academicJournals

Vol. 7(11), pp. 976-989, November 2013
DOI: 10.5897/AJEST2013.1589
ISSN 1996-0786 © 2013 Academic Journals
http://www.academicjournals.org/AJEST

African Journal of Environmental Science and Technology

Full Length Research Paper

Solid waste dumping site suitability analysis using geographic information system (GIS) and remote sensing for Bahir Dar Town, North Western Ethiopia

Tirusew Ayisheshim Ebistu[1] and Amare Sewnet Minale[2]

[1]Department of Civil Engineering, Ambo University, Ambo, Ethiopia.
[2]Department of Geography and Environmental Studies, Bahir Dar University, Bahir Dar, Ethiopia.

Accepted 30 September, 2013

Solid waste dumping is a serious problem in the urban areas because most solid wastes are not dumped in the suitable areas. Bahir Dar Town has the problem of solid waste dumping site identification. The main objective of this study was to select potential areas for suitable solid waste dumping sites for Bahir Dar Town, which are environmentally suitable. The main data used for this study were spot image with a spatial resolution of 5 m; digital elevation model (DEM) with 30 m spatial resolution, and ground control point (GCP) collected by ground point survey (GPS) and topographical map of the study area. The maps were prepared by overlay and suitability analysis of geographic information system (GIS), remote sensing techniques and multi criteria analysis methods. The final suitability map was prepared by overlay analyses on Arc map and leveled as high, moderate, less suitable, and unsuitable regions of the study area were determined. The results indicate that 65% of the study area is unsuitable for solid waste dumping; 1.3% less suitable; 21.8% moderately suitable; and 11.9% most suitable. The potential most suitable areas for solid waste dumping sites fall on southern and south eastern part of the town where there are least environmental and health risks. The GIS and remote sensing techniques are important tools for solid waste site selection. Hence, the capacity to use GIS and remote sensing technology for the effective identification of suitable solid waste dumping site will minimize the environmental risk and human health problems.

Key words: Dumping site, geographic information system (GIS), remote sensing, multi criteria analysis, solid waste, weight overlay.

INTRODUCTION

Waste is a material discharged and discarded from each stage of daily human life activities, which leads to adverse impacts on human health and the environment (Bringi, 2007); whereas, solid waste refers to the leaves/ twinges, food remnants, paper/cartons, textile materials, bones, ash/dust/stones, dead animals, human and animal excreta, construction and demolishing debris, biomedical debris, household hardware (electrical appliances, furniture, etc) (Sha'Ato et al., 2007; Babatunde et al., 2013). Solid waste is a global environmental problem in today's world both in less developing and developed countries. Increasing population, rapid economic growth and the rise in community living standards accelerate solid waste generation in the world (Elmira et al., 2010).

Solid waste disposing is an important part of waste management system, which requires much attention to

*Corresponding author. E-mail: amare1974@gmail.com. Tel: 251918768356.

avoid environmental pollution and health problems. However, most solid waste disposal sites are found on the outskirts of the urban areas where there are water bodies, crop filed, settlement, around road, etc. These are suitable sites for the incubation and proliferation of flies, mosquitoes and rodents. They transfer diseases that affect human health (Abul, 2010). Inappropriate disposal of solid waste can be manifested by conta-mination of surface and ground water through leachate, soil contamination through direct waste contact, air pollution by burning of wastes, spreading of diseases by different vectors like birds, insects and rodents, or uncontrolled release of methane by anaerobic decomposition of waste (Visvanathan and Glawe, 2006). Solid wastes indiscriminately thrown resulted also in aesthetic problems, nuisance, and pollution of land and water bodies of an area (Hammer, 2003).

Therefore, locating proper sites for solid waste disposal and selecting appropriate landfill site far from residential areas, environmental resources and settlement is the main issue for the management of solid waste. One way to dispose solid waste is to place it in properly designed, constructed, and managed landfills, where it is safely contained. African nations (with the exception of South Africa) had the fewest engineered landfills, with most nations practicing open dumping for waste disposal. So as to identify appropriate site, several studies have indicated that slope less than 12% would be suitable for the prevention of contaminant runoff. This will reduce the amount of earth moving required during landfill construction, thereby reducing the overall costs.

Similarly, most studies suggested that the solid waste dumping site should be located within a 1 km buffer from the roads and other transportation facilities (Chang et al., 2008). Also, solid waste disposal sites should not be placed too far from the roads to decrease the cost of transportations. Solid waste disposal site should not be placed too close to settlement areas and recreation centers.

The finding in Turkey by Sener et al. (2011) had shown that the distance between disposal sites and settlement areas must be more than 1000 m and the haul distance between the solid disposal site and the main city centre should not exceed 30 km. Land use types such as grassland, forests, agricultural land, wet land, bush lands would be considered and assigned an appropriate index of land use suitability. The importance of minimizing the association of conflicting land-use (LU) in solid waste disposal siting can be realized by reviewing locally unwanted land-use areas. Public acceptance of unwanted facility sitings vary with land-use (Baban and Flannagan, 1998).

However, selecting appropriate site and managing the solid waste dumping in countries like Ethiopia with limited financial and rapid population growth rate is more severe. Degnet (2008) stated that, like in many other developing countries, the majority of inhabitants in most towns of Ethiopia often use unsafe solid waste disposal practices, such as open dumping, burning and burying. As a result, many households practice uncontrolled open dumping and others employ various household solid waste disposal practices, such as burning, burying and composting. However, all self-managed waste disposal practices do not guarantee cleanliness and safety. For example, burning one's trash can give rise to significant albeit localized, negative externalities, like air pollution depending on how it is burned, local hydrology, etc.

Similarly in Bair Dar town, the study area, there are problems of solid waste disposal sites. Even if most of the solid wastes are collected from the source using push carts to the temporary transfer stations, there are no scientifically approved sites. There are no standard transfer stations in the city. All health institutions and industries follow their way of removal of waste, while some others dispose it to the nearby water body, Abay/Blue Nile and Lake Tana. The dumping sites are not well planned, and they are open field disposal (no sanitary landfill), are close to rural settlements and not at appropriate distance from the center of the city.

In order to alleviate these problems, integrating GIS and remote sensing techniques to select the best possible solid wastes dumping is a recent essential technology. The selection of solid waste disposal sites using GIS and remote sensing requires many factors that should be integrated into one system for proper analysis. The selection criteria should consider and combine surface water, soil type, slopes, settlements, groundwater, protected areas, land use and road networks. However, because of absence of data geology, groundwater data were not included in the study.

Remote sensing can provide information about the various spatial criteria such as land use/land cover, drainage density, slope, etc (Emun, 2010), where as GIS aided utilizing and creating the digital geodatabase as a spatial clustering process and easily understood way for solid waste dumping site selection process. In multi-criteria evaluation many data layers are to be handled by GIS and remote sensing in order to arrive at the suitable site, this can be achieved conventionally using GIS. Therefore, the study was aimed at providing suitable solid waste disposal sites by using GIS and remote sensing techniques in order to minimize risk of ecological and human health problem from Bahir Dar. It is also helpful to set appropriate selection criteria for the identification of new solid waste dumping sites through scientific methods.

