one that met the road network proximity criteria was suitable (Figure 5).

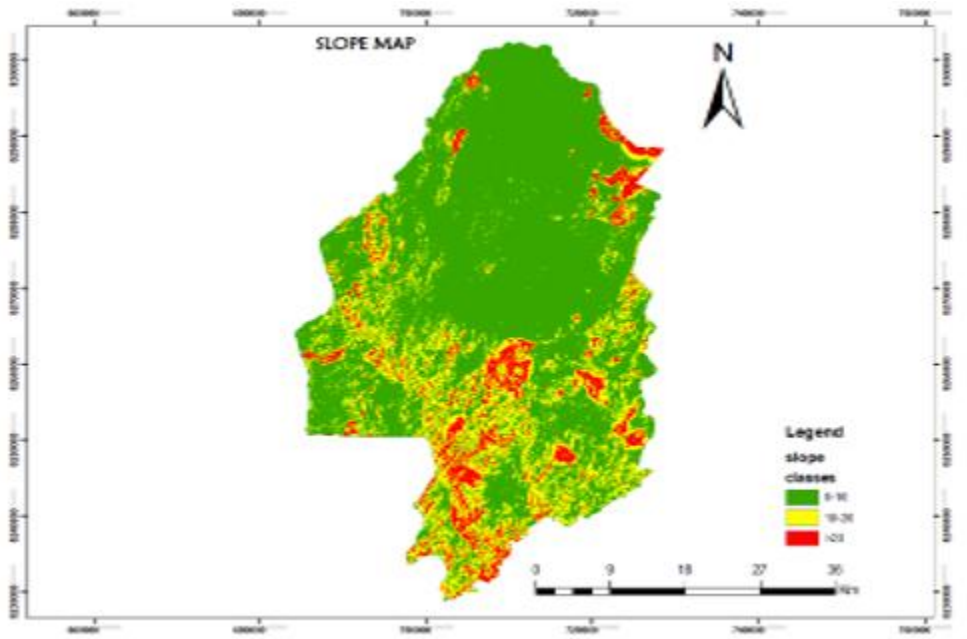
4.2.1 BUILT-UP AREA CONSTRAINT BUFFER DISTANCE SUITABILITY MAP

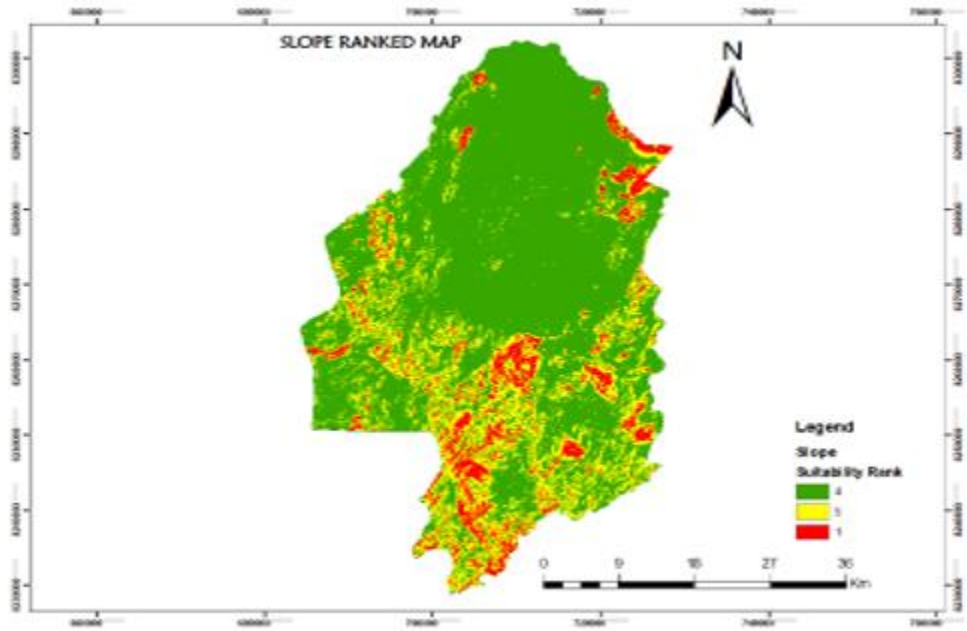
The built-up area constraint map was made to identify dump site dangers such as scavenging animals and unpleasant odors and noise. For locating a solid waste disposal location, the buffer zone of built-up area distance 700 m was assigned 0 (unsuitable), whereas >700 m was allocated 1 (suitable) (Figure 5).

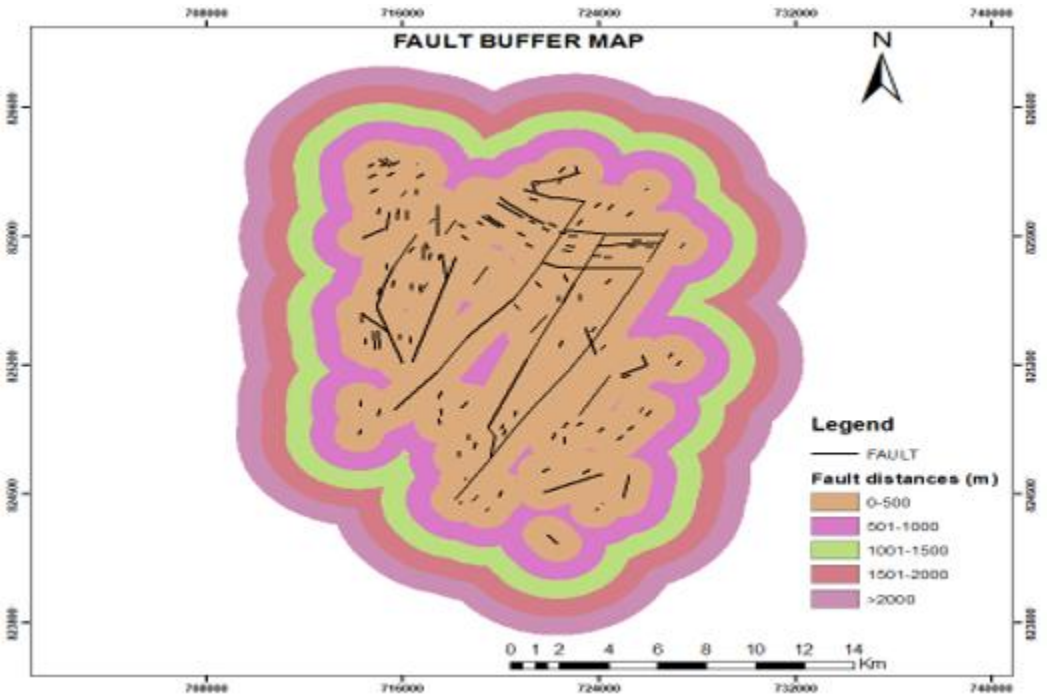
Figure 5: Showing Original and reclassified thematic maps

