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LANDFILL SITE SELECTION FOR MANZINI CITY, ESWATINI

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ABSTRACT

Waste management is a monumental environmental concern globally especially in developing countries. In Eswatini, a number of factors have prevented the implementation of effective waste management systems. Open dumping is a serious problem in Eswatini, even in regions or cities that have functioning landfills such as Mbabane and Matsapha. For Manzini city, which is the largest city in Eswatini, there is no functioning sanitary landfill; but an open dumping facility. This impairs the countrys' ability for sustainability as the environmental pillar, which is one of three sustainability pillars, is weakened. This necessitates the urgent need for a sanitary landfill, which this paper endeavoured to identify a suitable site. The study based the site selection procedure on Geographic Information System (GIS) integrated with Multi-Criteria Decision Analysis / Making (MCDA/MCDM) using the Analytic Hierarchy Process (AHP) methodology. The identified sites were then scored according to criteria weights to identify the most suitable site for a landfill location around Manzini. The study concluded that Manzini needs a landfill, as well as stating policy implications.

Keywords: *Landfill, Dumpsite, Waste management, Site selection, AHP, MCDA, Sustainability.*

INTRODUCTION

The most troubling environmental issues and, especially in the waste management sector, seem to have emerged in the twenty-first century due to industrialization and increasing global population growth. The growth in population results in an increased demand for essential goods and services, which in turn produced host of waste materials that need to be disposed of. This caused a monumental environmental challenge for Municipalities globally and especially in developing countries.

Municipalities in metropolitan areas play a crucial role in solid waste management. Environmental hygiene and cleanliness concerns occur if this function is not performed effectively and efficiently. More than that, solid waste management is crucial in sustainable development. This is because it touches on environmental and social pillars that constitute two of the three pillars of sustainability (Calderón Márquez et al., 2019). However, different countries have diverse waste management strategies. Lately, many developing countries are moving from managing their solid waste by dumpsites to landfills. On the contrary, a majority of the developed countries are phasing out landfills to minimizing waste production and managing the remaining waste through recycling and mechanical-biological approaches to pre-treatment that aim for zero waste (Oladejo & Otene, 2018). This implies that the challenges faced in waste management vary greatly from developing countries to developed countries. The major challenges faced by developing countries seem to revolve mainly around effective service coverage for waste collection, introduction of recycling and reusing, and, efficient waste disposal (Zurbrugg, n.d.). Krause (Krause & Townsend, 2014) points out that waste management methods in developing countries can be grouped into three categories: open burning of solid waste, open dumping of solid waste, and municipal collection for disposal of the solid waste.

Juxtaposing Eswatini with other developing countries, the major contributing factors to waste management problems, and thus, preventing the implementation of an effective waste management system are population growth, industrialization, consumer patterns and urbanization. Despite all these, Eswatini have put in place legal frameworks and ratified international conventions and treaties that aim to enhance waste management in the country. Such legislations include the Waste Regulations 2001, the Swaziland Environmental management Act of 2002, the Bamako Convention on the Ban of Import of Hazardous Wastes into Africa, and the Basel Convention on the Control of Trans- boundary Movements of Hazardous Waste and their Disposal 1989. Eswatini had also put in place a National Solid Waste Management Strategy (NSWMS) which was a long-term plan ending in 2012. The goal of the NSWMS was to implement an integrated solid waste management system (Eswatini Environment Authority, n.d).

Numerous studies globally have been undertaken on solid waste management (Haas et al., 2015; Kaur et al., 2015). The primary issue emphasised in these studies is the open dumping of waste. Notably, it is quite serious in cities in developing countries such as Eswatini. Needless to say, dumping sites worldwide are associated with various environmental and human health impacts (Kaur et al., 2015). Settlements close to dump sites are cited as areas that suffer the most from impacts of waste dumping. Eswatini is not excluded from such concerns. Open dumping is a serious problem in the country; even in the four regions and/or cities of the country that have functioning landfills such as Mbabane and Matsapha. For Manzini city, which is the largest city in Eswatini, the waste disposal method is worse. This is because the city does not have a functioning sanitary landfill. The city has an official dumping site regulated by the city's Municipality. The residents close to the dumping site such as those living in Mangwaneni, nearby Madonsa and those down at the Mzimnene River have been complaining over the years, of the nuisance, and health effects the dump site has on them (Salam & Abul, n.d.) and also the foul odour.

LITERATURE REVIEW

According to Kaur *et al.,* 2015, disposal of solid waste is becoming an alarming environmental concern because of the rapid population growth and urbanization (Bartone and Bernstein, 1993, Mehra *et al*., 1996; Eugenia et al, 2002). Approximately 60% of the waste generated ends up in dumpsites, especially in developing countries. Dumpsites, irrespective of where they are located, have a vast number of environmental effects, including being a point source of diseases, pests and vectors, plus ecological concerns (Rathi, 2006; Jha et al, 2003; Bundela *et al.,* 2010) including affecting the health of nearby residents (Kaur *et al.,* 2015). Furthermore, the leachate produced from dumpsites pollutes surface and groundwater sources as well (Bahaa-eldin *et al.,* 2010). This inadequate disposal of solid waste is what prevents most developing countries from sustainable development as solid waste management is part of the sustainable development goals. The aforementioned effects of improper waste disposal cut across the environmental, social and economic pillars of sustainability (Calderón Márquez et al., 2019).

Effects for humans living near dumpsites goes beyond causing a nuisance and polluting their water sources. Studies conducted in the Philippines, Vietnam, Cambodia and India indicate that breast milk of women living near dumpsites had a high content of dioxins such as polychlorinated biphenyls and polychlorinated dibenzo-p-dioxins (Kunisue et al., 2004; Kaur et al., 2015). Infants that are exposed to such breastmilk have been studied to have changes in thyroid hormones (Zhou et al., 2002). With all the environmental and human health impacts that dumpsites have, it is imperative to avoid it and adopt the utilization of sanitary landfills as a method of final solid waste disposal.

Although landfilling is the most common method of solid waste disposal, it is not always done right. This is the reason why emphasis is being placed on sanitary landfilling (Marin et al., 2012) which has minimum infiltration and percolation rate, thereby protecting groundwater (Ali et al., 2020). Landfills have been studied and proven to have environmental effects as well, such as leachate production that pollutes surface and groundwater (Kaur et al., 2015). However, a well-designed sanitary landfill has fewer environmental consequences when compared to dumpsites, making them a better option than open dumping of waste.