METHODS AND MATERIALS

Study area

Bahir Dar Town is located at 11° 38'N, 37° 25' E on the southern

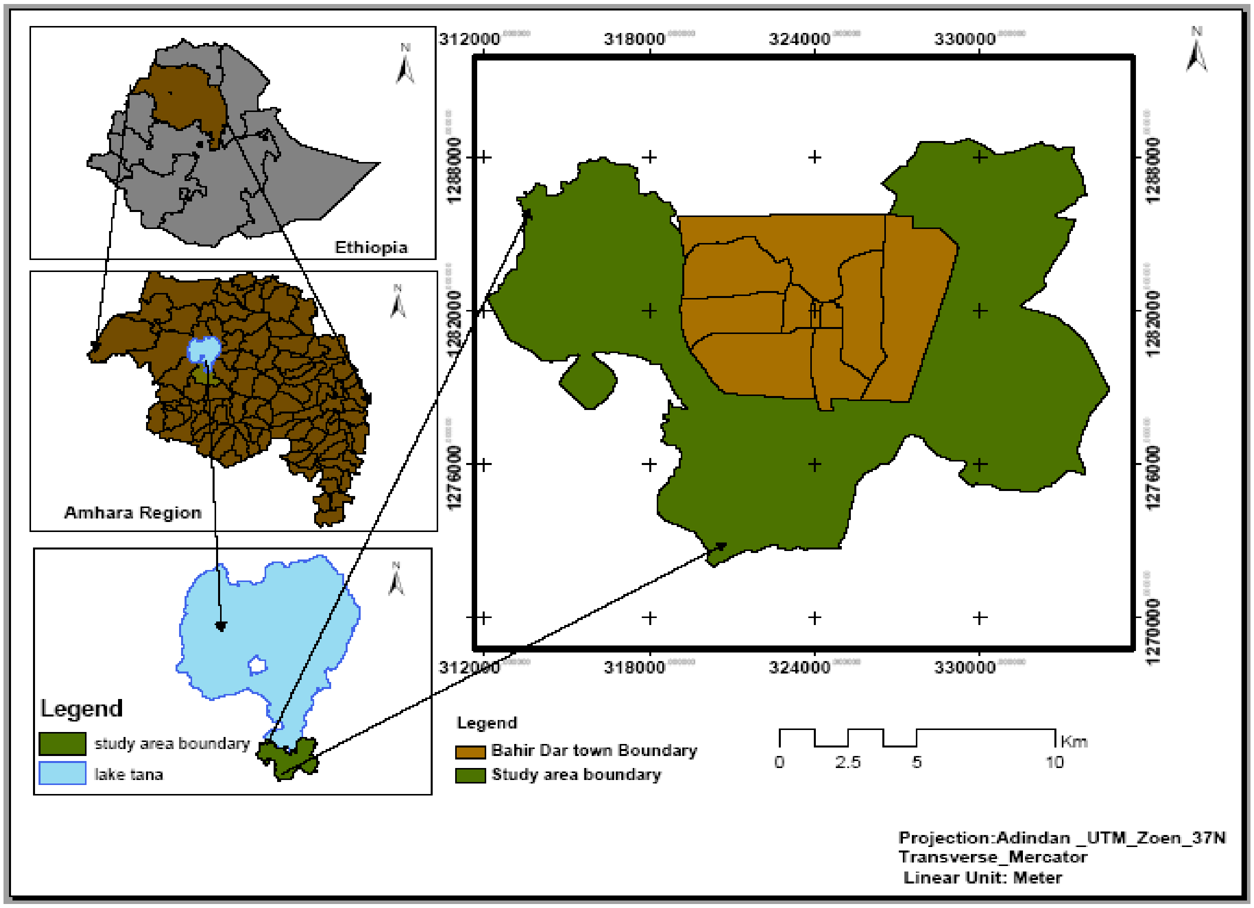

Figure 1. Bahir Dar Metropolitan City study area map.

end of Lake Tana (the source of Blue Nile) (Figure 1). The altitude of the town is about 1800 m above mean sea level. The general slope orientation of the town is slightly towards Abay River, which crosses the city proper from north west to south east. The mean annual rainfall in Bahir Dar town is 1384 mm. The rainy season extends from June to September. The mean annual temperature in Bahir Dar town is 27°C (Dagmawe, 2007). According to the population and housing census of 2007, the population of Bahir Dar was 180,094. Annual population growth of the town is about 6.6% where as 2.6% by birth rate and 2.8% by migration rate (CSA, 2007).

Methods

Both primary and secondary data were used in the study. The primary data were collected from field surveys and observation. Whereas, the secondary data for the study was acquired from internet, reports, books, journals, governmental institutions and other documents. The main data used for this study were SPOT5 image of the town with spatial resolution of 5 m, master plan of the town and topographical map of the town. Pre-processing operations such as radiometric, image restoration and rectification were applied in order to enhance the analysis of the SPOT5 image.

The study used spatial multi-criteria analysis technique to identify the most suitable solid waste site. Spatial multi-criteria approaches (SMCA) have the potential to reduce the costs and time involved in siting facilities by narrowing down the potential choices based on predefined criteria and weights and permitting sensitivity analysis of the results from these procedures (Higgs, 2006). The solid waste disposal site selection mapping was done using multi criteria evaluation and creating layers to yield a single output map or index of evaluation (Wiley and Sons, 2009). The weights were developed by providing a series of pair wise comparisons of the relative important factors to the suitability of pixels for the activity being evaluated. The procedure by which the weights were produced follows the logic developed by Saaty (1977) under the analytical hierarchy process (AHP) which is utilized to determine the relative importance of the criteria in a specified decision-making problem. Linear distances were derived for each factor at maximum size for the purpose of classification.

Classifications were done on various layers and the values were assigned ranging from most suitable to unsuitable. Whereas, reclassification of layers were classified into the 1's, 2's, 3's and 4's scoring system, where 1 represented unsuitable, 2 less suitable, 3 moderate suitable and 4 highly suitable after distance calculation was done, respectively. These criteria were developed by referring to different sources from the literature as indicated above. Then pair-wise comparison of criteria was performed and results were put into a comparison matrix. The matrix is populated with values from 1 to 9 and fractions from 1/9 to ½ representing importance of one factor against another in the pair. The values in the matrix need to be consistent, which means that if x is compared to y, it receives a score of 5 (strong importance), y to x should score 1/5 (little importance). Something compared to itself gets the score of 1 (equal importance). The weights calculated from each columns were summed and every element in the matrix was divided by the sum of the respective column. Finally, an average from the elements from each row of the normalized matrix was calculated. The consistency ratio (CR) was calculated in order to ensure that the comparison of criteria made by decision makers was consistent. The rule is that a CR less than or equal to 0.10 signifies an acceptable reciprocal matrix, whereas greater than 0.10 is not acceptable. Weights obtained by this method are interpreted as average of all possible weights.

RESULTS AND DISCUSSION

Suitability analysis of solid waste dumping site in Bahir Dar town

River and lake

The farther lands from lake and river banks got more preferences for solid waste dumping site suitability. In Bahir Dar town, there is a lake at the northern side, Lake Tana and the River Abbay at northwestern part. Hence, to maintain the environmental health of these water sources at least 2000 m buffered distance should be ringed through straight line calculation.

Accordingly, four different zones were specified consi-dering relative distance from Lake Tana shore and Abay River (Tables 1 and 2; Figures 2 and 3). By consi-dering only the lake, the deep green shaded area was the most suitable for solid waste dumping site (Table 1 and Figure 2). Similarly, deep green shaded area was the most suitable for solid waste dumping site by considering Blue Nile River (water source in the town) (Table 2 and Figure 3).