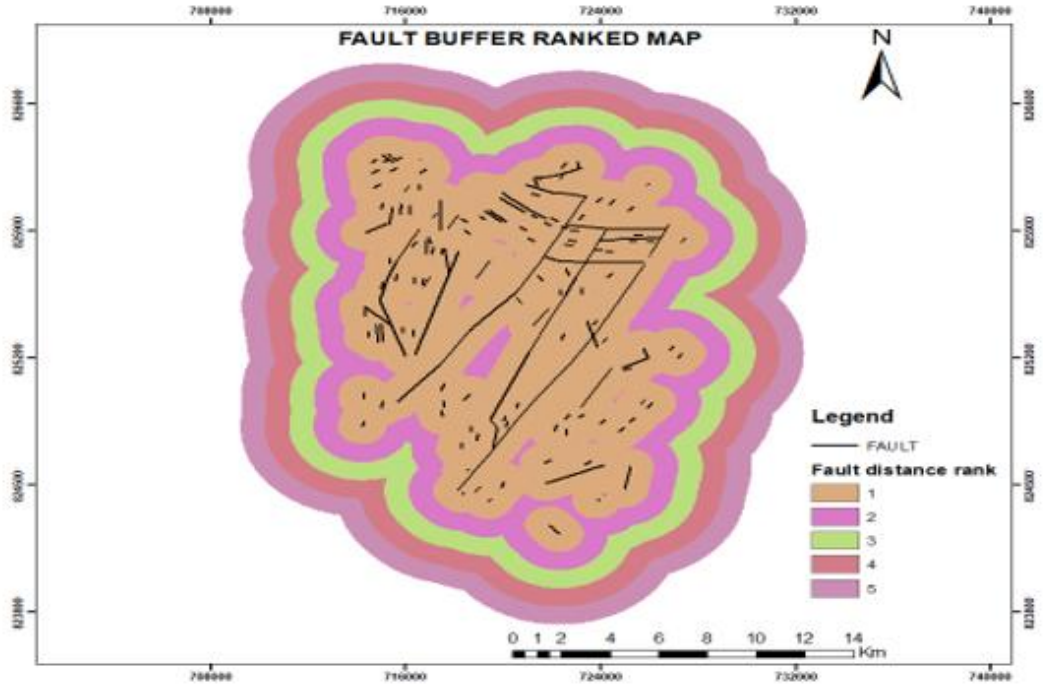

BLANTYRE CITY 2020 LANDCOVER AND LANDUSE MAP
0
2.5
5 km
LAND COVER
Waterbody
Built up area
Vegetation
Bareland

