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Research Article

GIS and Remote Sensing Based Suitable Site Selection for Solid Waste Disposal: A Case Study of Gondar Town, North West Ethiopia

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Abstract

Solid waste dumping is a severe problem in the Gondar town since the majority of solid wastes generated are not dumped in an appropriate area. The most important objective of this study was to select appropriate disposal site which is cost-effective, environmentally sound and communally satisfactory in Gondar town by using remote sensing, geographic information system and over lay methodology. In the present study, the factor maps used such as slope, road, river, land use/land cover, and geology and were reclassified in GIS environment followed by preparation of their aptness map. Even if the degree of weight to each factors vary, the factors were considered very significant and compulsory in the selection of suitable sites for solid waste disposal. Finally suitability map was prepared by overlay analyses on ArcGIS platform based on over lay investigation to choose appropriate solid waste disposal sites and leveled as suitable and unsuitable. In general, the selection of highly suitable sites needs additional geotechnical and hydro-geological analyses to make certain conformity with stringent standards required for design and construction of capability.

Keywords: Solid waste disposal site, geographic information system, remote sensing, Gondar, Ethiopia.

Introduction

Population growth, fast urbanization, a booming economy, and also the increase in standards of living in a very community have well increased the speed of municipal solid waste generation in developing countries (Deng and Englehardt 2006; Koshy *et al*., 2007; Minghua *et al*., 2009; Eggen *et al*., 2010). Municipalities, usually to responsibility for the management of waste within the cities, have the challenge to afford associate degree economical and effective system for the inhabitants. In recent years, many of analysis studies and papers are done to specify helpful and influential factors moving the waste management system in cities of developing countries. The elementary goals of solid waste management methods are to handle the aesthetic, land use, economic considerations, health and environmental aspects connected with the inappropriate disposal of waste (Henry *et al*., 2006; Nemerow, 2009). In developing countries, waste is generated by growing cities is devastating domestic authorities and also the federal government in a very similar method (Yousif and Scott, 2007; Tacoli, 2012). Such waste disposal creates severe environmental issues that have an effect on the welfare of humans and animals and produce concerning serious economic and welfare losses.

Additionally, the environmental deterioration caused by shy disposal of waste will contaminate surface and groundwater through leaky of the leachate, soil contamination through direct waste association or leachate, pollution by open burning of wastes, spreading of infectious diseases by numerous vectors like insects, birds and rodent, or uncontrolled unleash of methane gas by anaerobic decomposition of waste everywhere the cities (Jankowski and Nyerges 2001; Jilani *et al*., 2002; Hammer, 2003; Visvanathan and Glawe, 2006; Khamehchiyan *et al*. 2011). The increasing population and economic activities of the Gondar town resulted in the creation of a high quantity of solid wastes. The town administration spends a giant proportion of its budget on collection, transport and disposal of wastes. Currently, there's only one open dumping site situated at eastern a part of the Fasil campus, University of Gondar, wherever all collected waste has been dumped. The majority solid waste disposal sites in Ethiopian cities and towns are established on the limits of the urban areas just about water bodies, faults, crop fields, settlements and on roads sides. Such an unsuitable disposal of solid waste leads to severe environmental contamination and health-related troubles, contagion of surface and groundwater, soil pollution through straight waste