Another alternative research shows is landfill mining. Benefits of landfill mining include extending the lifespan of a landfill as well as minimizing the environmental effects that general landfills present, through recovery of valuable waste. This solution is also presented as an alternative for developing countries to satisfy multiple sustainable development goals (Calderón Márquez et al., 2019).

Sustainable landfills are also introduced to refer to landfilling that releases less greenhouse gases into the atmosphere as a result of stable waste mass disposed. Furthermore, this phenomenon states that the waste disposed in landfill has already been treated and stripped of any potential uses before the final disposal, making the waste non-potent to the environment (Tintner & Schott, n.d.).

STUDY AREA

Eswatini is a country in the Southern part of Africa lying between latitude 25° 39' and 27° 25' south and between longitudes 32° 10' and 31^{0}48’ east (Mbuende, 1997). It is a landlocked country bordered by South Africa to the South, West, and North and Mozambique to the East. It has a population of 1 093 238, which is estimated to reach 1 300 000 by the year 2030 (*2017-2038 Population Projections Based on the 2017 Eswatini Population and Housing Census Kingdom of Eswatini*, n.d.). Like the rest of the global community, Eswatini is experiencing rapid population growth.

The Kingdom of Eswatini is divided into four main administrative regions namely: the Manzini Region, Hhohho Region, Lubombo Region and the Shiselweni Region. The study area falls in the Manzini Region. The Manzini urban area was chosen because it is the largest city in Eswatini, yet having no landfill to cater for issues of waste management. Figure 1 shows the four regions of Eswatini, with a zoom in on Manzini urban area.

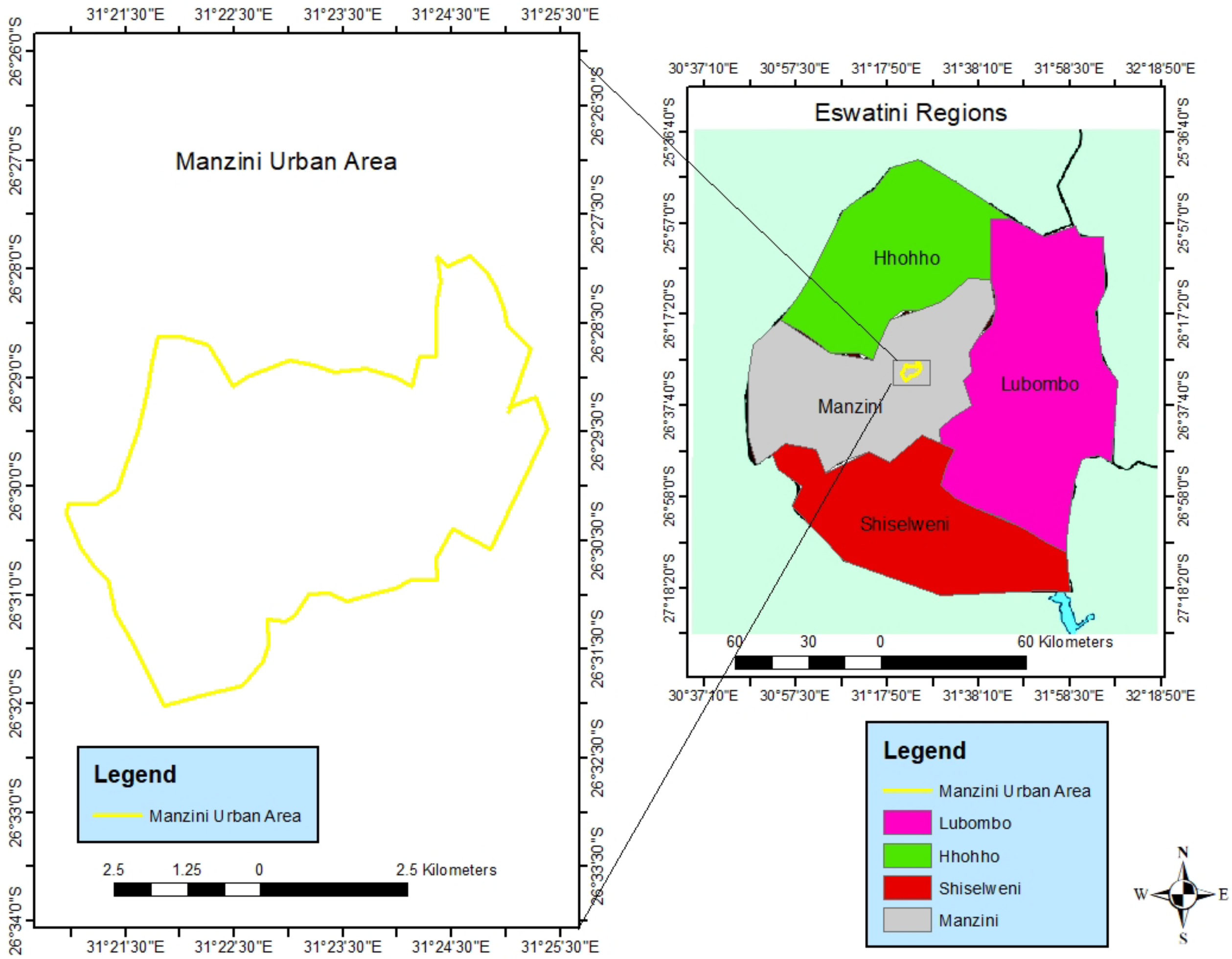

Figure 1: Map Eswatini showing Manzini city (the study area)

METHODOLOGY

Landfill site selection based on Geographic Information System (GIS) integrated with multiple-criteria decicion analysis / making (MCDA/MCDM) using the analytic hierarchy process (AHP) methodology was used (Cobos Mora & Solano Peláez, 2020). Figure 2 states the criteria that were used to assess the suitability of landfill sites. Road network, which is one of the criteria used, is imperative in landfilling because it impacts the travelling costs to and from the landfill by delivery vehicles which by extension increases carbon emissions which contributes to climate change. However, a landfill should be at least 1000m away from a main road to avoid nuisance (Rezaeisabzevar et al., 2020). A landfill is not supposed to be close to an urban area, especially the central business district (CBD). This is because of aesthetic and health reasons. A suggested distance of 10 to 15 km is considered optimal (Rezaeisabzevar et al., 2020).