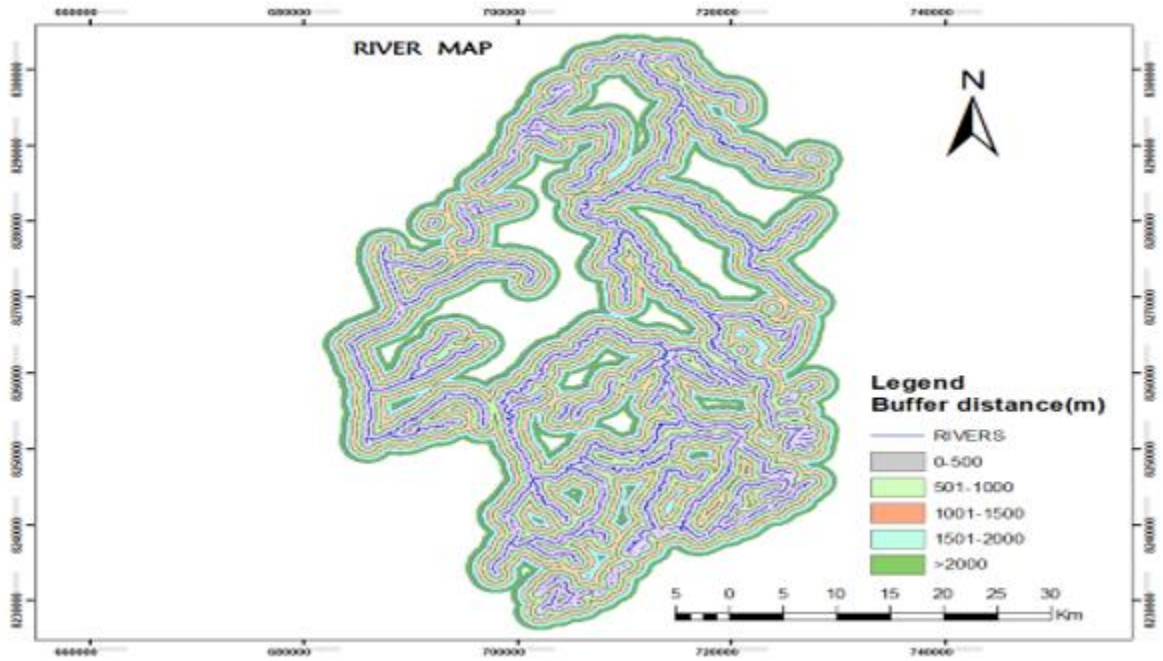

BLANTYRE CITY 2020 LANDCOVER AND LANDUSE RANKED MAP
0
2.5
5 km
LAND COVER RANK
1
2
3
5

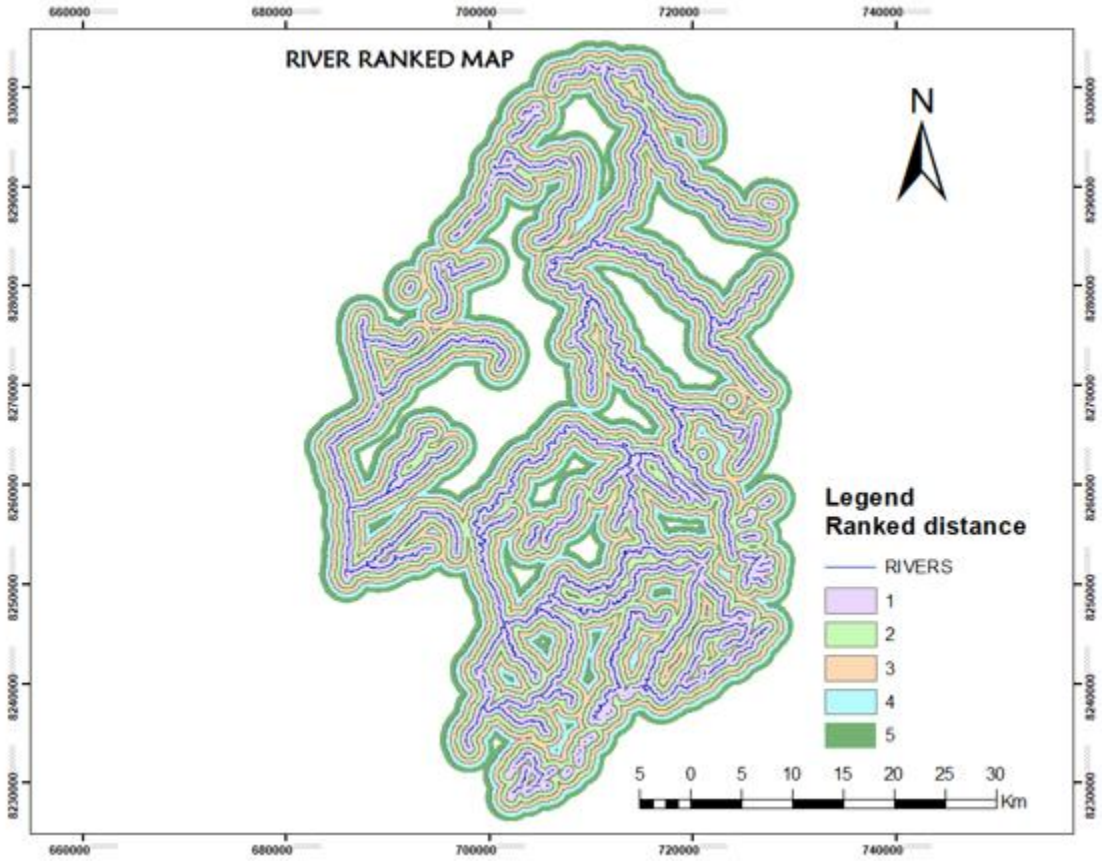

SLOPE MAP
N
Legend
slope
classes
0
9
18
27
36

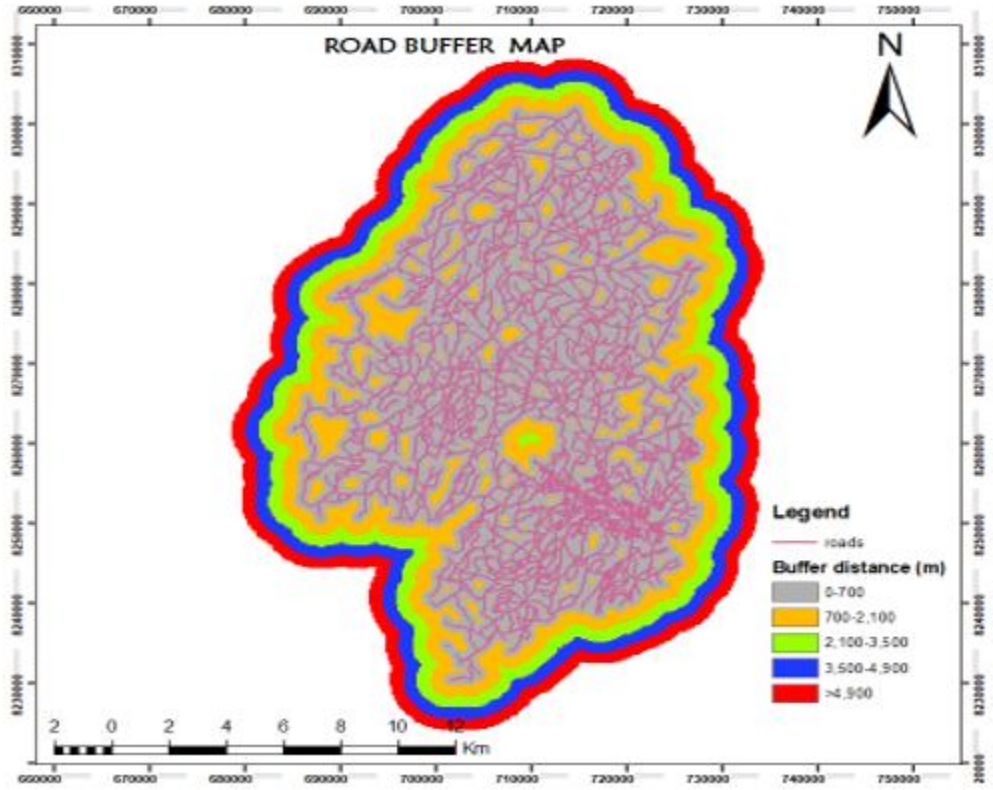

SLOPE RANKED MAP
N
Legend
Slope
Suitability Rank
0
9
18
27
36
Km

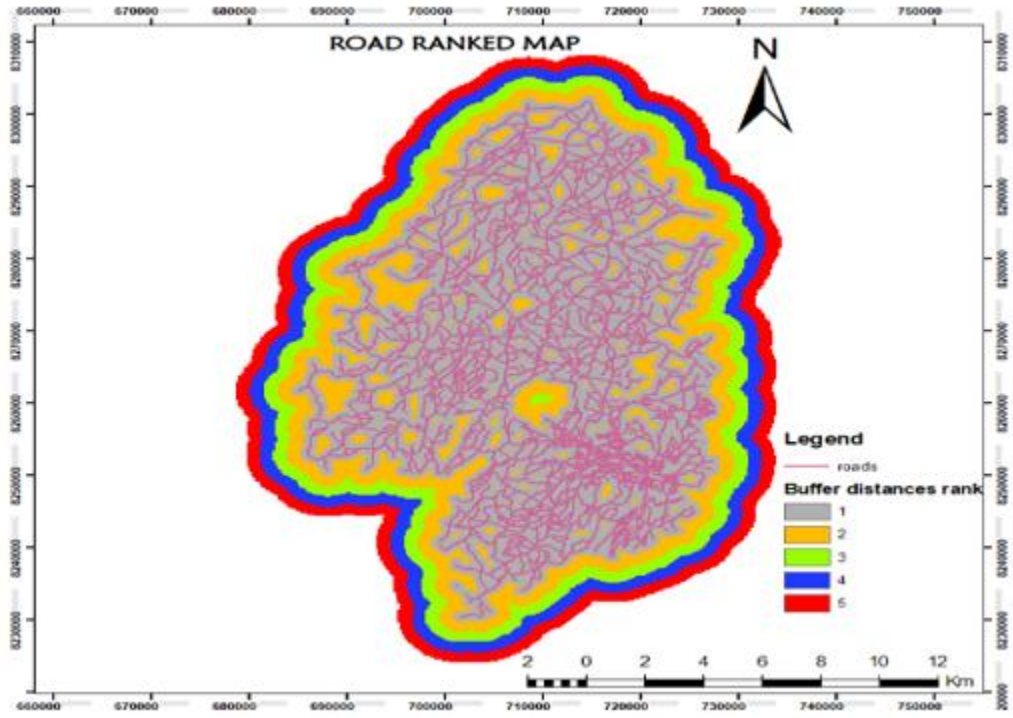

FAULT BUFFER MAP
N
