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RESEARCH ARTICLE

Management of Municipal Solid Waste Using GIS

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ABSTRACT

Municipal solid waste management has emerged as one of the greatest challenges facing environmental protection agencies in developing countries. This paper presents a characterization study of the municipal solid waste generated. Solid waste dumping is a hectic problem in urban and developing areas due to shortage of land for the purpose. The main goal of this study was to check the measure and characteristic of municipal solid waste and to select potential areas for suitable solid waste dumping for Dilla town, Ethiopia. A simple random sampling technique applied for sample size choice of all waste generators. For the analysis of this study both quantitative and qualitative techniques were carried out by using primary and secondary data sources. The physical composition and the per capital waste generated per each waste generators within the Dilla town was studied over a period of 7 days. The results showed 85.69% biodegradable, 14.31% non-biodegradable materials in the solid waste composition. 80% of the waste had the potential for reuse and 26.35% can be recycled recycle-able. The average per-capita waste generated was 0.13 kg/ca/day. The average moisture of biodegradables waste was 56.2%. Laboratory test conducted for both physical and chemical characteristics of the MSW. The result of the study revealed that for using current waste generation site is not suitable. The proposed selected landfill site can fulfill all requirements in terms of both environmentally and socially.

Keywords- : Waste composition, waste characterization, MSWMS, suitable landfill,

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INTRODUCTION

Solid waste management (SWM) is a part of the urban environment and planning of the urban infrastructure to make sure a safe and healthy human environment while considering promotion of sustainable economic growth. The high rate of urbanization and population growth in most African countries has made it difficult to develop and implement effective solid waste management system [1]. It is a challenge for the urban authorities in developing countries mainly due to the increasing generation of waste, shortage of resources and burden posed on the municipality, waste is an important cause of environmental load and a marker of dissipating resources. Proper waste disposal, without compromising natural reserves and environmental quality, has become an absolute necessity to avoid environmental and public health risks [2].

Ethiopia is the most populous landlocked country in the world with an estimated population of 97.1 million with a growth rate of 2.5% in 2014 and with a GDP per capita of 550$. Ethiopia is one of the poorest countries in the world; nevertheless, there has been a great economic growth of 10.8% per year between 2003/04 and 2013/14. In the horn of Africa, the regional annual average economic growth is 5.0% shown Table 1. The economic growth has brought a significant reduction in poverty from 38.7% to 29.6% since 2005, the government planned to reduce this figure to 22.2% by 2015 [3].

Table 1 Percentage urbanization in Ethiopia 1984-2007

Particulars	1984	1994	2007
Urban population	11.2	13.8	16.2
Share of Addis Ababa	31.9	28.8	22.9
Urban growth rate	--	4.8	3.9
Population growth rate	2.9	2.8	2.6

Source; Ethiopian Environment Review No. 1, 2010 (2008)

Solid waste management is becoming a major public health and environmental concern in urban areas of Ethiopia. People moving to urban centers of Ethiopia for better living conditions cities like Addis Ababa, Bahir Dar, Adama and Hawassa are under increasing pressure to manage waste effectively in order to avoid outbreaks of disease [4].

Dilla town is one of the rapid growing town in Ethiopia due to availability of facilities and employment. This rapid urbanization caused to increase migration of people as well as increasing waste generation in the town. The increased volume of the waste generated would bring big issues to the society. The most obvious issue was their impact on hygiene and public health. Uncollected waste would always end up somewhere, but generally not in the right place. Illegal dumps on streets, open spaces and water bodies were common. Like other public services solid waste management must considered as one of the most energetic

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urban service given to protect the public and urban health. Lack of adequate solid waste management, absence of a sanitary landfill and limited public awareness of good waste management practices was broadly identified. This poor waste management practices have create a direct impact on public health and the natural environment. Therefore, the research was initiated, and aimed the characterization of municipal solid waste composition and identifying suitable landfill site for Dilla town, Ethiopia.

Material and Methods

Historical background of study area

The study area Dilla is located at 365km from Addis Ababa the capital city of the country and 96 km from Hawasa seat of SNNP Regional State. Geographically, the town lies on the intersection of 6°24′38″N and 38°18′37″E, as shown in Figure 1. It is found in kola agro ecological zone with an average altitude of 1570 m above mean sea level and annual temperature ranging from 22°C-29°C, respectively.