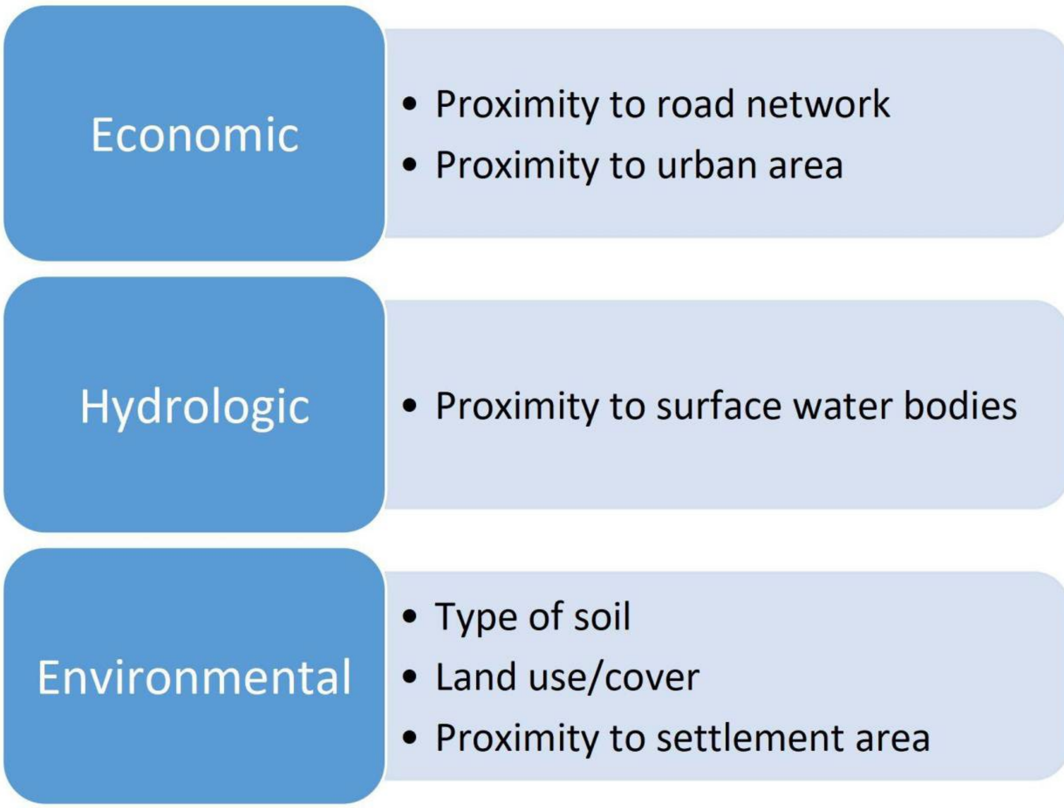

Figure 2: Criteria for landfill site selection

Settlements are areas where people live. Landfills have certain environmental and health effects such as acting as breeding ground for pests, unpleasant odours and leachate that pollutes the surrounding soil and water bodies. Therefore, landfills should not be in close proximity to human settlements. According to (Xiang et al., 2019) landfills should be at least 500m away from human settlements. The distance of a landfill from surface water bodies must not be less than 250m (Chabuk et al., 2016; Rezaeisabzevar et al., 2020). It is important that water bodies and groundwater are protected from the environmental effects of a landfill, such as the leachate.

Land cover plays a critical role mostly because it influences the costs for clearing land. Also, barren/bad land is much preferred (Chabuk et al., 2016). The type of soil plays a vital role in a landfill because it determines the water permeability of the area. Soils that is highly permeable such as *cambisols, haplic* and *gleyic solonchalks*, are unsuitable for landfilling. Soils that have medium permeability such as *molic glaysols*, *calcaric* and *eutric cambisols* are fairly suitable for landfilling. It is soils that have very low permeability that are considered the best for landfilling, such as clay, shale and *fluvisols* (Javaheri et al., 2006).

Input map layers for each criterion were accessed from the country's' Ministry of Natural Resources, Ministry of Agriculture and Eswatini National Trust Commission. These input data layers were generated from related maps by scanning and digitizing relevant information using ArcGIS and Google Earth. All the aforementioned criteria did not have the same weight or score because they were not of equal importance in selecting landfill site. Therefore, SpiceLogic AHP software was used to calculate the weights of the criteria using a scale factor of 1-9 in pairwise comparisons. The scale for pairwise comparison is as presented in table 3 (Donevska et al., 2012).

Table 1: Pairwise Comparison Scale

INTENSITY OF IMPORTANCE	DEFINITION
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values

After the pairwise comparison matrix was calculated, the values were normalized to get the criteria weight. These criteria weights revealed the hierarchy of criteria in terms of importance, with the most important criteria having the highest weight. It was however, very vital to determine the consistency ratio of the process of obtaining the criteria weights. Both these factors were calculated using the same SpiceLogic AHP software. To calculate the consistency ratio, the following formulae were used (Chabuk et al., 2016)

$$CR = \frac{CI}{RI}$$

Where; CR is the consistency ration, CI is the consistency index, and RI is the random index.

The random index depends on the number of criteria to be used, whereby each number has its own random index, as presented in table 2.

Table: 2: Random Index Scale

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The consistency index was calculated using the following formula

$$CI = \frac{max - n}{n - 1}$$

The consistency ratio must not be more than 0.1, otherwise the criteria was to be deemed non- consistent (Chabuk et al., 2016). To ensure that consistency ratio was 0.0, the Transitivity Rule was enforced on SpiceLogic AHP software, which was also used to determine the most suitable landfill site as well.

RESULTS AND DISCUSSION

Proximity to road network, urban area, settlements and surface water bodies

Figure 3 shows a map sourced from the Ministry of Natural Resources, Surveyor General. This map shows the settlements, surface water bodies, road network and boundary of Manzini urban area.