Legend
FAULT
Fault distances (m)
0-500
501-1000
1001-1500
1501-2000
>2000
0 1 2 4 6 8 10 12 14
Km

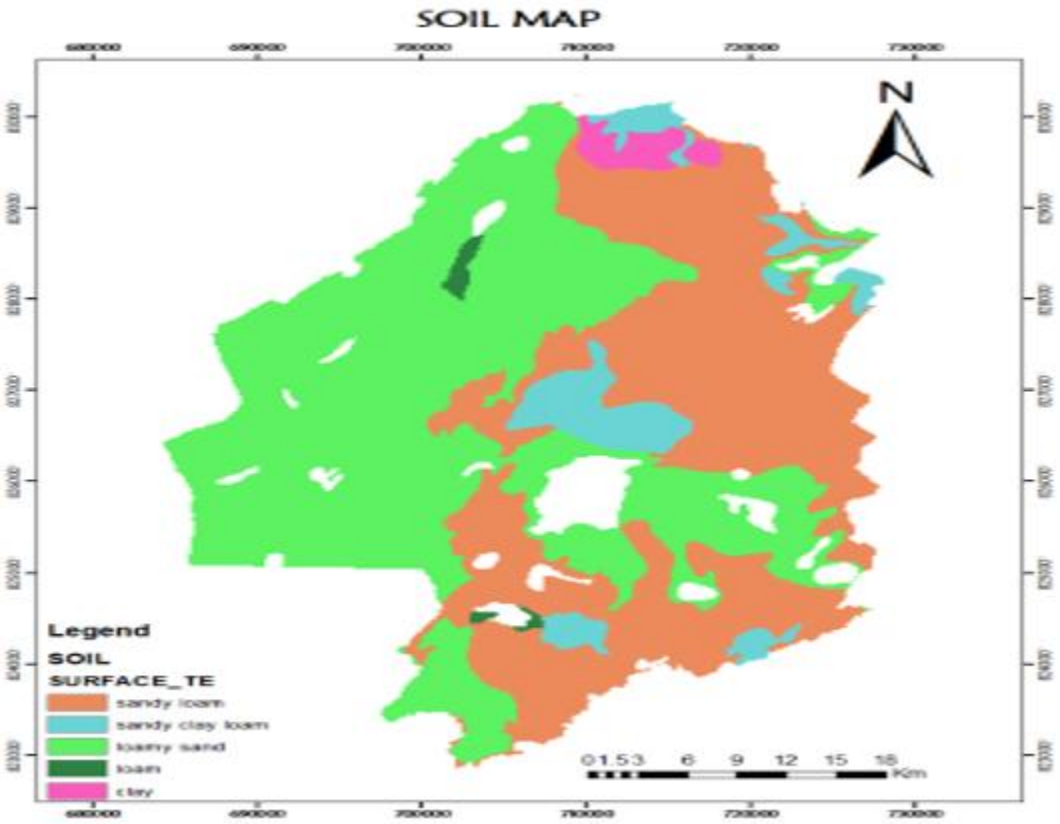

FAULT BUFFER RANKED MAP
N
Legend
FAULT
Fault distance rank
1
2
3
4
5
0 1 2 4 6 8 10 12 14
Km

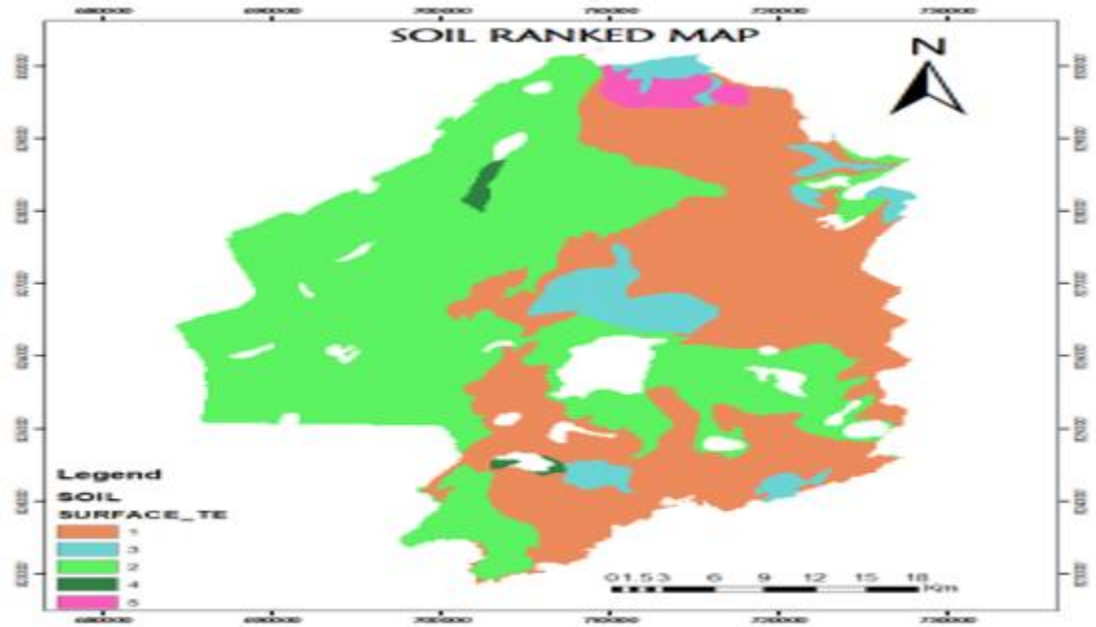

RIVER MAP
N
Legend
Buffer distance(m)
RIVERS
0-500
501-1000
1001-1500
1501-2000
>2000
5 0 5 10 15 20 25 30
Km