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associates, greenhouse gas release, environmental pollution, ecology damage, damages to people and belongings, depress tourism and business actions (EGSSAA, 2009). Therefore, locating proper sites for dumping solid waste far from environmental resources, residential areas, water bodies, roads, faults and settlements is essential for the management of solid waste in a proper way. The solid wastes disposed at this site is generally from domestic, industry, markets, hospitals and business sources, which can contain leachable toxic parts like methane, hydrogen, nitrogen, sulfide and greenhouse gas. The main issues are because the waste dumping site is bordered by housing areas and institutions. Runoff and leachate from the dump site is the key source for surface water and water pollution.
Bolton and Curtis (1990) suggested the subsequent objectives to reduce the environmental collision connected with the landfill site selection: (1) landfill site should be chosen in such a way that it is suitable for the community and should be situated in such places which assist to reduce contagion and contamination connected with noise, dust, smoke, traffic, and odor; (2) the site should fulfill with preparation and expansion in the area; (3) the site should be satisfactory for progress of a waste disposal in stipulations of convenience, land vacancy, flood potential, and the life of the site; and (4) the ecosystem of the site should not be considerably distorted. Special deliberation must be given to the biodiversity and individuality of the area; (5) public healthiness and protection is also significant issue which should be taken into account. The groundwater contamination hazard must be reduced to defend portable water provisions and (6) the site must be suitable for operation and maintenance in stipulations of the accessibility of cover matter and ease of machinery operation. To select a protected site for solid waste disposal isn't a straightforward mission. However, incorporating Geographical Information System (GIS) and Remote Sensing is the best tool in choosing environmentally sound and socially adequate disposal site/s with actual exactness cost and time with efficiency. In recent years, organizing the vast quantity of solid waste produced has become a major apprehension, and in this regard, GIS has established to be a benefit for planners. Remote sensing can provide information about the various spatial criteria such as land-use/land-cover, drainage, geology, elevation and slope etc., Whereas, GIS can be used to utilize, creating and analyzing spatial or attribute data for the solid waste dumping site selection process. Remote sensing and GIS can be used for the identification of sites for disposal of solid waste (Natesan and Suresh, 2002; Padmaja *et al.*, 2006; Twumasi *et al.*, 2007; Sumathi *et al.*, 2008; Emun, 2010; Adeofun, 2011; Saxena and Srivastava, 2011; Sener *et al.*, 2011). One of the advantages of GIS is its capability for dumping site choice; select the dumping siting is advanced, tedious and expensive because it needs multiple criteria from surroundings, social and economic point of reading. Moreover, landfill siting may be a difficult method requiring elaborated assessment over a huge space to spot a suitable location for constructing a dump selection subject to several completely different criteria (Chang *et al.*, 2008). Geographic system application will facilitate in determining the dump location in accordance with technical necessities, with associate degree overlay thematic map to induce applicable landfill. So considering the above facts in view, the present study focused on incorporating GIS and Remote Sensing strategies to pick out appropriate solid waste disposal site exploitation different terrain connected factors in Gondar town.

Materials and methods

Study area: The study area is located at the northwestern part of the country at a distance of 727 km from the capital city, Addis Ababa. The study area is located in between North latitudes 12° 29' 45" and 12° 31' 29" and East longitudes 37°23' 52" and 37°30' 11" (Fig. 1). The study area covers 310 km^2. The mean above sea level elevation of the study area is ranging from 1870 to 2550 m above sea level is shown in Fig. 2. The drainage basin is an area of land drained a river and tributaries. The main stream, Shinta which is in the west of the study area flows from north to south. All other smaller tributaries flow towards this main stream and towards Keha River in the eastern part of the study area that flows north to south and enter in to Megech River with Shinta River. The drainage system of the study area has been mapped using Landsat- 8 and ASTER DEM satellite images (Fig. 1).

Fig. 1. Location map of the study area.

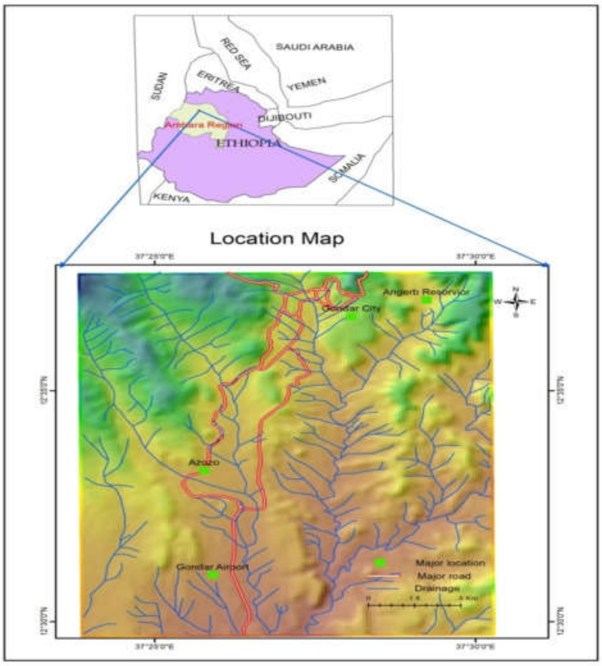

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Table 1. Weight and score of different thematic layers and its classes.