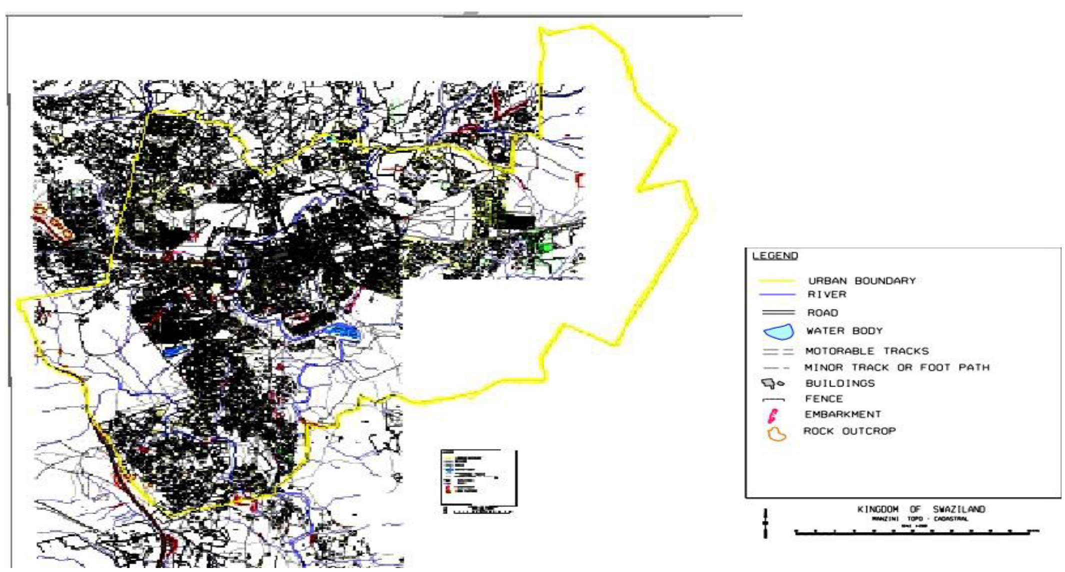

Figure 3: Settlement, water bodies, road network, urban area map of Manzini city

Figure 4 shows potential landfill sites in accordance to the boundaries obtained from literature.

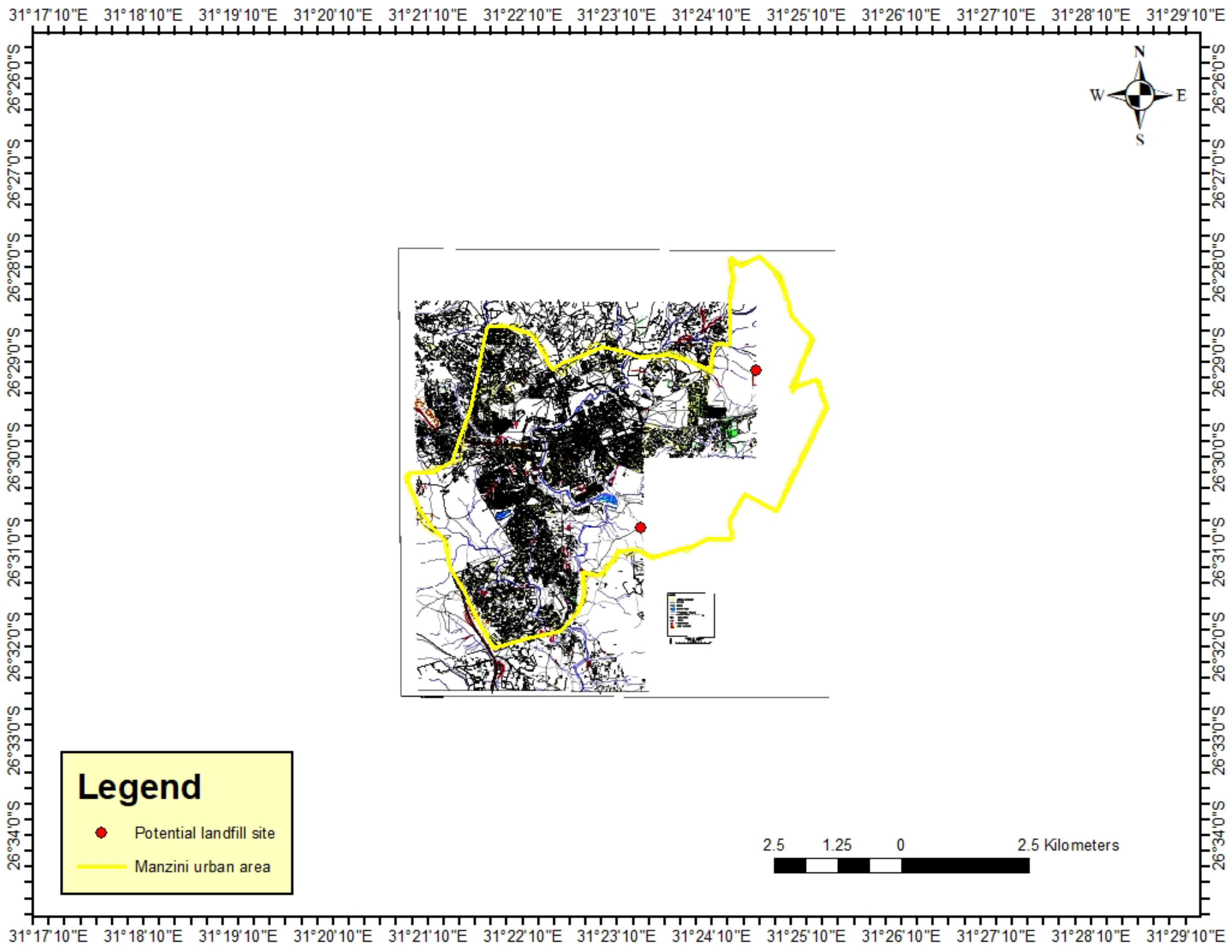

Figure 4: Potential landfill sites for Manzini based on settlement, water bodies, road network, and urban area map

Land use/land cover

Figure 5 is a land use/land cover map sourced from the Ministry of Agriculture in Eswatini.