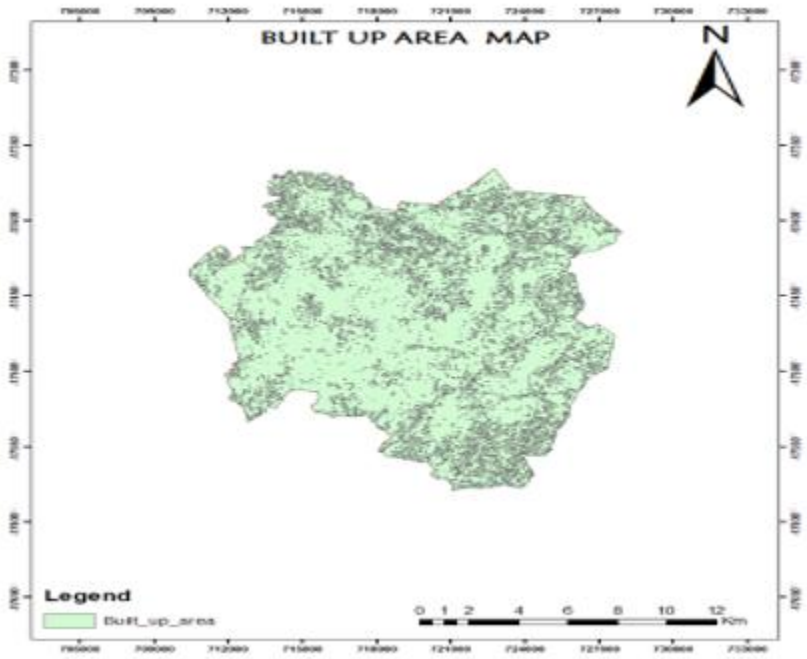

RIVER RANKED MAP
N
Legend
Ranked distance
RIVERS
1
2
3
4
5
5 0 5 10 15 20 25 30
Km

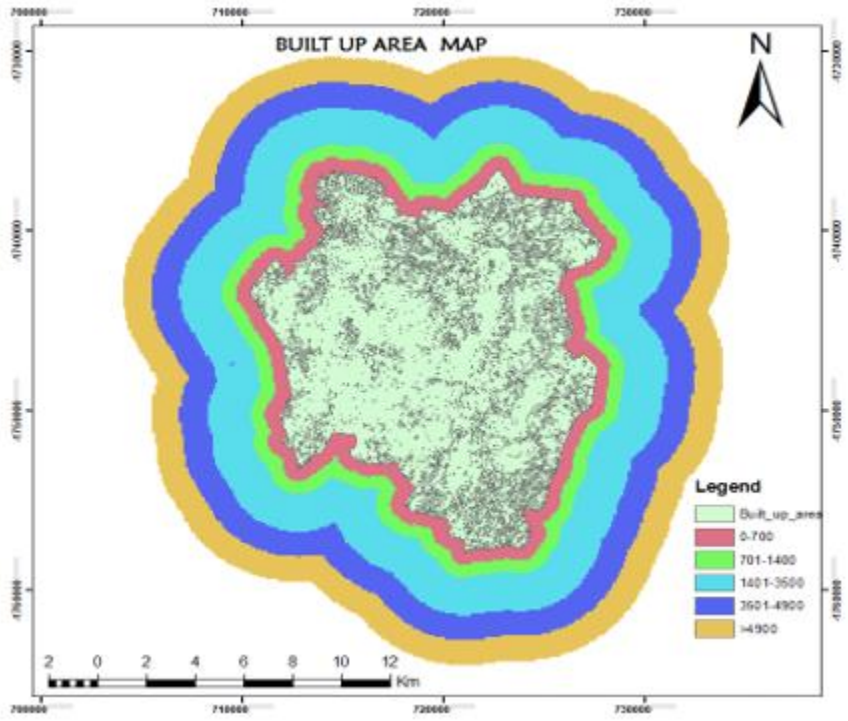

ROAD BUFFER MAP
N
Legend
roads
Buffer distance (m)
0-700
700-2,100
2,100-3,500
3,500-4,900
>4,900
2 0 2 4 6 8 10 12
Km

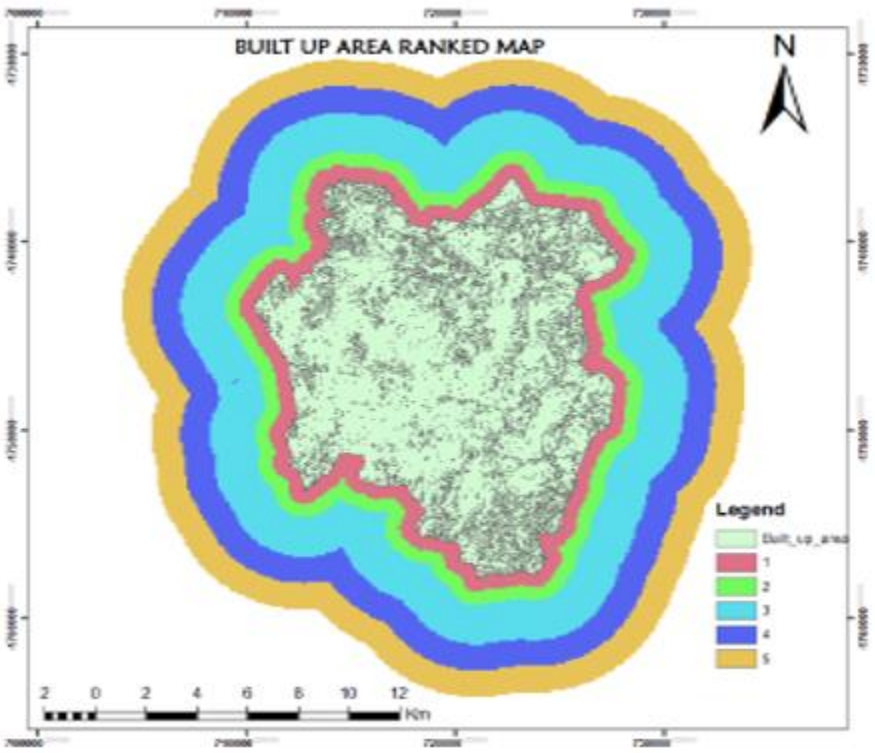

ROAD RANKED MAP
N
Legend
roads
Buffer distances rank
1
2
3
4
5
2 0 2 4 6 8 10 12
Km