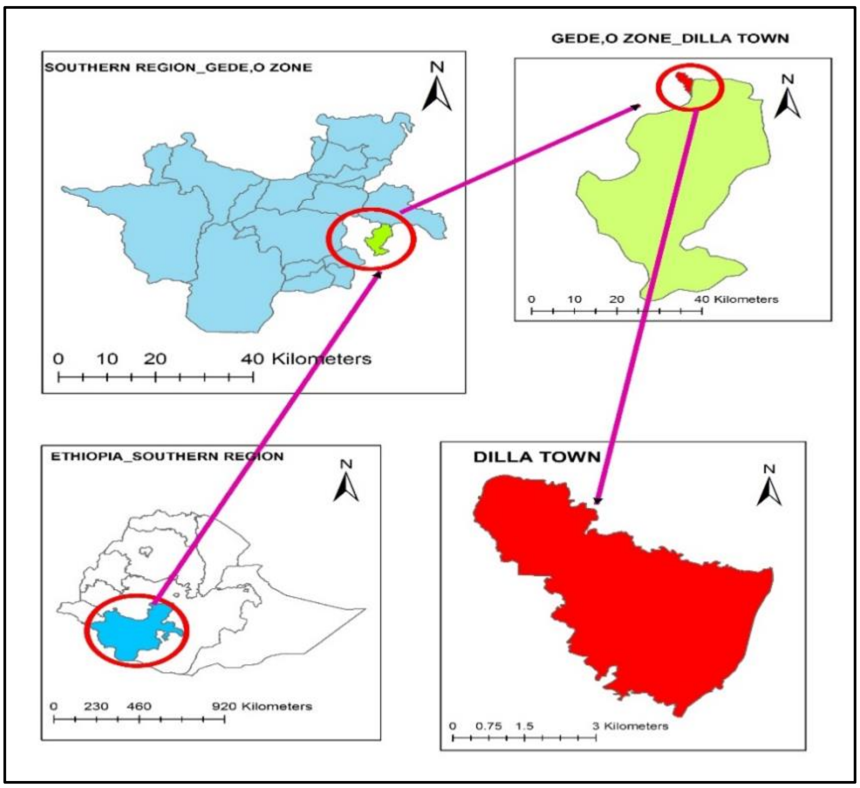

Figure 1: Map of Dilla town

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Based on the Census conducted by the CSA (2012), this town has a total population of 79,892, the source of solid waste that generated in the town was form Households**,** Commercial Activities**,** Institutions, and light industries. The micro and small enterprises (MSEs) were established and commenced solid waste collection service, and door to door solid waste collection service was practiced in the town a decade ago. However, this service not touched once for all residents, they differ in time they have been served. Most of the wastes from house hold remains within their compound that use for composting to their garden and only 34% of the waste is collected [5]. The average per capital solid waste generation rate of the town is $3720m^3$/year as it is explained by the municipality.

Data collection methods

To conduct this study qualitative and quantitative approaches used to achieve the aim of research work. Questionnaires and interview used for evaluating existing MSM practice. A well-organized questionnaire was developed and randomly distributed to sample households for collection of relevant data on the research work. Then, the selected households filled the questioners before sample waste collection was started. It was used to get in-depth household information on the existing SWM practice at household level, as well as other waste generators. In order to get statistically acceptable waste sample results, it is necessary to determine the adequate size of households. For the public survey, a sample size (n) of households in the study was determined using the sampling technique (formula), which developed by Cochran (1977) with the desired degree of precision for general population [6]. Central limit theorem with a 95% confidence interval and a 5% error was suitable as a desired reliability.

$$n = \left(\frac{NZ^2pQ}{d^2(N-1)+Z^2pQ}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where: N = Total number of sample households, Z = standard normal deviation at the required confidence level that corresponds to 95% confidence interval equal to 1.96, d = the level of statistical significance (Allowable error) (0.05), P = the proportion in the targeted population estimated to have characteristics being measured (from previous studies or studies in other comparable countries i.e. 09 from [6], Q = 1-p i.e.1-0.9 = 0.1. Samples were collected randomly at 137 households at study area of Dilla town as per their suitability for succeeding necessary representatively and based on the economical state as well as location selected 50, 45 and 42 households at Boeti, Bareda and haroresa kebeles, respectively.