S.No.	Theme	Weight (Wt)	classes	Score (Sc)	Wt x Sc
1.	Lithology	10	Slightly weathered Aphanitic basalt	8	80
			Amogyloidal and vesicular basalt intercalation	6	60
			Moderately weathered Aphanitic and Porphyritic basalt	4	40
			Alluvial deposits	2	20
2.	Land use/ Land cover	8	Land without scrub	8	64
			Land with scrub	6	48
			Crop land and forest	4	32
			Barren hill, Settlement and Water body	2	16
3.	Slope in degrees	6	0 – 6.41 in degree	7	42
			6.42 – 13.58	5	30
			13.59 – 32.08	3	18
4.	Distance from the drainage	4	200m drainage buffer	2	8
			Other area	0	0
5.	Distance from the road	2	100 m road buffer	4	8
			Other area	0	0

Experimental design: The present study considered factors like lithology, land use/land cover, slope, drainage and road. The above-named data sets were prepared from remotely perceived and conventional information. The ArcGIS software package was used to process satellite image digitize conventional maps and satellite image and overlay thematic layers. The weights and score were assigned to the individual themes and their options respectively. The weight and score were assigned to the above said thematic layers and its classes and the same values were multiplied in order to identify the suitable site for the waste disposal in the study area. The assigned weight and score and final weight and multiplied weight and score are shown in Table 1. The weighed overlay analysis was performed in ArcGIS to get the suitability map. Weighted overlay analysis combines multiple themes inputs, representing multiple classes of different weights and scores. The higher weights and scores were assigned to the selected themes and its classes according to their importance in waste disposal site selection. For example, high weights were given to the lithology theme. On the contrary, low weights were given the distance from the roads and drainage. Finally, using the overlay method the suitable sites for solid waste dumping within the study area was identified; the study area was classified into a suitable and non-suitable area for solid dumping solid waste. The Advanced Space-borne emission and Reflection Radiometer-Digital Elevation Model (ASTER DEM) with the 30-m resolution is used to extract elevation, slope and drainage network. Topographic maps from the Ethiopian Mapping Agency (EMA) are used to alter road networks. Cloud-free Landsat 8 (Optical Land Imager) image was used to produce the land use/ land cover.

Results and discussion

There were five themes used when identifying the suitable landfill site in the study area. These were geology, land use/land cover, slope, distance from drainages and distance from road network. Discussion of each theme explained below in detailed.

Lithology: In Landfills site selection, the geological uniqueness and structures of the regions are very vital. The geology of Ethiopia comprises a mixture of ancient crystalline basement rocks, volcanic rocks associated with the East African Rift system, and sediment of various ages. Initially, the lithology map was prepared for the study area in GIS environment from the map published by the Geological Survey of Ethiopia. Further, the Landsat-8 OLI satellite image was used to refine the lithological contacts and updated lithology map (Fig. 2) was prepared for the study area. The major lithological units in the study area are Amogyloida land vesicular basalt intercalation and covered by (72 sqkm of areal extent and 43% of total study area), Slightly weathered Aphanitic basalt and covered by (29 sqkm of areal extent and 17% of total study area), Moderately weathered Aphanitic basalt and covered by (36 sqkm of areal extent and 21% of total study area), Moderately weathered Porphyritic basalt and covered by (24 sqkm of areal extent and 14% of total study area) and Alluvial deposits and covered by (9 sqkm of areal extent and 5% of total study area).Choosing a site with a good impermeability protects the soil and aquifers against contamination from leachate. The assigned weight and scores to the lithology theme for identification of suitable site for waste disposal site is shown in Table 1.

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Fig. 2. Lithology map.