SOIL MAP
N
Legend
SOIL
SURFACE_TE
sandy loam
sandy clay loam
loamy sand
loam
clay
0 1.5 3 6 9 12 15 18
Km


SOIL RANKED MAP
N
Legend
SOIL
SURFACE_TE
1
3
2
4
5
0 1.5 3 6 9 12 15 18
Km


BUILT UP AREA MAP
N
Legend
Built_up_area
0 1 2 4 6 8 10 12
Km


BUILT UP AREA MAP
N
Legend
Built_up_area
0-700
701-1400
1401-3500
3501-4900
>4900
2 0 2 4 6 8 10 12
Km


BUILT UP AREA RANKED MAP
N
Legend
Built_up_area
1
2
3
4
5
2 0 2 4 6 8 10 12
Km

4.2.2 CONSTRAINT MAP

The overlay function (using direct multiplication of binary integer values) was used to build the final constraint map, which included well points, rivers, roads, faults, and built-up areas. Finally, there were 7176.8 ha (85.2%) of unsuitable area cover and 1241.2 ha (14.8%) of suitable area cover identified from the whole area of the study (Table 4).

Table 8: Showing Constraint criteria accepted for dump site selection

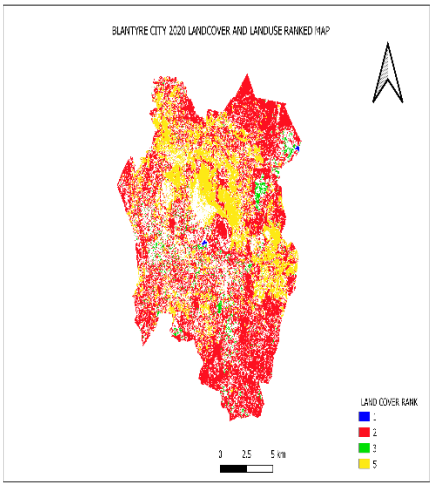
CRITERIA	PARAMETER(m)	SUITABILITY	RANK	WEIGHT	AREA (ha)	AREA (%)
River	0 – 500 >500	Unsuitable Suitable	0 1	0.2471 0.7520	427.7 7990.3	5.08 94.9
Road network	0 – 700 >700	Unsuitable Suitable	0 1	0.4531 0.5469	3704.8 4713.2	44.02 55.98
Built up area	0 – 700 >700	Unsuitable Suitable	0 1	0.3842 0.615	3704.8 4713.2	44.02 55.98
Fault	0-1000 >1000	Unsuitable Suitable	0 1	0.4686 0.5314	5398 3020	64.12 35.88

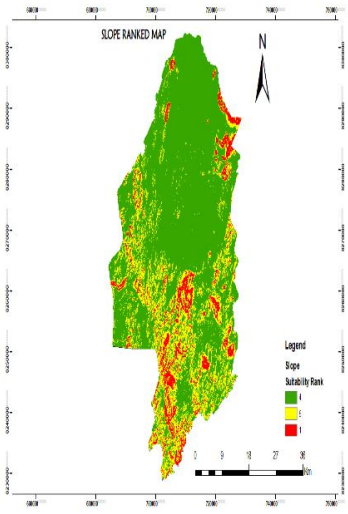
4.2.3 WASTE DUMPSITE SUITABILITY

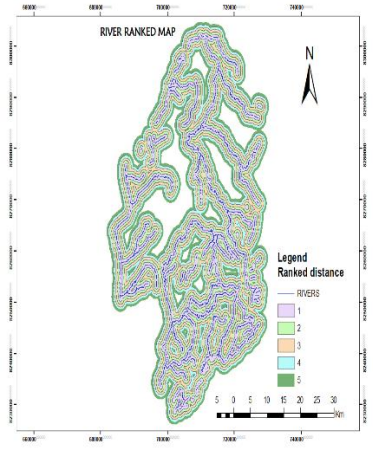
The datasets generated show that solid waste dumping location selection has varying degrees of influence. The relative relevance of each parameter was thus assessed using the primary eigenvector computation. River–31.69 percent, built-up 26.92 percent, Landcover–21.4 percent, Road–8.45 percent, Soil-4.92 percent, Fault-4.15 percent, and slope 2.4 percent were the most important disposal sites in decreasing order. The higher the weight, the greater the impact of a given factor on the solid waste dumping site selection model. The components were analyzed and weights were allocated based on

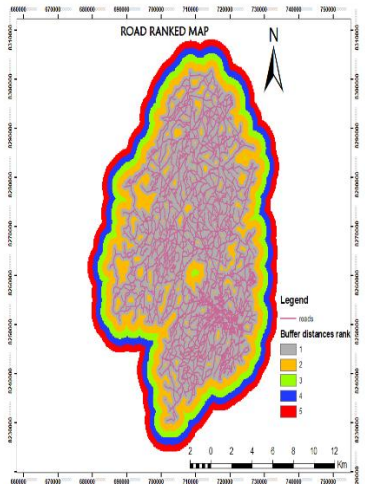
their relative importance in solving the stated problem. By applying equation (5) to all of the reclassified factor layers, a weighted overlay analysis (Figure 6) was performed, and a final solid waste dumping site selection map for Blantyre city was created (Figure 7): Solid waste disposal site selection = (Landcover) 0.2140 + (Slope) 0.0240 + (Fault) 0.0415 + (River) 0.3169 + (Road) 0.0845 + (Soil) 0.0492 + (Built up) 0.2692. About 5.93 percent (499.43 ha) of the entire study area is classified as highly suitable because it meets environmental, social, and economic criteria such as built-up area, faults, land-use/land-cover, soil, slope, and road network. These places were found in the research area's northern reaches. 6.5 percent (537.5 ha) is suitable, 3.23 percent (272 ha) is somewhat suitable, 1.02 percent (86.10 ha) is less suitable, and the remaining 83.32 percent (7154.61 ha) is unsuitable for solid waste disposal sites (Figure 7).