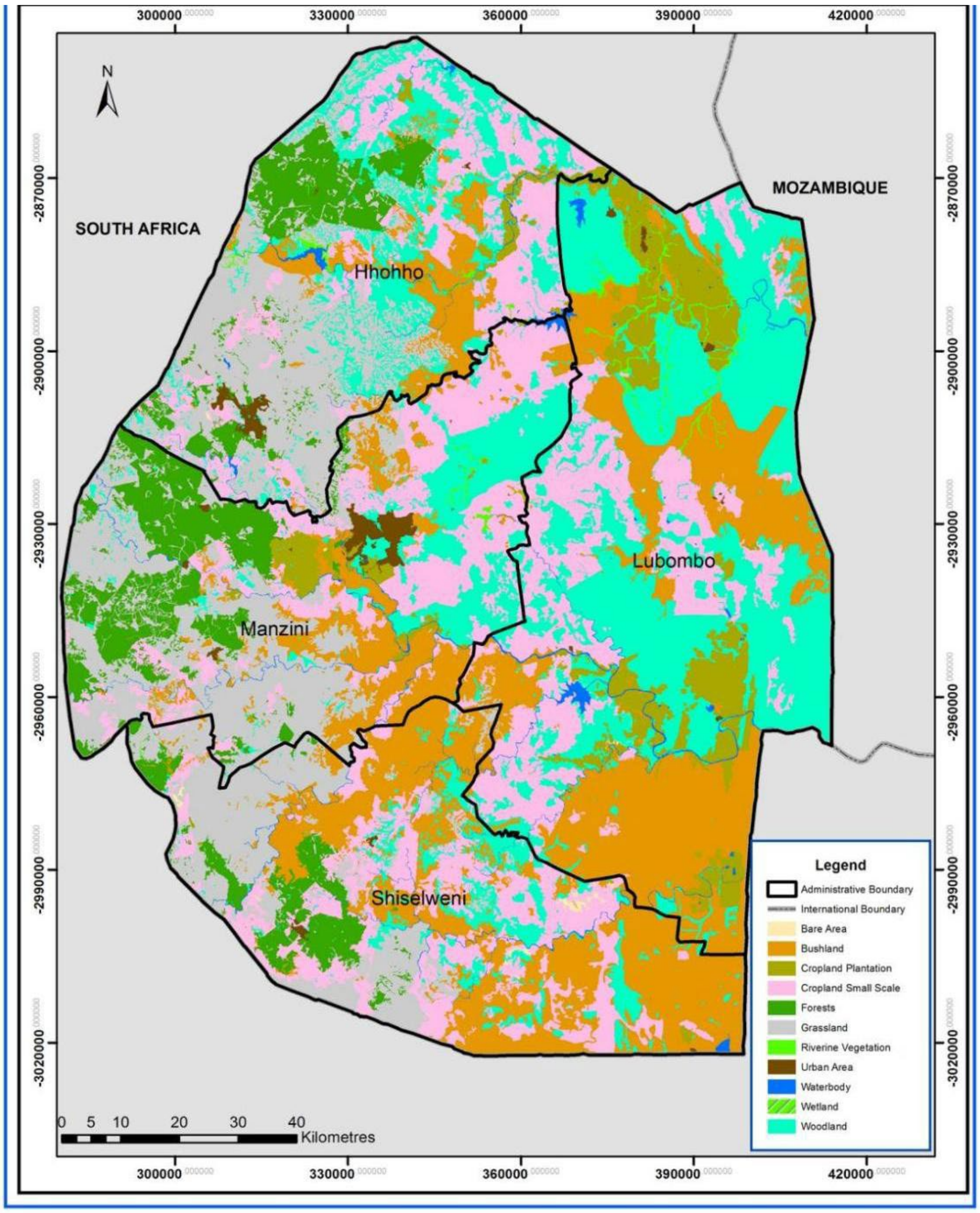

Figure 5: Land use map of Swaziland showing the land use in Manzini

Figure 6 shows the potential landfill sites for Manzini urban area, taking into consideration the different land uses.

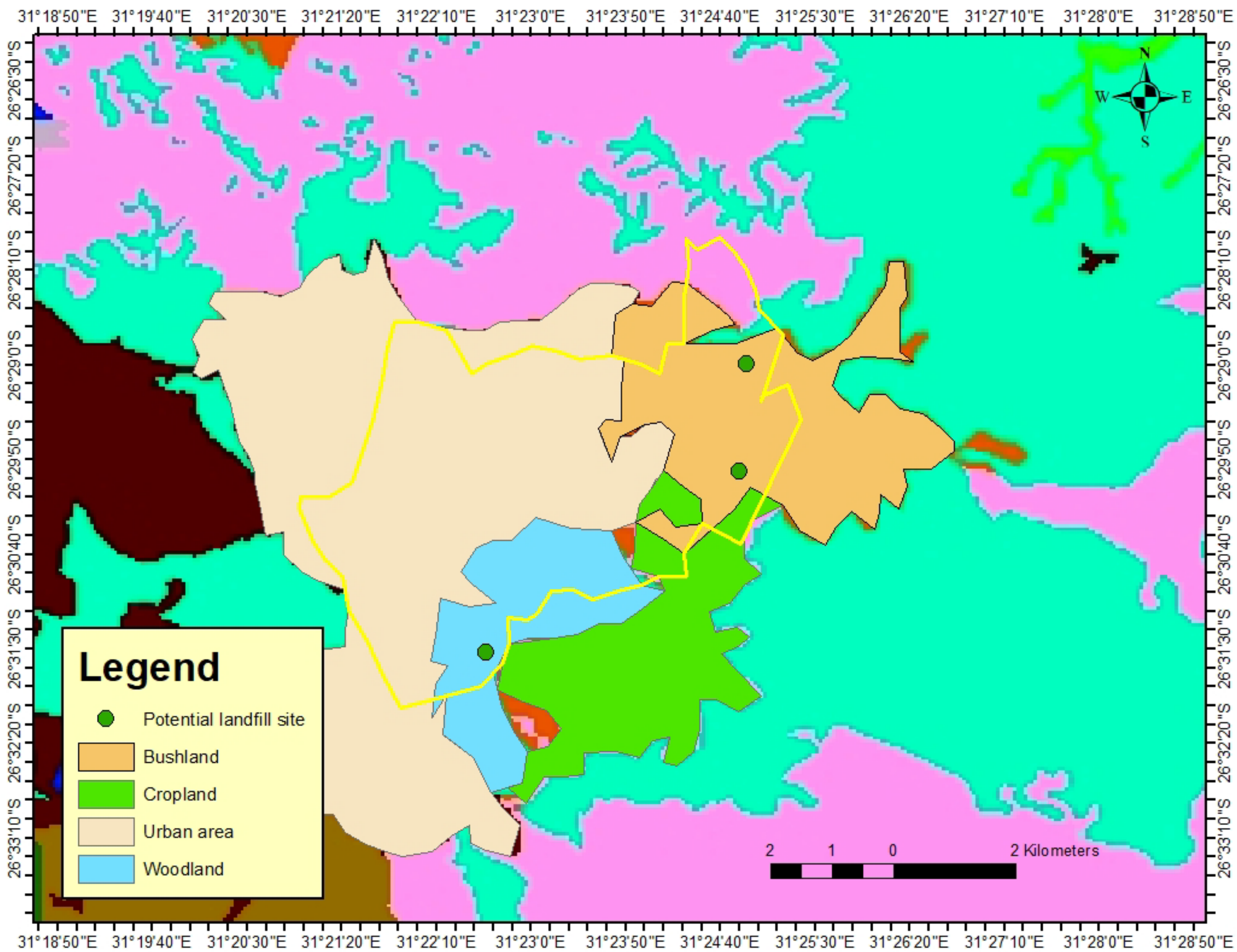

Figure 6: Potential landfill site for Manzini based on land use map.