Waste collection

Waste samples were collected from households by coded plastic bags before collecting the sample waste, the plastic bags distributed for each selected households one day before the waste collection being done. The identification code was assigned on waste collection bag and then given to each household. All households were informed how and when the sample collectors will come back during distributing the plastic bags. On the next day, sample collectors were collected all the distributed bags, with solid waste kept in, early morning and brought to the specific place ready for sorting purpose using hand push cart and horse cart. For quality of the data, the first day waste collected from each household discarded taking into account that these wastes might

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not generated at the time. Right after the second day up to the eighth day (8 days) samples were collected. The sampled waste was segregated according to the type of waste after collection and sorted manually based on the physical nature of the waste. The sorted waste components were weighted and determined volume by using known volume wood boxes. The waste samples from household were transported to the laboratory for further examination to the waste characteristics. The generation rate per capita per day of the conducted area is estimated as total waste collected within seven days divided by total population of the conducted area.

Waste characterization

a. Physical parameter

MSW from the households were segregated and then the waste percentage composition was defined by the following relationship.

$$\textbf{Composition of separated waste (\%)} = \frac{\textit{weight of separeted waste}}{\textit{the total mixed weight sampled}} * 100 \ldots\ldots\ldots\ldots \textbf{(2)}$$

To measure the moisture content of the waste sample, the following procedure was followed. Weigh the sample and record the weight as W1. Place in a fan-assisted oven at a temperature of 105°C for 24 hours until it stabilized. Allow the sample to cool to room temperature and re-weigh record this weight as W2. The moisture content (% H_2O) was then calculated as follows:

$$\textbf{Moisture Content (\%)} = \frac{\textit{initial weight of sample}(W1) - (W2)\textit{weight of sample after drying}}{\textit{initial weight of sample}(W1)} * 100 \ldots \textbf{(3)}$$

Density as indicated above quantity of waste (kg) was determined by wooden boxes with different size (M^3). Therefore, Density of solid waste can be determined by using quantity of waste collected divided by it volume measured.

$$\textbf{Density} = \frac{\textit{mass of sampled waste}}{\textit{volume of waste}} \ldots\ldots\ldots\ldots \textbf{(4)}$$

b. Chemical parameter

Proximate analysis for the combustible components of municipal solid waste analysis was carried out in Dilla University at chemistry department to decide moisture content, ash content, volatile matter and fixed carbon. To perform this experiment different equipment's were used. By putting the selected sample to different range of the temperature, between 105°C to 950°C. The percent moisture of the MSW samples determined by weighing the samples `into a pre weighed dish and drying the samples in an oven at 105°C to a constant weight (ASTMD 3173). The percentage moisture content (MC) calculated as a percentage loss in weight before and after drying. The composite samples of MSW material used in the moisture content determination weighed and placed in a closed furnace for seven minutes at 950°C (ASTMD3175) and the weight measured percentage loss in weight before and after seven minute give us (VM) in percent. After combustion, the samples dried to 750^0c for half hour in open furnace to decide the ash dry weight. Fixed carbon defined by carbon found in the material which was left after ash test. The fixed carbon determined based on dry basis by the following equation:

$$\text{Fixed carbon (Wt. \% dry basis)} = 100 - Wt\%Ash + Wt\%\ volatile\ matter \ldots\ldots\ldots\ldots (5)$$

Land fill site selection

GIS based landfill site selection methods were used to identify suitable site for Dilla town municipal solid waste dumping. In this thesis, this part of study focuses on a suitable landfill

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site selection based on geographic information system (GIS) overlay analysis and multi criteria discussion to achieve objective, the overall conceptual model for landfill site selection shown in **Figure 2**.