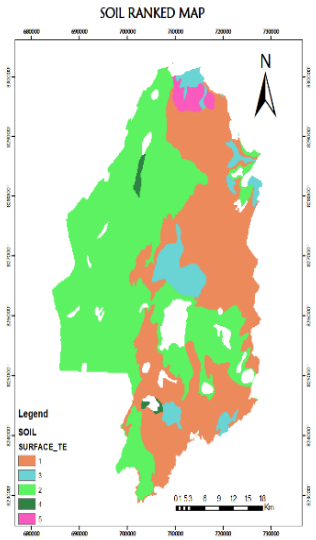
Figure 6: Showing weighted overlay analysis

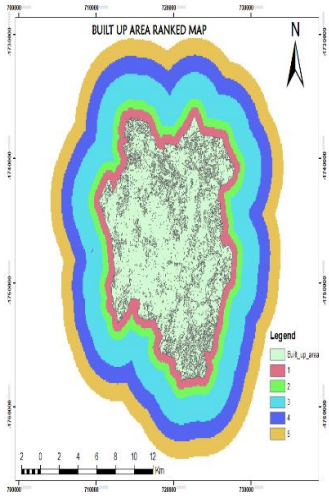
0.2140 * 

+0.0240 * 

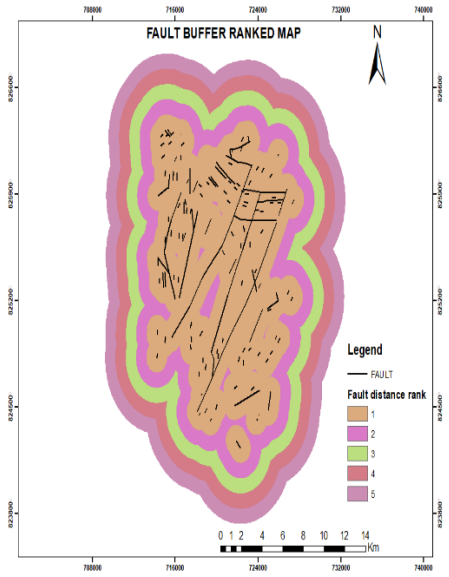
+0.2692 * 

+0.0845* 

+0.0492*+ 



0.3169*+



0.0415*

Figure 7: Showing Overall solid waste dump site suitability map for Blantyre city

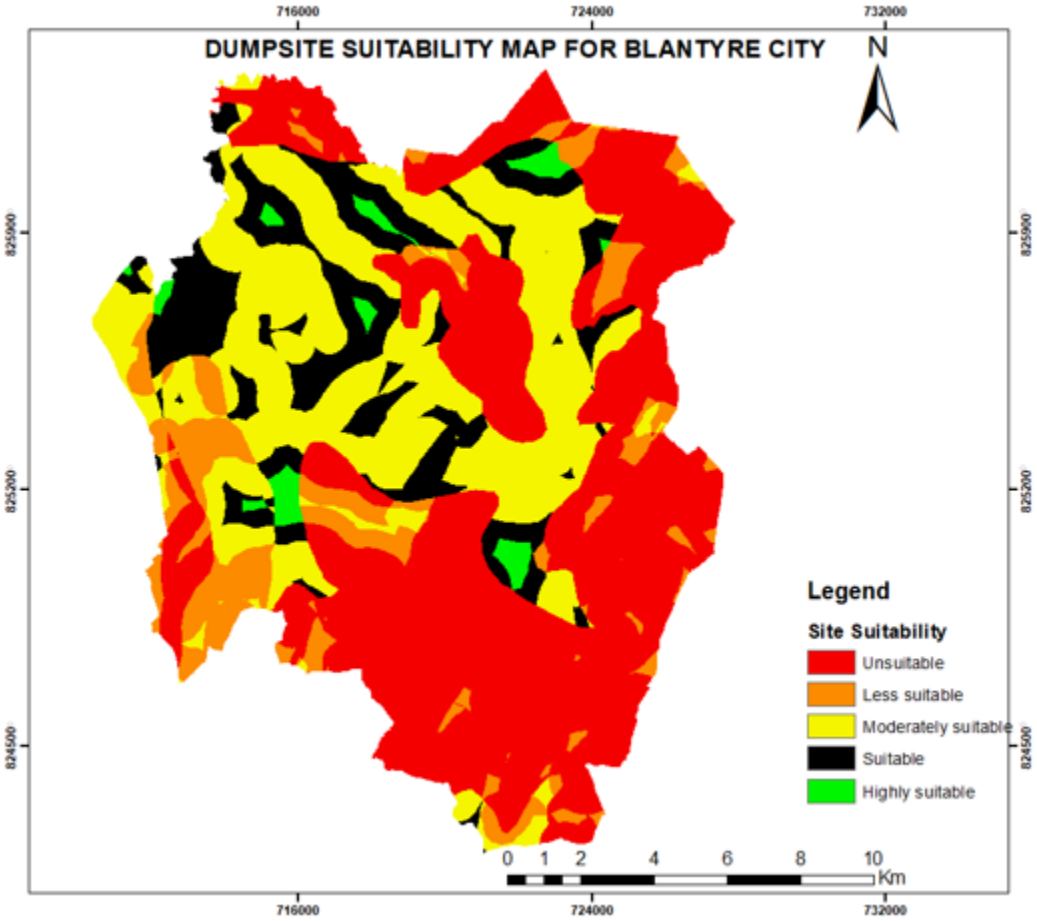
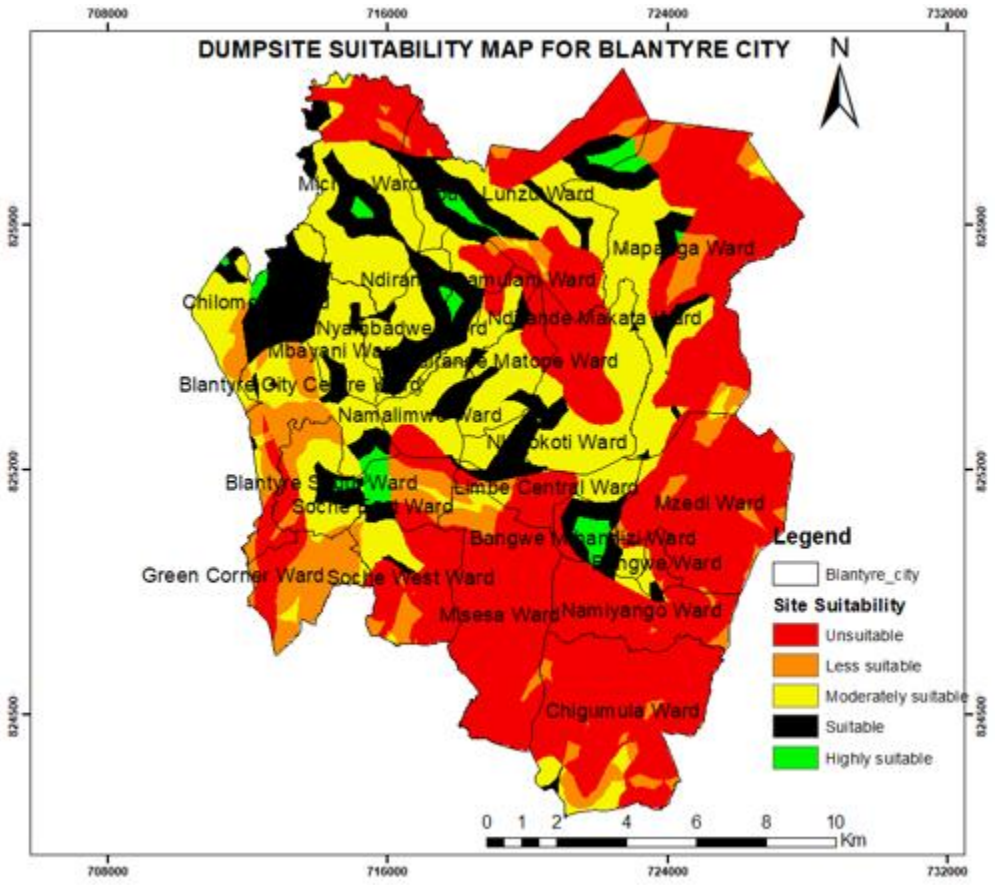