Bushland sites were chosen because it is the least land cover that can cause disturbance to the ecosystem as compared to the rest of the land covers. An alternative option to a bushland is woodland.

Type of soil

Figure 7 is a map that was sourced from Eswatini National Trust Commission, which provided soil map for the whole country using two separate maps for Northern and Southern spheres of the country. The two maps were then combined into one through printing and scanning.

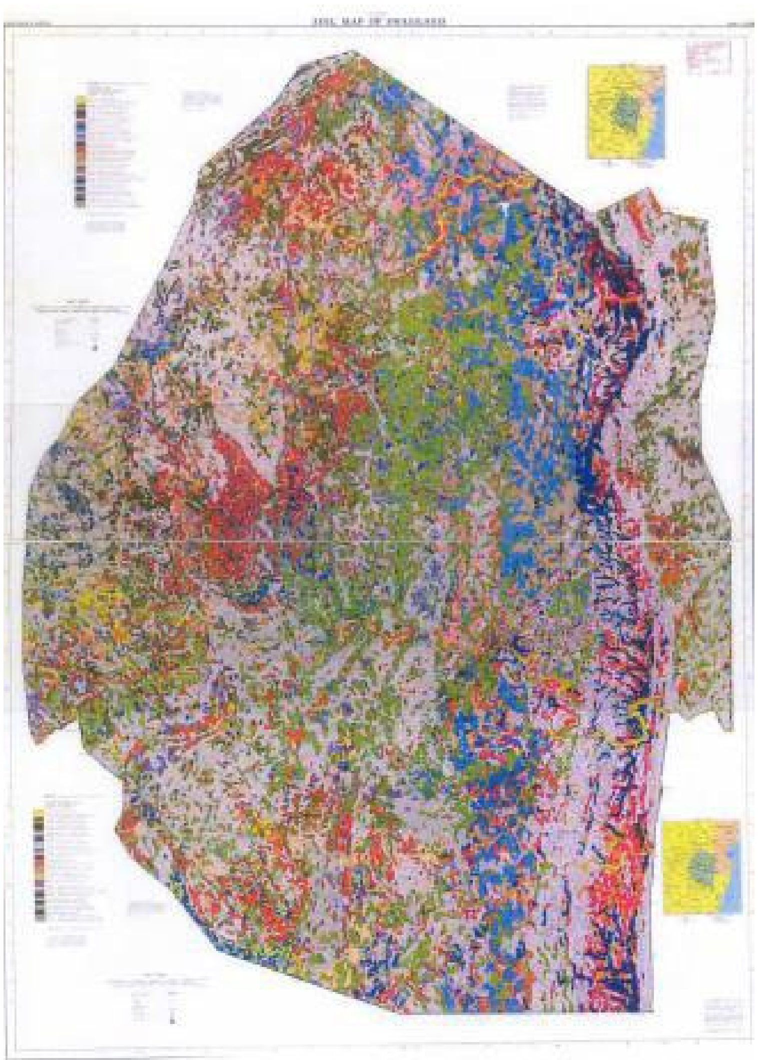

Figure 7: Soil Map of Eswatini

Figure 8 shows the potential landfill sites for Manzini determined in accordance to soil type, of which the preferred soils being clay and loam soils respectively.

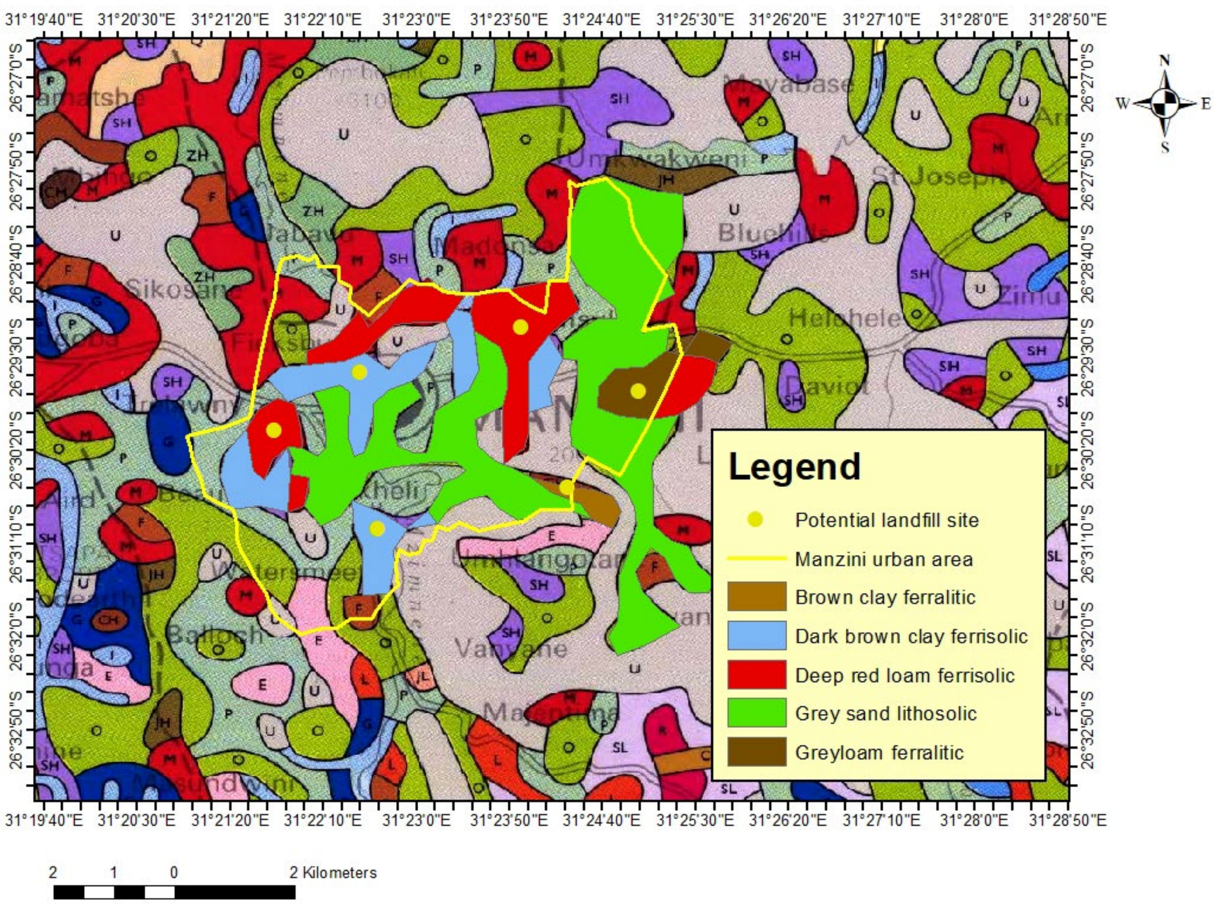

Figure 8: Potential land fill site for Manzini based on soil map.