Suitability of land use/land cover

The land cover of the town was analyzed from the SPOT5 image. The land cover and use is the natural and human landscape that may be exposed by the threats imposed because of landfill adjacency. By reviewing different literature, it was advisable to select land, which was occupied by bare and grass lands for solid waste disposal. In the study area, major land cover and use classes were water bodies (5%), ponds and swamp areas (11%), built-up areas (29%), agricultural fields (27%), bare (3%) and grass lands (9%). Hence, the highest value is given for suitable land class types to solid waste disposal site selection. The land which is covered by bare and grass lands account for about 23.9% from the total area (Figure 4). The grass and bare lands by referring only to the land use criteria indicated by the yellow color were the most suitable area for solid waste dumping site.

Suitable distance from main roads to solid waste dumping site

As the general concept, the landfills shall not be located within 100 m of any major highways, city streets or other transportation routes. Solid waste dumping site must be located at suitable distance from roads network in order to facilitate transportation and consequently to reduce relative costs. The study preferred a buffer of 2000 m distance from main roads by referring to different sources. It was reclassified as unsuitable road within 500 m, low suitable between distances from 500 to 1000 m. The distance starting from 1000 up to 1500 was consi-dered as moderate suitable and highly suitable is dis-tance between 1500-2000 m. The result indicated that 31.3% from the total buffered distance is highly suitable for solid waste dumping site with the class of value 4 for this study. The land that is unsuitable for solid waste dumping site by referring to distance from road is 30.9% of the total area (Table 3 and Figure 5).

Suitable distance from protected areas

The protected area in this study includes churches, mosques, parks and others. The landfill should not be located in close proximity to sensitive areas listed above to limit of 3,000 m buffer surrounding. When the distance increases the suitability also increases (Table 4). Simi-larly, the criteria of Ersoy and Bulut (2009) and Babalola and Busu (2010) show that the area located at the distance greater than 3000 m from environmentally sensi-tive area (such as church, school, mosque) were selected as highly suitable for solid waste dumping site. In the present study, about 29.8% (Table 4 and Figure 6) from the total area were located at distance of 3000 m form environmentally sensitive area. This was the most sui-table area for solid waste dumping site.

Suitability of slope

This study considered the lower slope more highly suitable than the land with higher slope. Different research shows that areas with high slopes will have high risk of pollution and potentially not a good site for dumping. The majority of the study area falls under the slope class of 0-10%, which covers 90.7% of the total study area. According to Sener et al. (2011) and Leao et al. (2001), the land with a slope less than 10% is highly suitable for solid waste dumping. Depending on this, most of the land is suitable for solid waste disposal site. Whereas 4.2, 2.3 and 2.8% of the study area was covered by slope classes 10-15, 15-20 and 20% res-pectively. This shows that slope is not a significant criterion for solid waste dumping site selection in Bahi Dar town (Table 5 and Figure 7). This means that the town is more or less flat in its topography.

Table 1. Distance from Lake Shore and area coverage of suitability levels.

Distance from lake shore (m)	Level of suitability	Value	Area (ha)	Percent of total area (%)
0-500	Unsuitable	1	8366	7.7
500-1000	Less suitable	2	1356	6.6
1000-1500	Moderate suitable	3	1380	7.6
>2000	Most suitable	4	10253	78.12

Table 2. Distance from river and area coverage of suitability levels.

Distance from river (m)	Level of suitability	Value	Area (ha)	Percent of total area (%)
0-500	Unsuitable	1	1349	6.3
500-1000	Less suitable	2	1066	5
1000-1500	Moderate suitable	3	2212	10.4
>2000	Most suitable	4	16728	78.3

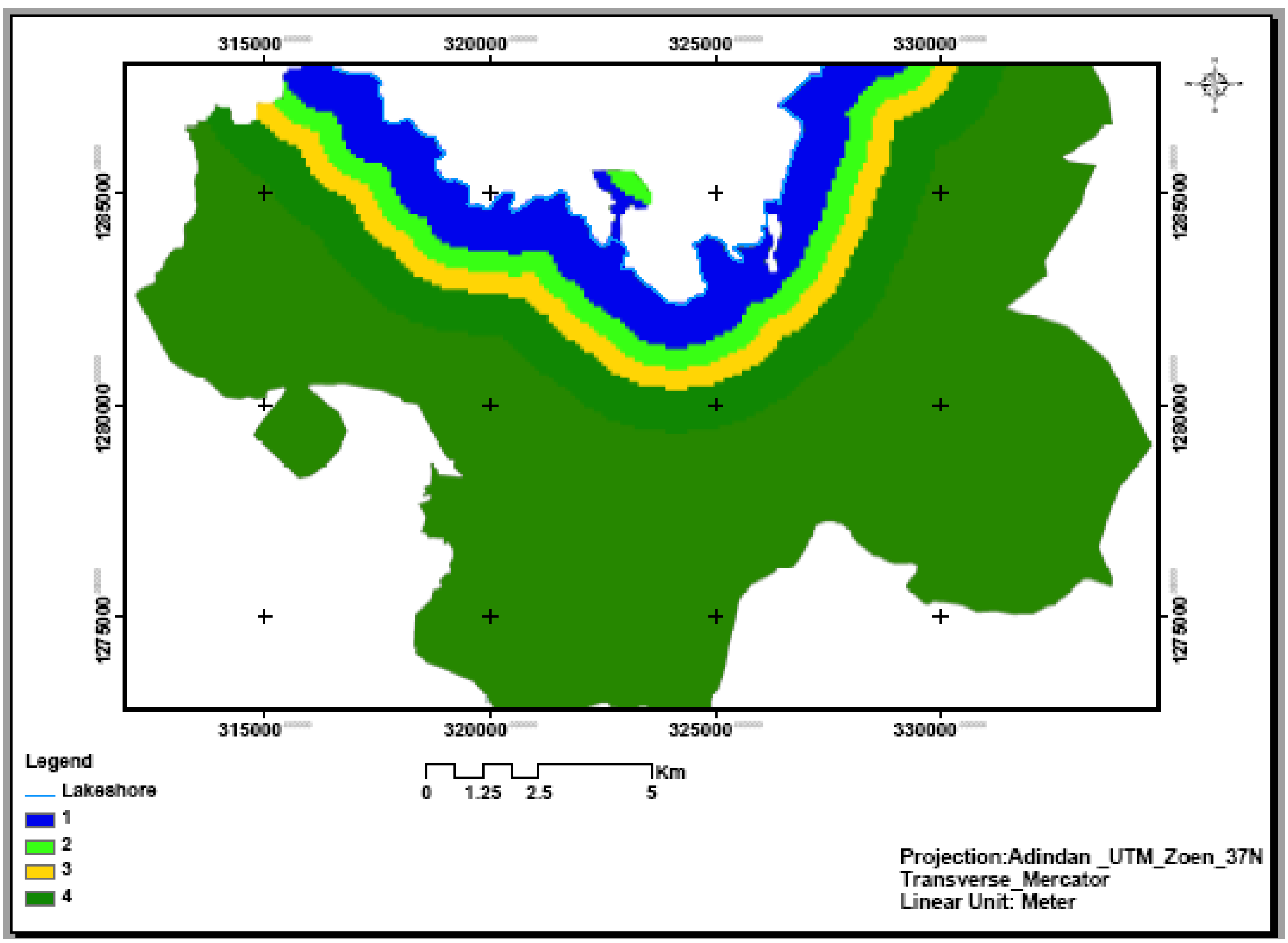

Figure 2. Reclassified distance from lakeshore line.