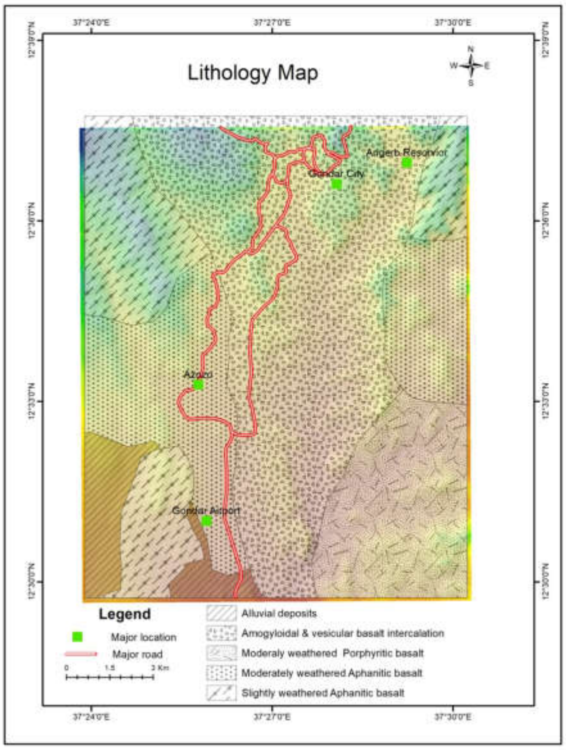
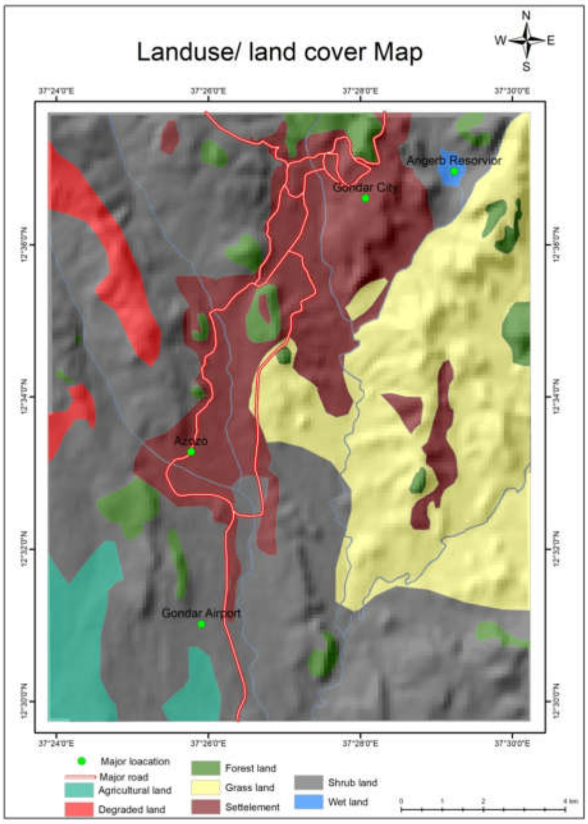


Fig. 3. Land use/Land cover map.



Land use/ Land cover: The land cover of the study area was analyzed from the Landsat-8 OLI satellite image and Google earth image also. By reviewing different literature, it was advisable to select land, which was occupied by land without scrub and land with scrubs for solid waste disposal. It is significant to make sure the comfort of the people living around the landfill and to defend them from damage that can be reasoned by the landfill: the smells, the flights of plastic bags and paper, animals (birds, rodents and insects), fire, the sound of trucks and compacting machines, etc. The study area land use/ land cover map is shown in Fig. 3 and assigned weight and score is shown in Table 1.

Elevation and slope: The elevation map was prepared from the ASTER Digital Elevation Model (DEM) (Fig. 4). The minimum and maximum elevation (in meters) of the study area is 1870 m and 2550 m accordingly. The slope was estimated from the ASTER Digital Elevation Model (DEM). Accordingly, the slope in degree map was prepared and classified into three slope classes the same is shown in Fig. 5. If the slope is too sharp, it would be hard to construct and dig the landfill components and would also contact the water drainage. Contaminants can therefore journey a better distance from the containment region (Higgs, 2006). The lower degree of slope is extremely appropriate location for waste disposal site than the higher degree of slope. In the study area the land with a slope class (0–6.41°) is highly suitable for solid waste dumping. Accordingly scores were assigned to the slope theme (Table 1).

Fig. 4. Elevation map.