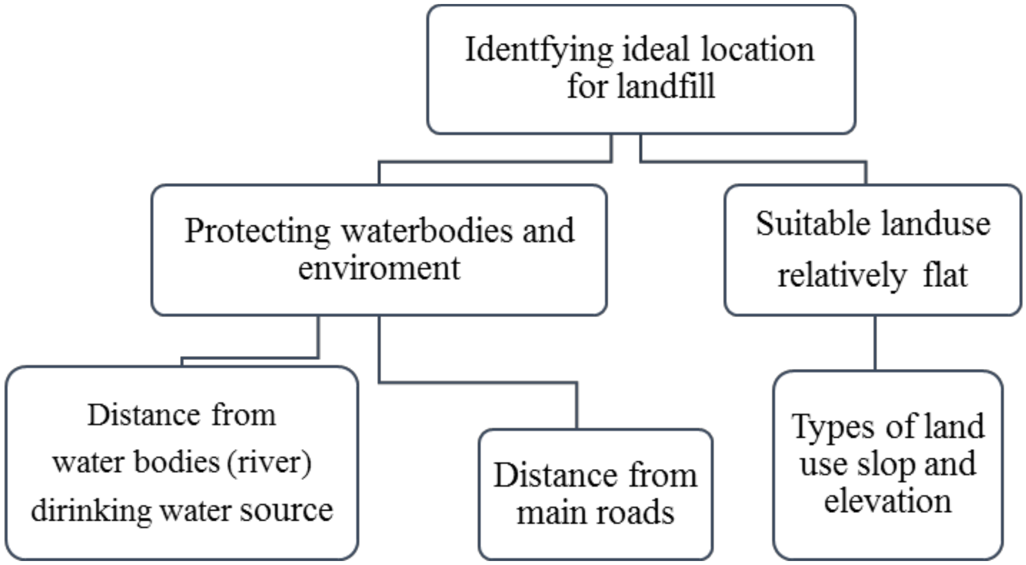

Figure 0: Conceptual model for landfill site selection methodology

In order to carry out this application, multiple datasets are needed to form the bases for setting criteria. These criteria will be the factors and constraints for selecting suitable landfill sites. Existing vector data layers were acquired from Government Information Centre to generate map layer for each criteria on ArcGIS.

Determining Unsuitable Areas

To decide these areas, one should enter the collected data into the ArcGIS environment and use geo-processing techniques like buffering. According to various studies, the factors considered that buffer zones for different extent were explained in **Table 2**.

Table 2: Representation the criteria of buffer zone

Criteria	Unsuitable Areas	Remark
Road Networks	100 m buffer zone	
Surface water (rivers)	200 m buffer zone	
Residential area	300 m buffer zone	
Important building	300 m buffer zone	
Boreholes	400 m buffer zone	
Reservoirs	400buffer zone	

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Datasets were used to form maps of factors or phenomena that contribute variably to site suitability, a factor is a criterion that enhances or detracts from the suitability of a specific alternative for the activity taken under consideration. A constraint serves to limit the alternatives under consideration, after finding out where the unacceptable areas are, the remaining areas should be classified into classes of high and low priority for being used as waste disposal areas.

Result and Discussion

Waste Collection practice

In order to assess the collector of solid waste from generation source questioner were prepared and result were expressed in percentage composition. This indicates that more than 50% households were not have solid waste the collection service regarding the primary storage facilities, 49.6% of resident have waste collection, 35.8% of resident have self and open disposal, 8.8% of resident do not know about waste collection service, and 5.8% of not specified, as indicated household data collection shown in **Table 3**.

Table 0: Household collection service

Collection	No households	Percentage (%)
Municipal collators	68	49.6
Self and open disposal	49	35.8
Do not know	12	8.8
Not specified	8	5.8
Total	**137**	**100.0**

According to the sanitation and beautification unit they have only one truck for transport waste from street dumping containers to the landfill site. Door to door waste collection system was failed due to improper management of local government. Lack of community participation and awareness about importance of the waste management in Dilla. **Table 4**, illustrates that the types of solid waste storage materials used by the town resident.

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Table 4. Types of waste storage material

No.	Types of storage (containers)	No of household	Percentage (%)
1	Metal (waste bins)	20	14.6
2	Suck (medaberiya)	57	41.6
3	Plastic suck	45	32.8
4	Carton	5	3.6
5	No container	10	7.3
	Total	**137**	**100**

Waste disposal practice

In order to assess the routine method of solid waste disposal practices of town and to know the disposal place. Based on data collection, the results shows that disposals at open field and road side is 36%, dumping in the nearby river side, bridge and galleries are 22.4%, burning or dispose in their compound is 17.6% completely burning 9.6% and waiting for waste collectors are 14.4%. As per the data collection more than 50% of households (52.4%) preferred improper and unauthorized solid waste disposal practices as shown in **Figure 3**.