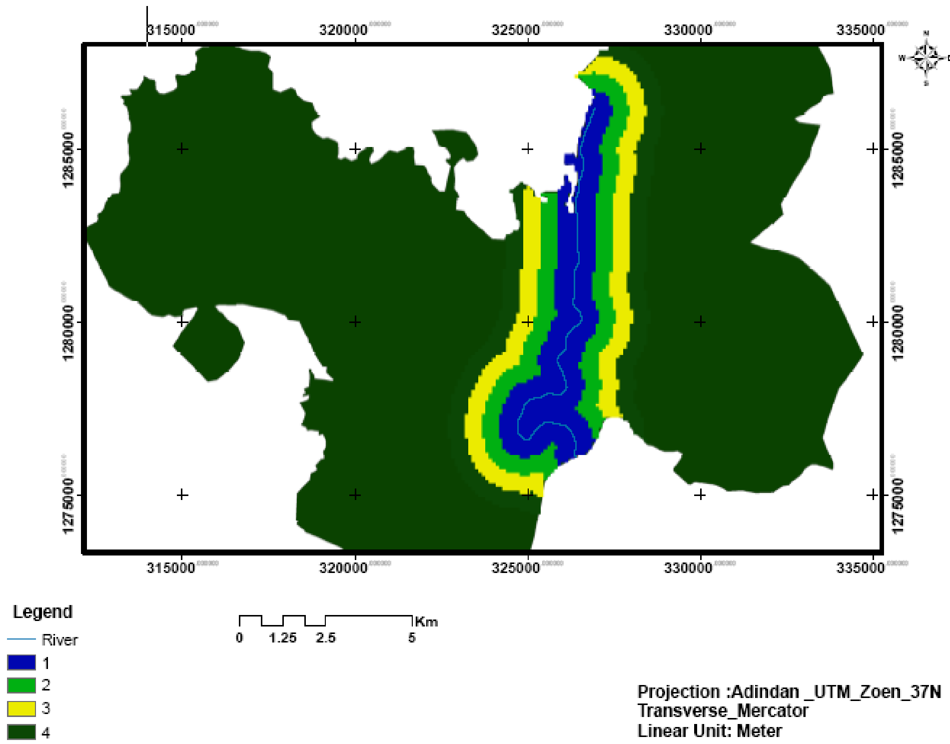

Figure 3. Reclassified distance from river.

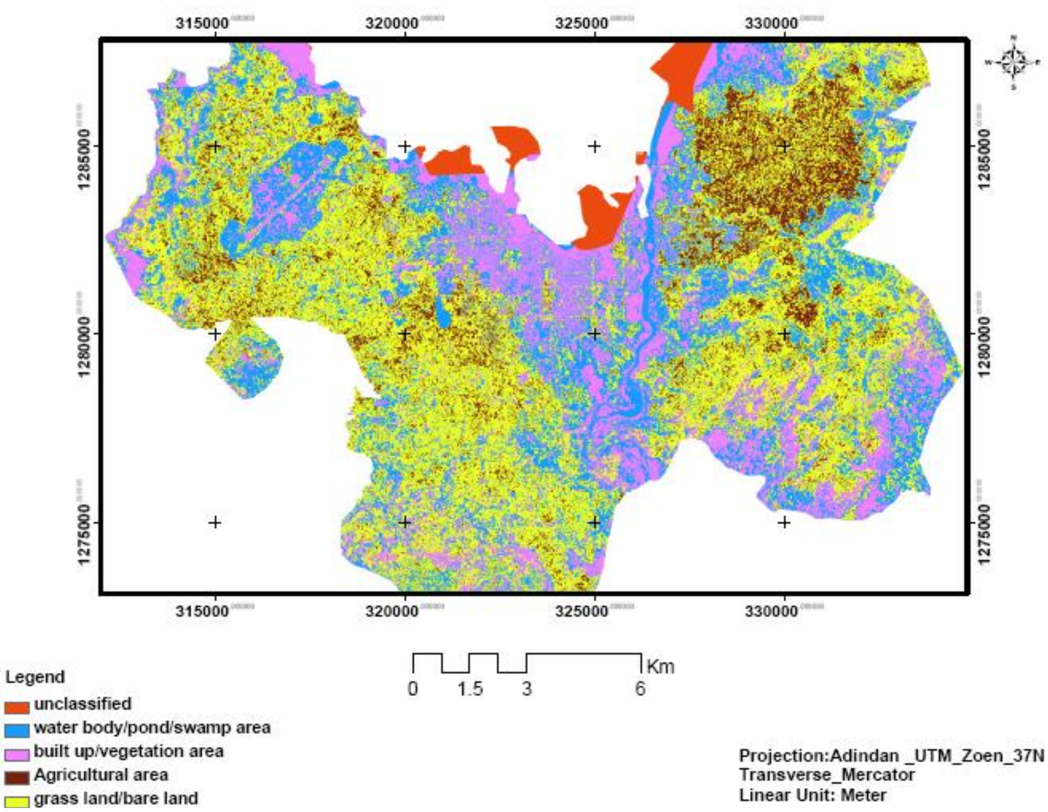

Figure 4. Reclassified land use and land cover map.

Table 3. Distance from main road and area coverage suitability levels.

Distance to road	Level of suitability	Value	Area (ha)	Percent of total area (%)
0-500	Unsuitable	1	6516	30.9
500-1000	Less suitable	2	3722	17.6
1000-1500	Moderate suitable	3	2420	20.1
1500-2000	High suitable	4	8697	31.3

Table 4. Distance from protected area and area coverage suitability levels.

Distance from protect area	Level of suitability	Value	Area in ha	Percentage
0-750	Unsuitable	1	5188	24.3
750-1500	Less suitable	2	5679	26.6
1500-2250	Moderate suitable	3	4118	19.3
>3000	High suitable	4	6370	29.8