Landfill sites

All the potential landfill sites were combined into the Manzini Urban area map/boundary. In total, there were 11 potential sites identified. Figure 9 shows these sites.

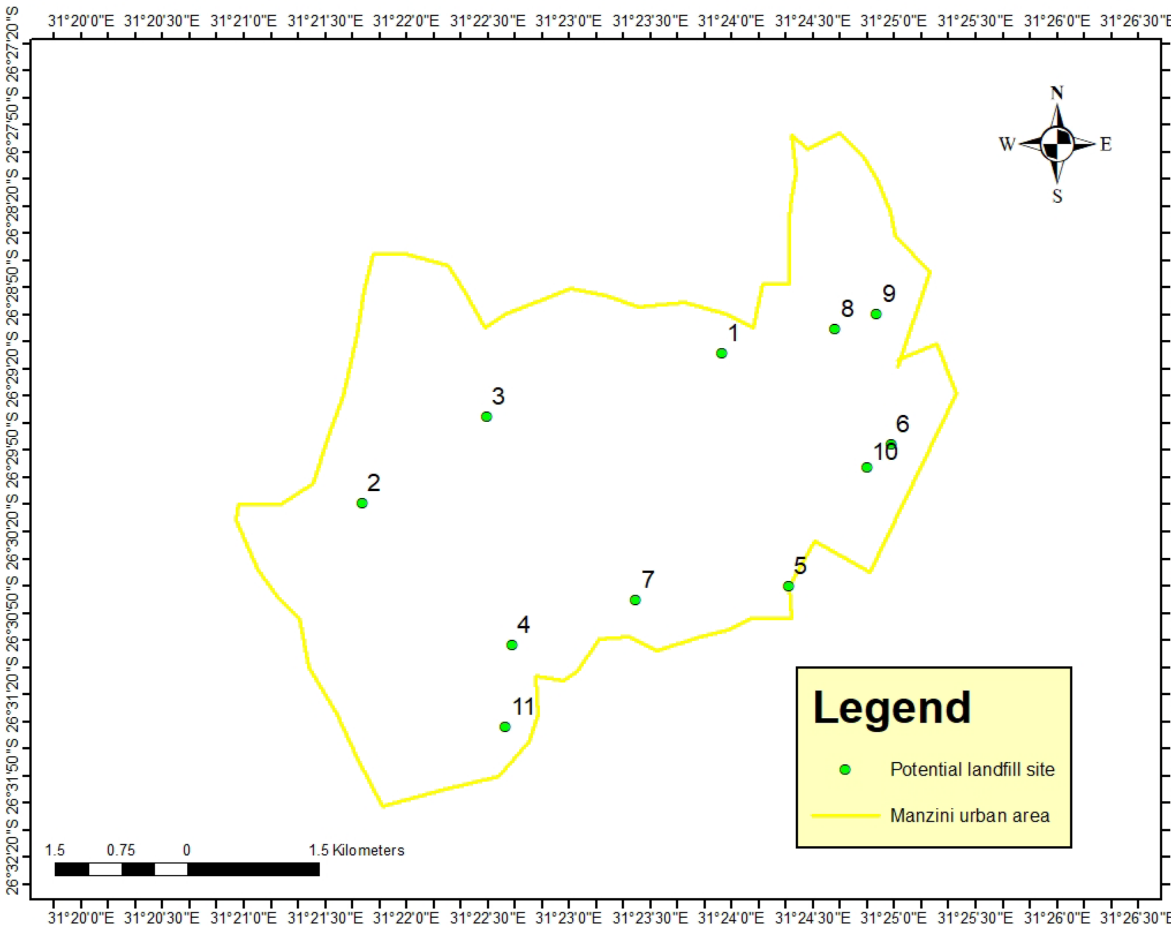

Figure 9: Locations for all potential landfill sites for Manzini

Figure 10 shows the weight, in percentages, assigned to each criterion, according to SpiceLogic AHP software.