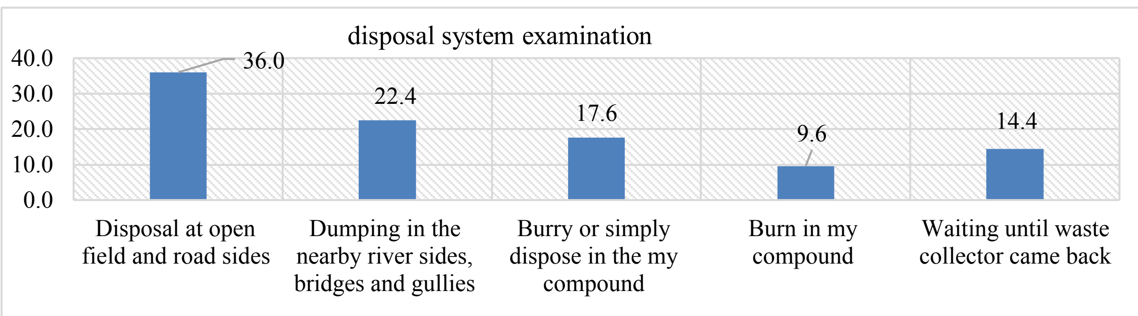

Figure 0: Represents result identified from waste disposal practices

This confirmed that the destination of the majority of uncollected solid wastes disposed of in roads, sewers, river banks, valleys, gullies, bridges, and open areas. This improper disposal of solid waste exposed communities to different respiratory and water borne diseases. On the other hand, illegal solid waste disposal of residents also closed and damaged sewerage systems and force liquid waste stagnant in street sides.

Composition of waste from household

Obtained result from sorting process and quantity of each individual component of the municipal solid waste at household level was given, different categories of solid waste stream were found during one-week period. Table 5, illustrates that the composition was then

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categorized into eleven major categories: food, yard, wood, paper, tissue paper, plastic, metals, glass and others.

Table 5: Daily waste generation composition from household

Household/day	Food waste	Yard waste	Wood	News/office print	Tissue paper/diaper	Plastic film	Other plastic	Metals	Glass	Textile	Inert	Total
Wt.(kg)/d	37.3	13.58	2.94	1.89	0.34	1.43	0.69	0.94	1.11	2.04	0.73	62.99
Wt.(%)/d	59.22	21.57	4.67	3	0.54	2.27	1.1	1.49	1.76	3.24	1.15	100
total HH	5849.52	2130.25	461.72	296.39	53.54	223.8	108.43	146.96	173.62	319.91	113.8	9877.94

The percentage by weight of the physical waste composition from all the randomly selected households, were combined over the entire period of the survey through the various areas of the town, rather different categories of solid waste stream were founded during one-week period characterization. The waste stream from the household had 88.89% biodegradable waste, 11.11% Non-bio degradable waste 9.94% were recyclable waste. The other composition are 3.6% paper and cardboard, 2.27% plastics, 1.49% metals, 1.76% glass, 3.24% textile, 1.15% inert and miscellaneous. This indicates that composting/biodegradation can be used for the disposal of this 88.89% of the waste and the fertilizer can be derived as the end product. Results from the study showed that food residues were on average the most abundant (82% putrescible; food and yard) waste in all the three classes of residential at study areas. This is in-line with previous research work by Hoornweg (1999) where they found out that waste stream over 50% is organic materials in developing countries. Related research was done (Abiyot, 2012) in Laga Dadi section showed that 85% percent waste made up of household's organic matter with a high density. In separate works in Bandung and Indonesia have shown that residential waste composed of 78% and 81% as compostable materials [7]. The results obtained from solid waste characterization in Istanbul and Turkey were reported, respectively, as 75% and 78% for organic wastes [8]. Comparing the rates of biodegradable wastes within the study town was higher percentage (88.89%) than previous studies.

Composition of the waste based on their degradability

For the purpose of recycling and reusing, collected waste based on their nature would be classified into bio-degradable and non-biodegradable classes. **Table 6** shows that result the percentage composition biodegradability of collected waste on the bases of their nature

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Table 6: Bio and Non- Bio degradable waste

Bio-degradable	per day (kg)	Wt.(kg)%	annually (kg)
Residential	8791.41	82.49	32,08866
Commercial	273.14	2.56	99,697
Road sweeping	67.92	0.64	24,793
Total	**9132.47**	**85.69**	**33,33356**
Non-Biodegradable			
Residential	50.32	10.19	396,580
Commercial	76.87	0.47	18,366
Institutional	231.57	0.72	28,057
Road sweeping	79.85	2.17	84,522
Light industry	10657.61	0.75	29,147
Total	**8791.41**	**14.30**	**556,672**

As result indicates, 85.69% of total waste generated in the town was bio-degradable and percentage 14.30% of the waste were identified as non-biodegradable. The percentages of organic waste in municipal solid waste in selected African cities were recorded as 56% in Ibadan, 75% in Kampala, 85% in Accra, 94% in Kigali and 51% in Nairobi which was preferable for composting rather than dumping it at landfill site [9]. Therefore, 85.69% organic waste was identified in this study indicates that composting would be a good waste management option for the Dilla town resident.