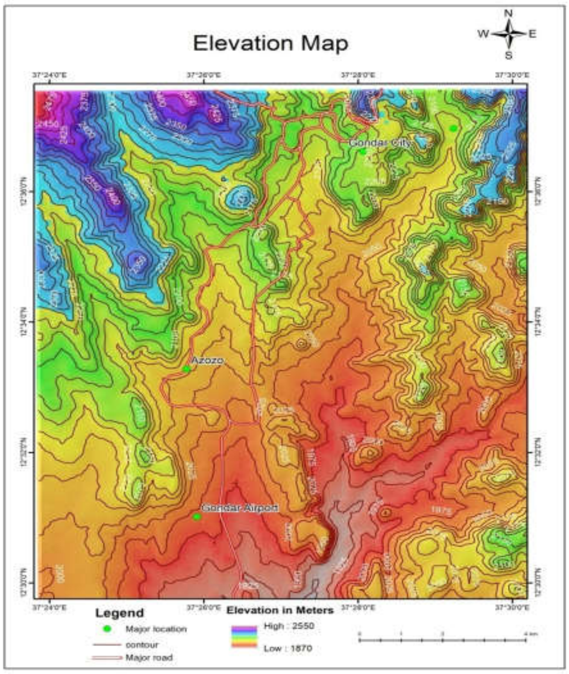


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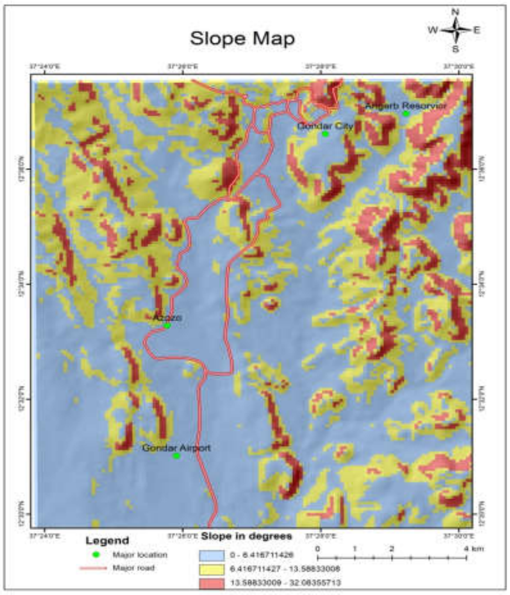
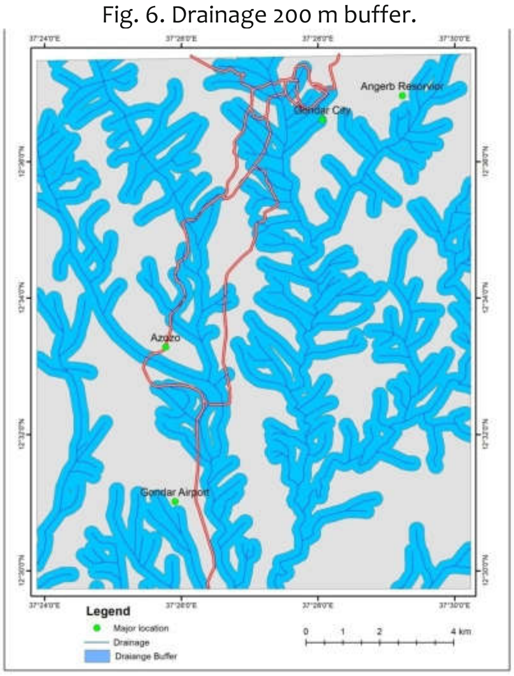
Fig. 5. Slope map.



Distance from the drainage: The study area drainage pattern was extracted from the SRTM DEM using Arc hydro tools in the GIS environment. The same was also updated with ETM and Google earth satellite imagery and the final drainage map is shown in Fig. 8. No landfill site should be sited within the drainage. Hence, buffer of 200 m (Fig. 6) were applied to the drainage to prevent the pollution from blown debris and runoff from the waste disposal site to the drainage. The assigned weight and scores to the drainage buffer theme for identification of suitable site for waste disposal site is shown in Table 1.