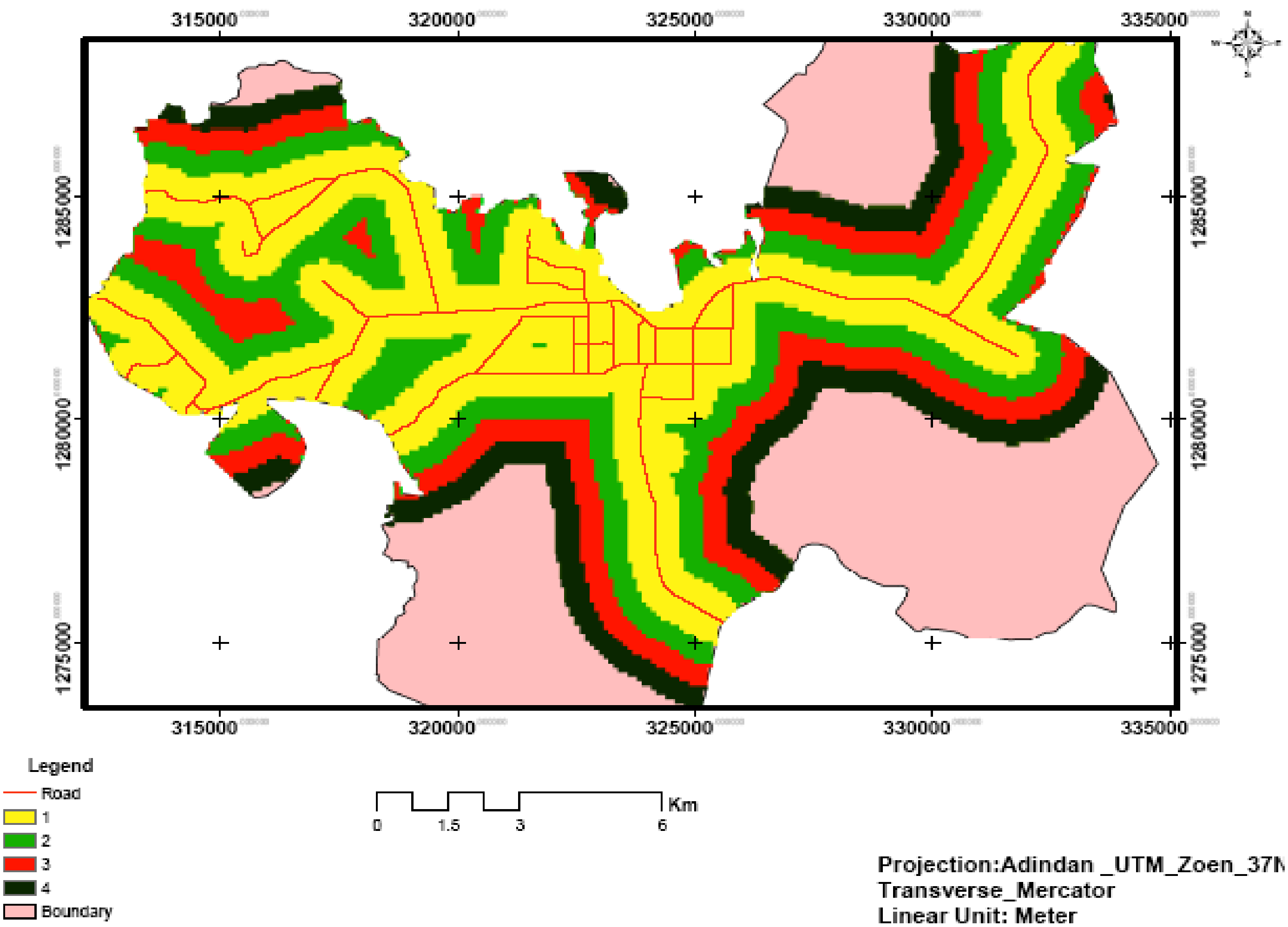

Figure 5. Reclassified distance from the main road.

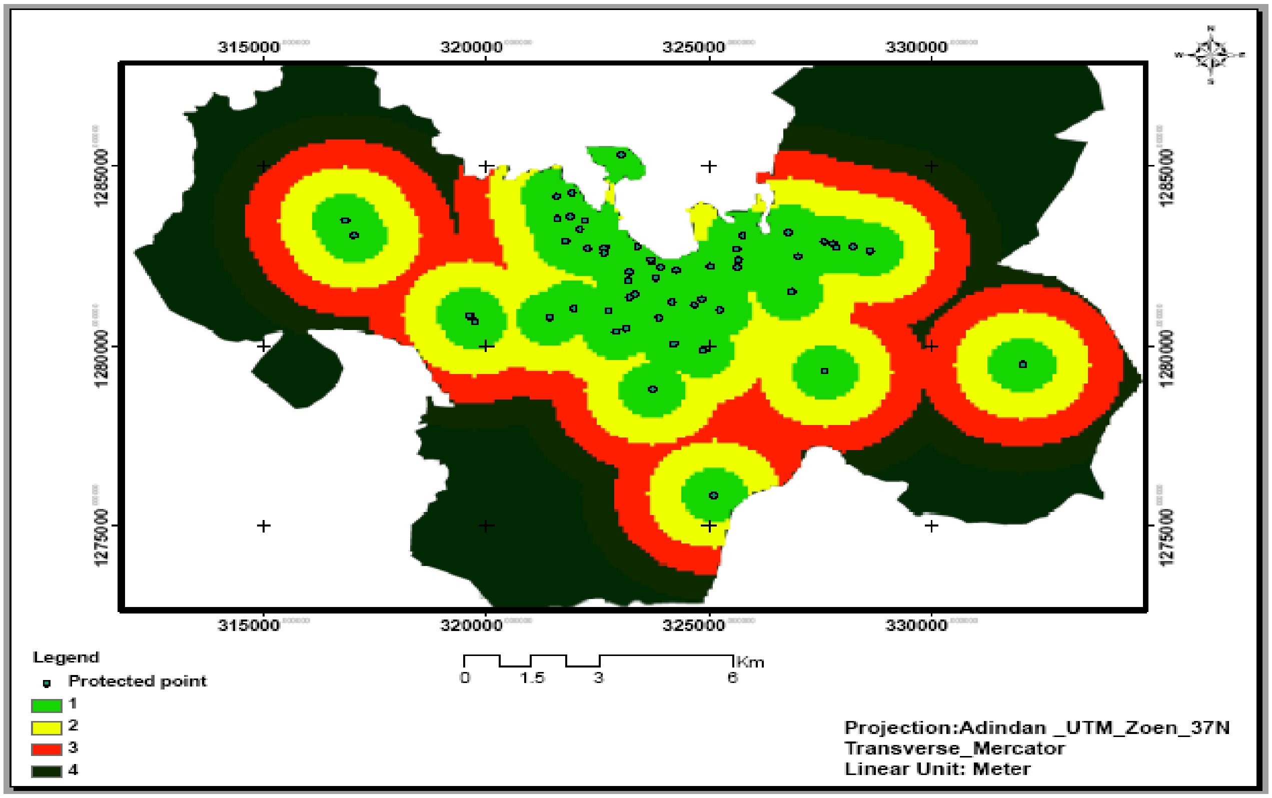

Figure 6. Reclassified distance from the protected area.

Table 5. Slope class with respective suitability levels.

Slope (%)	Level of suitability	Value	Area	Percent of total area (%)
<10	High suitable	4	19263	90.7
10 - 15	Moderate suitable	3	891	4.2
15 - 20	Less suitable	2	479	2.3
20 >	Unsuitable	1	598	2.8

Suitability of settlement

The safe distances from settlements are determined as 7000 m for urban centers and 3000 m for rural villages. Like other criteria, settlement areas were classified according to their suitability. The study considered the reclassified distances as unsuitable from 0 to 2500 m, less suitable between 2500 and 4500 m, suitable from 4500 to 5500 m and most suitable from 5500 to 7000 m for the urban areas. And for rural settlement according to Akbari (2011) 3000 m were put as criteria around the rural settlement. This distance was reclassified as unsuitable, 0 to 500 m, less suitable, 500-1000, moderate suitable from 1000 to 1500 m and most suitable area from 1500 to 2000 m. In the study area, the unsuitable area covered the highest share as compared to other level of suitability. It covers 45% of the total area. The class values were given based on the level of suitability from the lowest to the most suitable area used at the time of weighted over lay (Tables 6, 7, Figures 8 and 9). The location of solid waste sites for rural and urban areas were in opposite direction and required the other additional information to deterime the site.