Figure 8: Showing Overall solid waste dump site suitability map for Blantyre city with Blantyre city shapefile



4.2.4 DISCUSSION

The current research is an essential step toward closing a major gap in the detection of trash disposal sites and improving waste management efforts' cost-effectiveness and efficiency. GIS is appropriate for site selection studies (Kaoetal.,1997) because of their ability to manage enormous volumes of geographical data from multiple sources, and they have been frequently used in the recent past for site selection research (Curtis&Hardin,2000; Haaren&Fthenakis, 2011; Nikolakaki, 2003; Thomas,2002; Woodhouse, Lovett, & Dolman, 2000). Because it creates an environment for transformation and aggregation of geographical data, combining GIS and multi-criteria

approaches help decision making. data and preferences of stakeholders (Malczewski,1997). To enable transportation and hence lower relative costs, solid waste dumping sites should be positioned at a reasonable distance from roadways. Waste is mostly dumped on the Mzedi wayside in Blantyre city. According to Sam and Steven (2017), for road appropriateness dump site siting, a minimum buffer of 700 meters should be maintained. Multiple buffer ring extents and road grading values were employed by Kontosetal (2005), Al-Hanbali, Alsaaideh, and Kondoh (2011), and Irfan Yesilnacar, Lütfi, Basak, and Vedat (2012). Blantyre city has grown at an unforeseen rate in recent years, and as a result, the distance between the facility and the nearest hospital has increased. There are barely a few kilometers of residential area. In the city of Blantyre in terms of public health, hygiene, noise, dust, and odor, the existing landfill site is clearly unfit. Unsuitable (restricted), less suitable, moderately suitable, suitable, and highly appropriate were the five dump site suitability classes identified in the overall dump site suitability selection. Due to their land-use/land-cover effect and values, bare land, aquatic bodies, built-up regions, and forest lands were employed for dump site selection processes. The best option for solid waste dump sites in the research area was bare land. Areas with a slope of more than 20 degrees were ruled out as unsuitable, whereas those with a slope of less than 10 degrees were judged to be ideal for dumpsites (Akbari, 2008 To reduce public health effects, areas within a 700 m radius were excluded (Sam & Steven, 2017). The study region is inappropriate (limited) for garbage dump sites in Blantyre city, according to an area-wise estimate of suitability classes. Rivers, highways, and built-up regions were the first to be prohibited, followed by permeable places, geology, places with a steep slope (>20°), built-up and forest, and regions near highways. Only 537.5 ha (6.4 percent) and 189.4 ha (2.2 percent) of the research area were identified as suitable and extremely suitable after removing the limited land with a

combination of environmentally sensitive, socially important, and commercially significant sectors for trash dump sites, respectively. Waste disposal sites in these places are selected because they have the fewest negative effects on the environment and the general public. The majority of the very suitable landfill sites are located in the research area's northern region. The high-elevation south-eastern sector of Blantyre city was omitted from the dump site selection because it serves as a recharge area for the city's low-lying areas. Similarly, the dump site has been excluded from the south-west area of Blantyre city since it is a possible supply of groundwater for the town and its environs. As a result, a high-quality dump site should preferably be found in the northern section of Blantyre city. The current open dump site is in an inconvenient location. It is situated in the vicinity of the built-up region, the roadside, and the nearby river. The suggested selected site may be accessed by road, taking into account the impact of solid waste on the environment, health, economics, and other elements of human existence. According to a study conducted by Olusina and Shyllon (2014) in Lagos, Nigeria, landfill sites created using the criterion sets must be accessible by road. Multi-criteria decision making with GIS integrated methodologies is clearly beneficial to the environment, human health, and the development of mental difficulties, and it should be made a legal requirement for the positioning of disposal sites in human dwellings.

5. CONCLUSION

Solid waste creation has increased significantly in recent years as a result of expanding global population and fast urbanization, as well as incorrect disposal and poor management in Blantyre. The purpose of this study was to follow a thorough selection procedure while avoiding environmental issues, and to recommend a suitable landfill site utilizing GIS and multi-criteria decision-making approaches to make it easier to relocate the current dumpsite. This location is convenient for solid trash disposal. It can be found in the study area's west, north, and east. There are a number of extremely appropriate and suitable classes that may be suitable from an environmental standpoint. From a transportation and economic standpoint. The use of AHP in conjunction with GIS and remote sensing to identify suitable solid waste dumping sites will reduce environmental risk and human health issues. Furthermore, the methodology outlined is user-friendly and can be used by authorities in underdeveloped nations to save time and money. As a result, it is recommended that municipalities seek trash minimization through recycling and reuse, as well as waste transformation alternatives, before turning to the landfill option.

The study was successful in identifying the best solid waste disposal locations in Blantyre, Malawi, and ranking them according to priority. The most highly favorable locations were located in the city's northern section, in the south Lunzu ward, michiru ward as well as some parts of chilomoni ward and a small portion of ndirande matope ward. Mzedi's present dumpsite has likewise shown to be the most suitable site thus far. Soche west ward and Mzedi ward are appropriate locations in the southern part of Blantyre city. The study found that GIS has the potential to manage massive amounts of spatially distributed data from a number of sources, as well as efficiently store, retrieve, analyze, and display data.

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