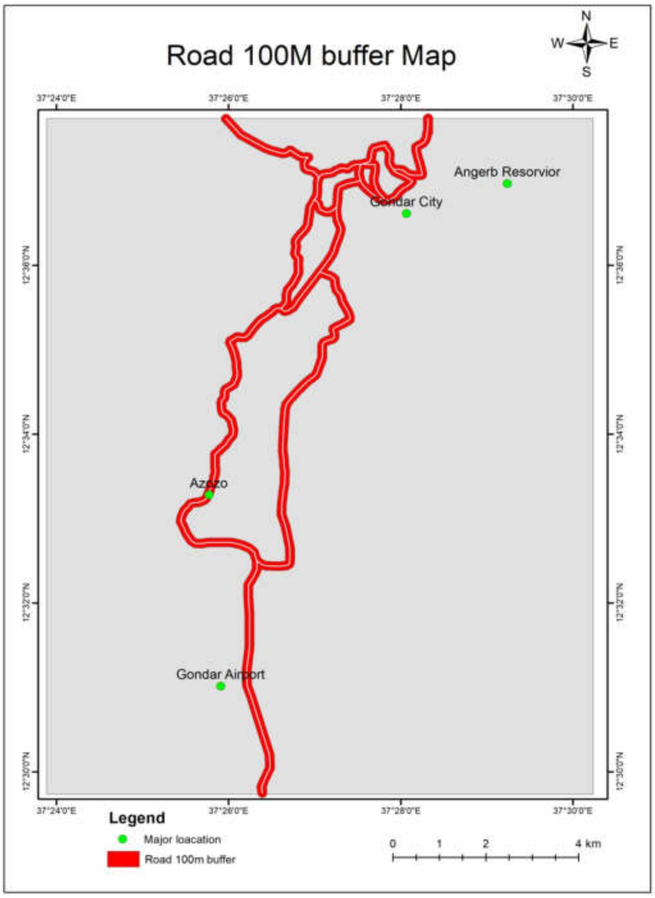
Fig. 6. Drainage 200 m buffer.



Distance from transportation routes: The landfill site should not be placed too far away from existed road networks, to avoid the expensive cost of constructing connecting roads. And the waste disposal areas should not be too close to the road networks (Sener *et al*. 2006; Nas *et al*., 2010). Therefore, a 100 m buffer zone is applied to road (Fig. 7). The assigned weight and score to this theme is shown in Table 1.

Overlaying the themes and identifying suitable waste dumping sites: The site selection for solid waste disposal dumping site involves comparison of different options based on environmental, social and economic impact.

Fig. 7. Road 100 m buffer map.



Hence, based on experience and likely impact on surrounding environment, different weights and scores were assigned to all selected themes and its classes. The larger the weight, the more important is the criterion in the site suitability analysis. After the overlay analysis was done in the GIS environment of the given themes and the suitable solid waste dumping site map was produced (Fig. 8). The site suitability map is showing suitable and un-suitable areas for waste site disposal in the study area.

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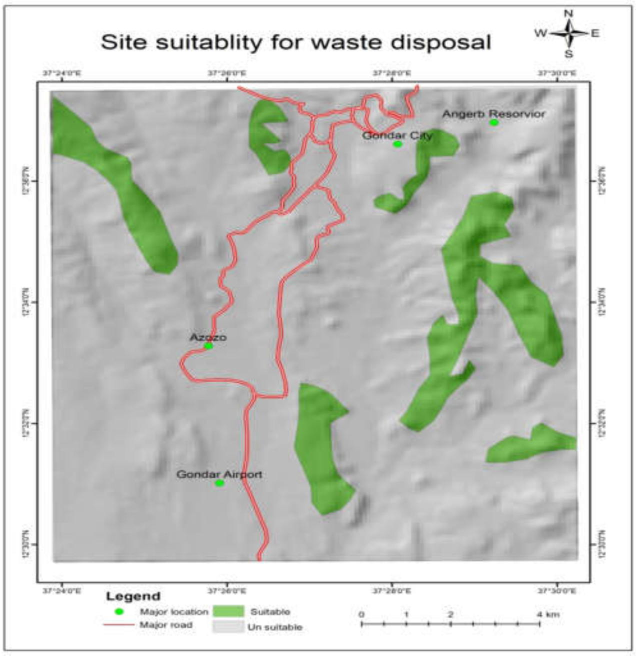
Fig. 8. Site suitable for waste disposal.



Conclusion

Selection of disposal sites for solid wastes generated in the urban area has forever remained a large mission as the selected site should not be affecting the environment harmfully. The methodology adopted in this study described the GIS and weighted overlay process techniques for the selection of suitable sites for the disposal of municipal solid wastes in Gondar city, Ethiopia. The study shows the capability of GIS as an authentic implement for decision support. The techniques considered a number of sitting criteria ranging from lithology, land use/land cover, slope, drainage and accessibility which are very important in identifying sites which have least amount or no risk to the environment. The present study is helpful in planning for the city in future. The study also demonstrated the effectiveness of GIS in the site identification and selection process and can therefore be applied elsewhere for sitting purposes. However for final selection of the waste disposal site, site field investigation of geology, environment and other factors are highly recommended so as to consider any other factors other than the factors listed above.

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