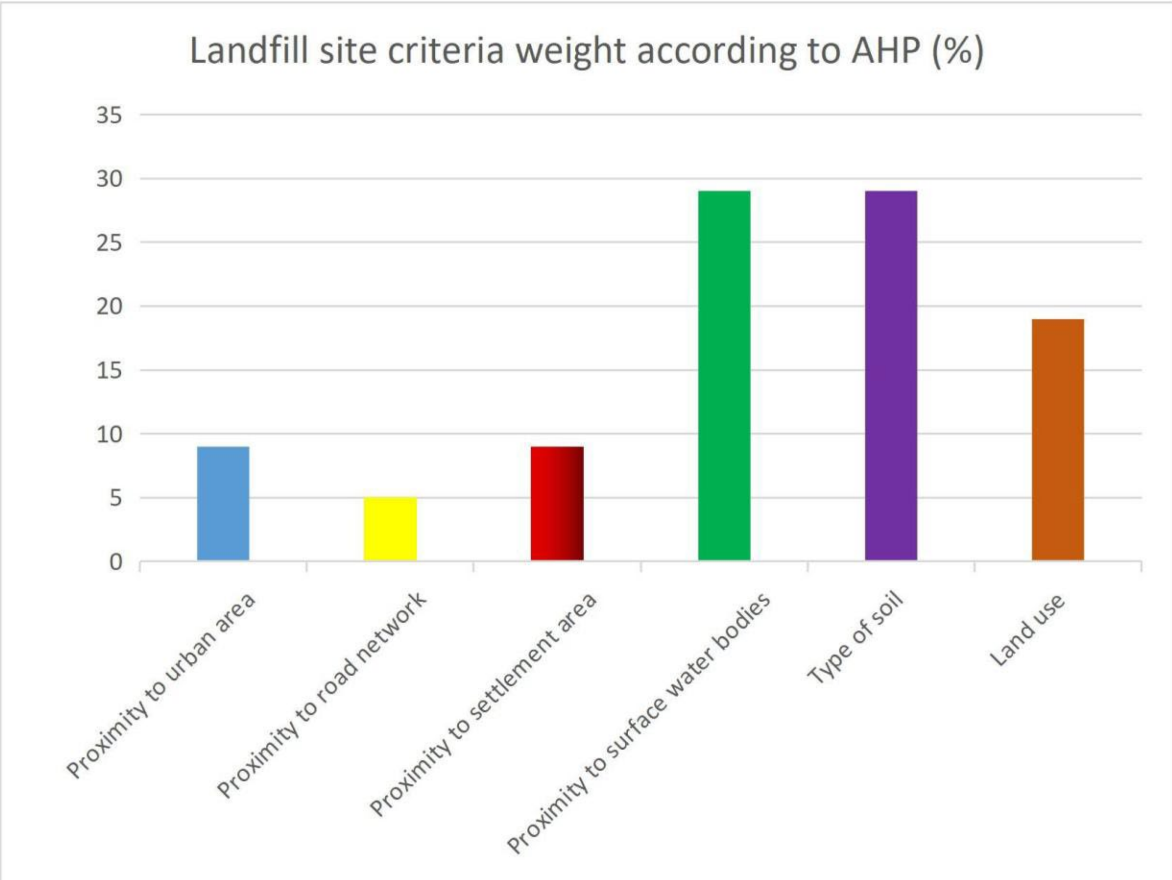

Figure 10: Criteria weighting based on SpiceLogic AHP software

Figure 1 1 shows how each site was scored in accordance to the weighted criteria assigned by SpiceLogic AHP software.

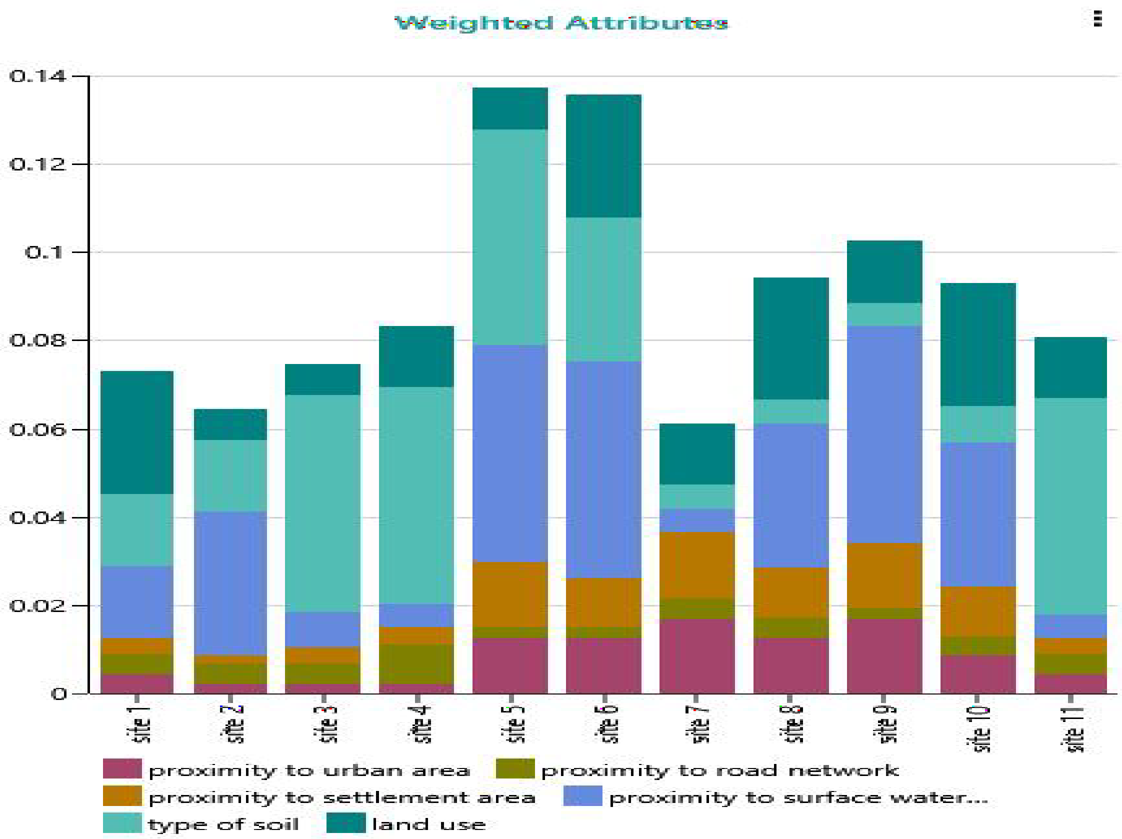

Figure 11: Landfill sites for Manzini weighted attributes

According to SpiceLogic AHP, site 5 is the most suitable landfill site for Manzini urban area. This site is reasonably far from urban and settlement areas, water bodies, lies on clay soil and is encroached between a bushland and woodland.

CONCLUSION AND RECOMMENDATIONS

The landfill site selected accommodates all the restrictions placed on the criteria, making it the most suitable landfill site. A lot of research still has to be done in terms of actually constructing the landfill. Nonetheless, the Manzini Municipality is not handling its waste disposal well as it uses an open dumping method. This measure has been researched enough to present the environmental and social effects it has, affecting sustainability. This study has identified a possible site for constructing a landfill which the municipality could make use of. Without a landfill, the Manzini municipality will continue dumping in the current open dumping site and continue stressing the residents of the close by areas with the environmental effects that emanate from incorrect waste management. The Municipal Council of Manzini must take a deliberate effort to develop a landfill for managing waste in the city. In addition, the municipality should enforce measures to reduce waste generation from source. This would reduce the amount of waste destined to the landfill. The Ministry of Housing and Urban Development in collaboration with the Ministry of Tourism and Environment must ensure that the municipality develop a landfill. This study also has policy implications that the Ministry of Health can implement. For instance, it could be policy that every city and town in Eswatini should make use of sanitary landfills as the base method for waste disposal, nothing less. Robust biocover systems can also be implemented in landfilling to ensure that Eswatini reduces greenhouse gas emissions from the waste sector as it was identified in the Nationally Determined Contributors. This would ensure that methane is captured before its' release to the atmosphere, promoting sustainable development as well as fighting against further climate change. This would task all the municipalities with the mandate of identifying landfill sites, measuring the waste produced from their area, so as to know the landfill size needed and careful construction of landfills. This is a basic human need for survival, as waste affects a lot of sectors including environmental, human, economic and social. Therefore, waste management is of utmost importance.

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