Overlaying and identifying suitable sites

The site selection for solid waste disposal dumping site involves comparison of different options based on environmental, social and economical impact. Hence, based on

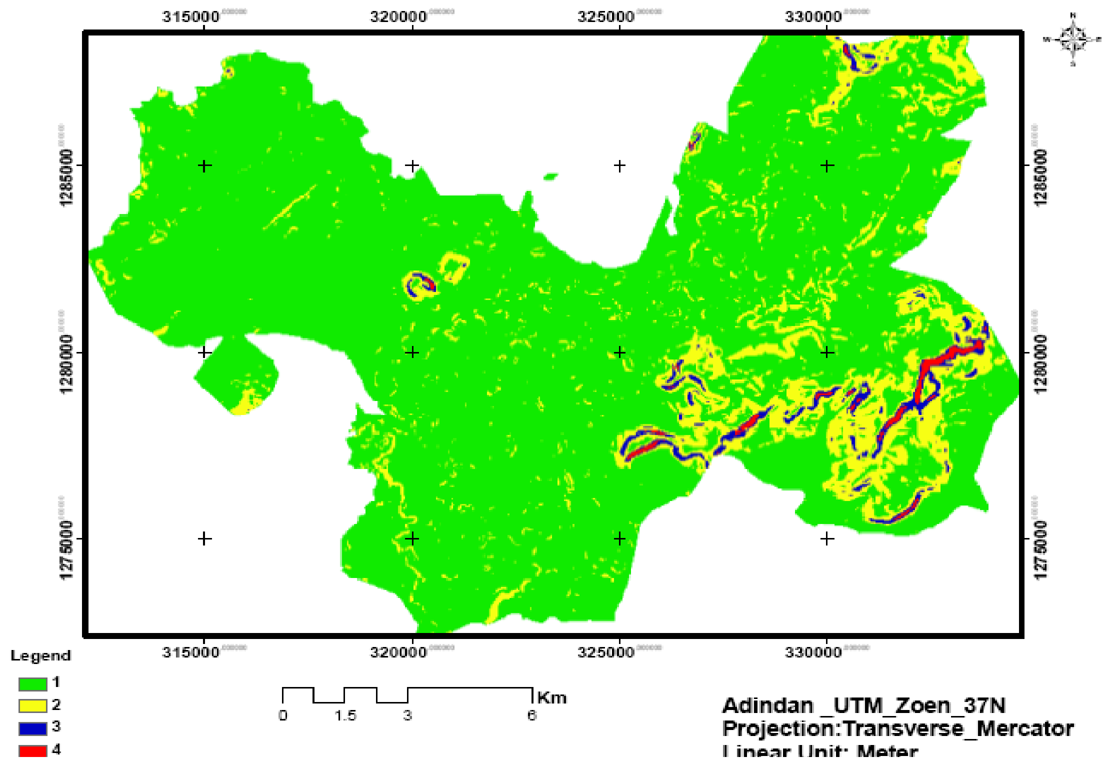

Figure 7. Reclassified slope.

Table 6. Distance from urban center and coverage suitability levels.

Distance from Urban center	Level of suitability	Value	Area(ha)	Percent of total area (%)
0-2500	Unsuitable	1	8633	47.5
2500-4500	Less suitable	2	6129	29.1
4500-5500	Moderate suitable	3	5326	12.9
5500-7000	High suitable	4	1267	10.5

Table 7. Distance from rural settlement and coverage suitability levels.

Distance from rural settlement	Level of suitability	Value	Area	Percent of total area (%)
0-750	Unsuitable	1	12150	45.0
750-1500	Less suitable	2	5044	21.8
1500-2250	Moderate suitable	3	2420	13.8
2250-3000	High suitable	4	1741	19.4

experience and likely impact on surrounding environment, different weights were assigned to all the parameters. The larger the weight, the more important is the criterion in the overall utility. The weights were developed by providing a series of pair wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. The procedure by which the weights were produced follows the logic deve-loped by Saaty (1980) under the Analytical Hierarchy Process (AHP). Weight rates were given based on pair wise comparison 9 point continuous scale (Table 8). These pair wise comparison were then analyzed to produce of

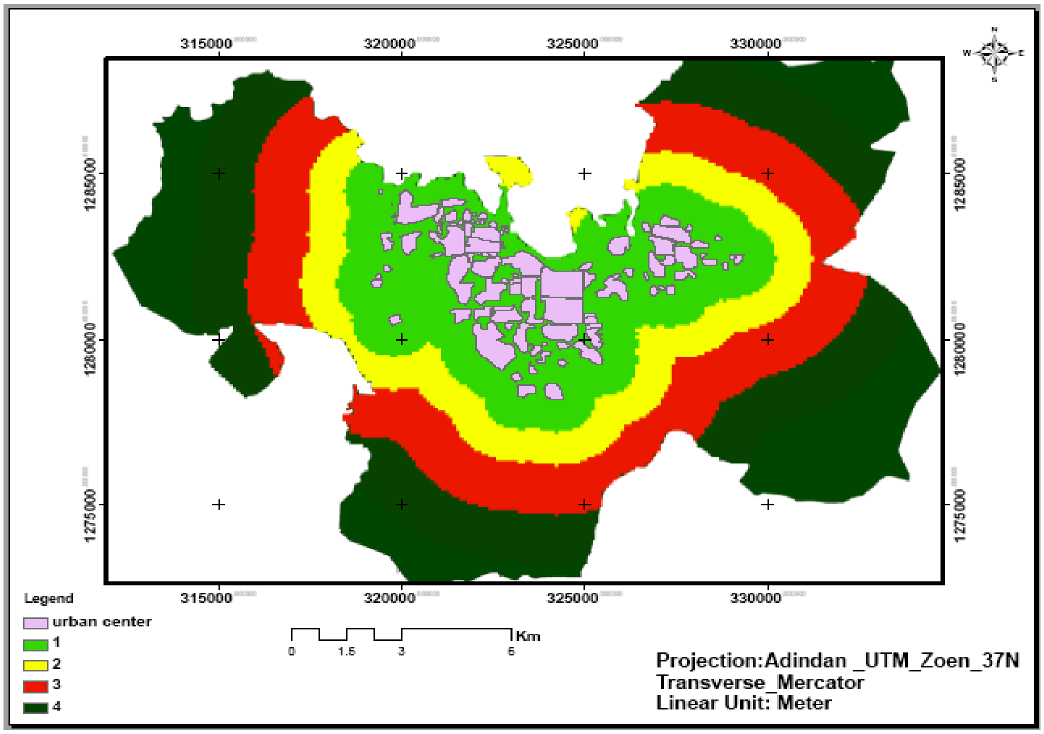

Figure 8. Reclassified distance from urban center.

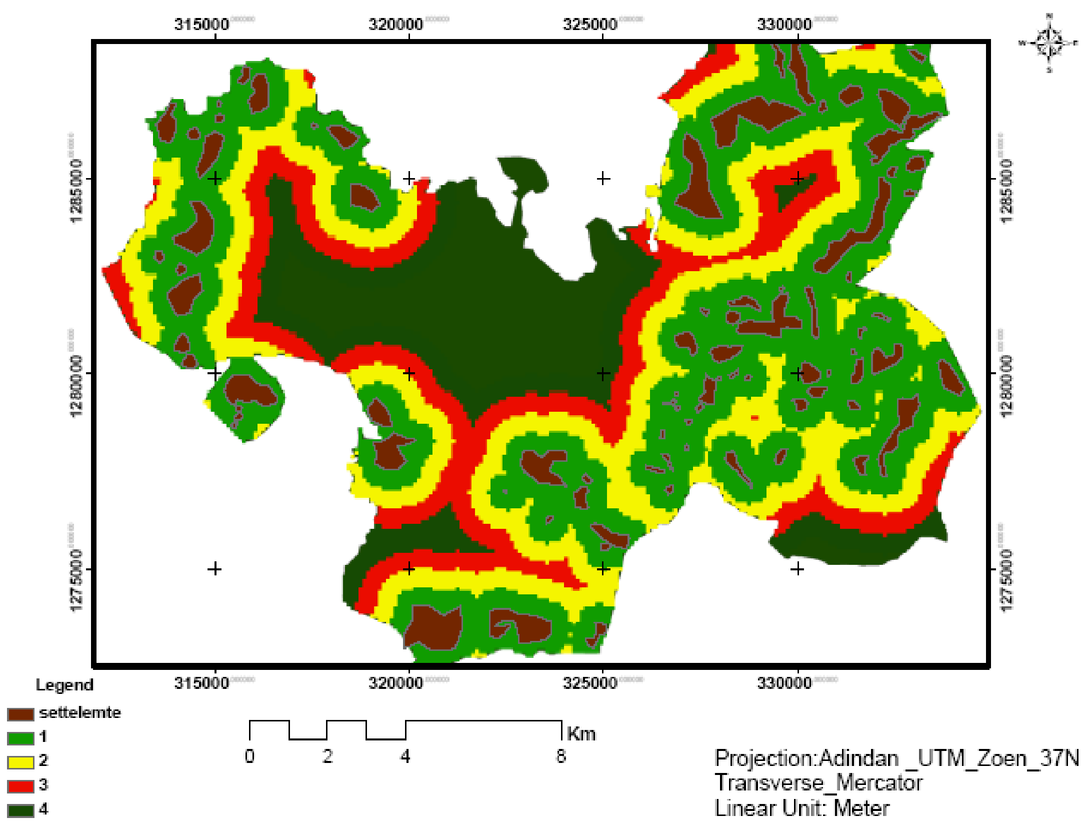

Figure 9. Reclassified distance from the rural settlement area.

Table 8. Pair wise comparison in 9 point continuous scale.

	Less important								More important
	Land use/land cover	**Urban center**	**Rural settlement**	**Protected area**	**Road**	**River**	**lake**	**Slope**	**Airport**
Land use/land cover	1								
Urban center	1/2	1							
Rural settlement	1/3	1//2	1						
Protected area	1/4	1/3	1/2	1					
Road	1/5	1/4	1/3	1/2	1				
River	1/6	1/5	1/4	1/3	1/2	1			
Lake	1/7	1/6	1/5	1/4	1/3	1/2	1		
Slope	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	

1/9, Extremely; 1/7, very strongly; 1/5, strongly; 1/3, moderately; 1, equally; 3, moderately; 5, strongly; 7, very strongly 9, extremely.

Table 9. Weights derived by calculating the principal eigenvector of pair wise comparison matrix.

Factor	Eigenvector weight	Percentage (%)
Land use /land cover	0.3210	32.1
Urban center	0.2201	22.01
Rural settlement	0.1538	15.38
Protected area	0.1063	10.63
Distance from road	0.0730	7.3
Distance from river	0.0493	4.93
Distance from Lake	0.0341	3.41
Slope	0.0241	2.41
		100.0

Consistency ratio = 0.03, consistency is acceptable.

weights that sum to 1 (Table 8). The factors and their resulting weights were used as input for the multi criteria evaluation (MCE) module for weighted linear combination of overlay analysis.

According to Lawal et al. (2011) if the consistency ratio is less than or equal to 0.1, it signifies acceptable reciprocal matrix. The consistency ratio of this study indicated that 0.03 was acceptable (Table 9). In order to combine all the layers to process overlay analysis, standardization of each data set to a common scale of 1, 2, 3, 4 (value 1 = unsuitable (restricted), value 2 = less suitable, value 3 = moderately suitable, value 4 = highly suitable) was performed. Finally, all the parameters were weighted with their respective percent of influence and overlay to produce the suitability map. The factors, their values and weights are summarized in Table 10. According to the degree of importance, they have the role of selecting suitable solid waste dumping site. After the overlay analysis of the given factors the following suitable solidwaste dumping site map was produced (Figure 10).

The final map (Figure 10) has four colors (classes): yellow, green, blue and violet. The most suitable area for solid waste dumping site is marked by yellow color shaded (class 4). Out of the total area of the study site, about 11.9% (2528 ha) fall under this category. The green color represents moderate suitable area (3) and it cover an area of 21.8% (4644 ha). The area which is shaded by blue color covers 1.3% (273 ha) representing less suitable class and the remaining 65% (13836 ha) under unsuitability class and the value is 1 (Table 11).

By using the stated criteria, the suitable areas for solid waste dumping site fall on the eastern and southern west direction from the town (Figure 10). The selected site areas are significantly at the optimum distance from Lake Tana and River Abay and from major roads. The areas were most suitable for solid waste dumping site. Similarly, Babalola and Busu (2010) and Al-Hanbali et al. (2011) suggested that selecting the optimum site for solid waste dumping may facilitate transportation and reduce the cost of transport. Moreover, suitability, for slope

Table 10. Weight of suitable solid waste dumping site selection factors.

Factor	Class	Value	Level of suitability	Influence (%)
Land use	Pound/water body/wetland	1	Very low	32.1
	Built-up, agricultural area, vegetation area	2	Low	
	Bush land	3	Moderate	
	Bare land and grass land area	4	Highly	
Distance from Urban settlement	0-2500	1	Unsuitable	22.01
	2500-4000	2	Suitable	
	4000-5500	3	Moderate suitable	
	5500-7000	4	Highly suitable	
Rural settlement	0-500	1	Unsuitable	15.38
	500-1000	2	Suitable	
	1000-1500	3	Moderate suitable	
	1500-2000	4	Highly suitable	
Protected area	0-1000	1	Unsuitable	10.63
	1000-2000	2	Suitable	
	2000-3000	3	Moderate suitable	
	>3000	4	Highly suitable	
Road	0-500	1	Unsuitable	
	500-1000	2	Suitable	
	1000-1500	3	Moderate suitable	
				7.3
	1500-2000	4	Highly suitable	
Distance from road				
Distance from River	0-1000	1	Unsuitable	4.93
	1000-1500	2	Suitable	
	1500-2000	3	Moderate suitable	
	>2000	4	Highly suitable	
Distance from Lake	0-1000	1	Unsuitable	3.41
	1000-1500	2	Suitable	
	1500-2000	3	Moderate suitable	
	>2000	4	Highly suitable	
Slope	<10	4	Highly suitable	2.41
	10-15	3	Moderate Suitable	
	15-20	2	Suitable	
	20>	1	Unsuitable	

analyses had shown that slope less than 10% are more suitable in order to minimize environmental impacts. The second suitable selected site is indicted by letter “B”. Similar to findings of Sener et al. (2011), the suitable area

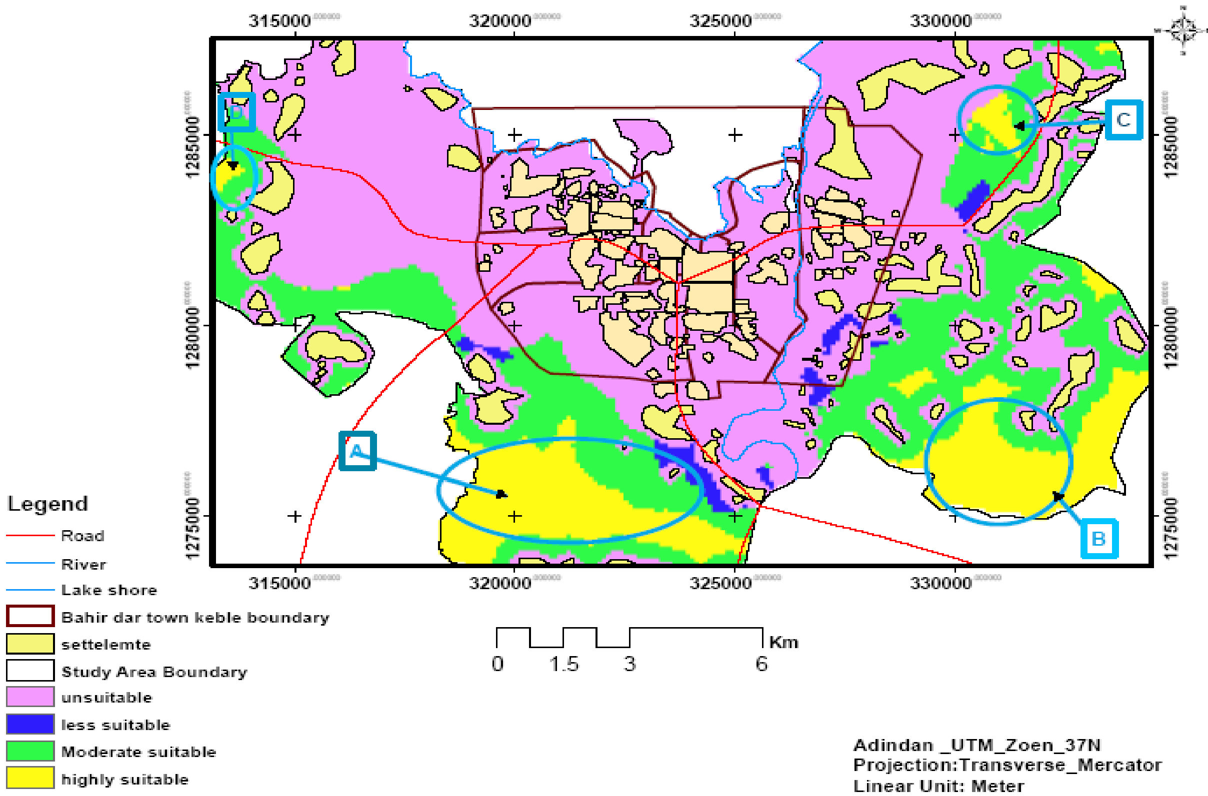

Figure 10. Final suitability map.

Table 11. Suitability area level of suitability and the percent of total area coverage.

Level of suitability	Range of score	Area (ha)	Percent of total area coverage
Unsuitable	Class 1 (yellow)	13836	65
Less suitable	Class 2 (blue)	273	1.3
Moderate suitable	Class 3 (green)	4644	21.8
Highly suitable	Class 4 (violate)	2528	11.9

was far away from settlement and urban center, and is covered by grass lands.

Conclusion

The findings have shown the ability of GIS and remote sensing as a veritable tool for analysing the criteria for decision support. The analysis has taken land use, slope, water sources, settlement and transport facilities as determining factor in order to find appropriate site for solid waste dumping site. The results have shown that four sites were selected as the most suitable. The sites are easy to access; manage for disposal of solid wastes. These places are far way from any water sources and other variables put into analysis. They are located in southern and south east of the town and are dry agricultural areas, bare land and grass land with 0-10% slope. Hence, the capacity to use GIS and remote sensing technology for the effective identification of suitable solid waste dumping site will minimize the environmental risk and human health problems.

REFERENCES

Abul S (2010). Environmental and health impact of solid waste disposal at mangwaneni dumpsite in Manzini: Swaziland. J. Sustain. Dev. Afr. 12(7):1520-5509.

Akbari D (2011). Appointment of appropriate sites for waste disposal by GIS. Marrakech, Morocco.

Al-Hanbali A, Alsaaideh B, Kondoh A (2011).Using GIS-based weighted linear combination analysis and remote sensing techniques to select optimum solid waste disposal sites within Mafraq City, Jordan. J. Geogr. Inf. Sys. 3(2): 267-278.

Babalola A, Busu I (2010). Selection of landfill sites for solid waste

treatment in Damaturu Town-Using GIS Techniques. University Technology Malaysia, Johor state, Malaysia.
Baban SMJ, Flannagan J (1998). Developing and implementing GIS assisted constraints criteria for planning landfill sites in the UK. Plan. Pract. Res. 13(2):139-151.
Babatunde BB, Vincent-Akpu IF, Woke GN, Atarhinyo E, Aharanwa UC, Green AF, Isaac-Joe O (2013). Comparative analysis of municipal solid waste (MSW) composition in three local government areas in Rivers State, Nigeria. Afr. J. Environ. Sci. Technol. 7(9):874-881.
Bringi SD (2007). Application of 3D principles to solid waste management on the Asian Institute of Technology (Ait) Campus. Unpublished M.Sc. Thesis.Indonsia.
Chang N, Parvathinathan G, Breeden JB (2008). Combining GIS with fuzzy multi criteria decision-making for landfill sitting in a fast-growing urban region. J. Environ. Manage. 87(1):139-153.
CSA (Central Statistical Authority) (2007). Summery and statistical report of the population and housing censes result. Addis Ababa, Ethiopia.
Dagmawe N (2007). In depth investigation of relationship between index property and swelling characteristic of expansive soil in Bahir Dar. Unpublished MSC Thesis, Eurohazcon. Collaboration Addis Ababa University.
Degnet A (2008). Determinants of solid waste disposal practices in urban areas of Ethiopia: a household-level analysis. East Afr. Soc. Sci. Res. Rev. 24(1):1-14.
Elmira S, Behzad N, Mazlin BM, Ibrahim K, Halima T, Saadiah H (2010). Urban solid waste management based on geoinformatics technology, University Putra Malaysia, Malaysia. Environmental Engineering and Management Program School of Environment, Resources and Development -SERD.
Emun GM (2010). Multi criteria approach for suitable quarry site selection in Addis Ababa using remote sensing and GIS. Unpublished M.Sc. Thesis, Addis Ababa University, Ethiopia.
Ersoy H, Bulut F (2009).Spatial and multi-criteria decision analysis-based methodology for landfill site selection in growing urban regions Karadeniz Technical University, Trabzon. Turk. Waste Manage. Res. 7(4):56-67.
Hammer G (2003). Solid waste treatment and disposal: effect on public health and environmental safety. Biotechnol. Adv. 22:71-79.
Higgs G (2006). Integrating multi-criteria techniques with geographical information systems in waste facility location to enhance public participation, Wales. Retrieved on 9(07) 2012: http://www.epa.sa.gov.au/pdfs/swlandfill.pdf
Lawal DU, Matori A-N, Balogun A-L (2011). A Geographic Information System and multi-criteria decision analysis in proposing new recreational park sites in Universiti Teknologi Malaysia. Mod. Appl. Sci. 5(3):79-86.
Leao S, Bishop I, Evans D (2001). Spatial-temporal model for demand and allocation of waste landfills in growing urban regions. Comput. Environ. Urban Syst. 28(2004):353-385.
Saaty TL (1977). A scaling method for priorities in hierarchical structures. J. Math. Psycho. 15:231-281.
Saaty TL (1980). The analytic hierarchy process, Mcgraw-hill. New York.
Sener S, Sener E, Nas B (2011). Selection of landfill site using GIS and multicriteria decision analysis for Beysehir Lake Catchment Area Konya, Turkey. J. Eng. Sci. Des.1(3):134-144.
Sha' Ato R, Aboho SY, Oketunde FO, Eneji IS, Unazi G, Agwa S (2007). Survey of solid waste generation and composition in a rapidly growing urban area in central Nigeria. Waste Manage. 27: 352-358.
Visvanathan C, Glawe U (2006). Domestic solid waste management in south Asian countries. A comparative analysis.
Wiley J, Sons L (2009). Essential image processing and GIS for Remote Sensing. Imperial College London, UK.