Total Amount of the waste generated in the town

Total waste generation rate of household that calculated from the average per capita per day is (0.13 Kg/cap/day). Table 7 illustrates that waste generated rate (Kg/day) based on the updated per capita household generation rate.

Table 7: Result for waste generated from different area of the town

source of waste	Quantity of waste generated Kg/day	Composition Wt.(Kg)%
residential	62.99	51.49
commercial	32.35	26.44
institutional	8.39	6.85
light industry	14.29	11.68
road sweeping	4.33	3.54
Total	122.35	100.00

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Significant differences in waste amount were analyzed and minor increases were found. As discussed higher amount of wastes was generated from the residential and commercial area and light industries, road sweeping, and institutional areas were generating less amount of waste in the town. The reason for this change is assumed to be higher fruit and unprocessed food consumption in the town were concluded.

Proximate analysis

Table 8 illustrates that overall result of the proximate analysis of composite waste for selected samples and individual waste type, basis of the data obtained from the laboratory experiments.

Table 8: Result of proximate analysis

Categories waste	Moisture content (%)	Volatile matter (%)	Ash (%)	Fixed carbon (%)
Food	64.7	25.5	7.5	2.4
Yard	52.8	23.1	16.3	7.8
Paper	1.7	81.9	7.8	8.7
Textile	2.9	58.0	18.9	20.1
Plastic	3.2	79.4	12.0	5.4
Fruit	48.5	27.8	11.3	12.4
Chat	48.5	17.9	32.3	1.4

Based on laboratory analysis result, food with 64.7 percent, yard waste with 52.8 percent and chat waste with 64.7 percent have the highest moisture content in this study area. Result from moisture content analysis directly affected by the quantity of wet basis materials such as chat waste and food waste in waste stream.

Ultimate analysis

The fractions of the elemental composition of the various waste components collected are computed. As shown in **Table 9**, the value of the ultimate analysis shows that the carbon content in all types of the waste components have higher percentage and lower Sulphur percentage compared with the typical value of domestic solid waste. Moreover, using incineration as a means of waste disposal for this study area have negative impact due to high carbon content

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which leads to environmental pollution when combined with atmospheric oxygen.

Table 9: Result of ultimate analysis and carbon nitrogen ratio

Sample	Carbon (%)	Sulphur (%)	Nitrogen (%)	Hydrogen (%)
Food waste	45	0.12	0.78	3.5
Fruit	40	0.2	1.51	3.78
Chat	42	0.3	1.3	2.57
Yard waste	49	0.3	3.9	5.67
Paper	52	0.2	1.3	6.3
Average	45.6	0.22	1.75	4.37
Waste component	**Carbon content**	**Nitrogen content**	**Carbon: Nitrogen**	
Food waste	45	0.78	45:00.78	
Fruit	40	1.51	40:01.51	
Chat	42	1.3	42:01.30	
Yard waste	49	3.9	49:03.90	
Paper	52	1.3	52:01.30	

Compared to landfilling, waste incineration and other thermal processes avoid most GHG generation, resulting only in minor emissions of CO2 from fossil carbon sources, including plastics and synthetic textiles. Estimated current GHG emissions from waste incineration very large. Major contributors to this minor source would be the developed countries with high rates of incineration, including Japan greater than 70% of waste incinerated, Denmark and Luxembourg greater than 50% of waste, as well as France, Sweden, the Netherlands and Switzerland. Incineration rates are increasing in most European countries as a result environmental pollution increase due to high carbon emission. Accordingly, the sample tested is more suitable for the production of the compost depending on

Therefore, buffer of 200 m is considered. Important Building, the data layer for important building centers is entered into the GIS function

result recorded. The standard carbon to nitrogen ratio of MSW to be composted is 25-50:1.

Landfill site analysis result

The waste disposal areas should not be in the vicinity of rivers, lakes, or swamps where the underground water level is high. **Figure 4** illustrate that River buffer and important building Map, since major rivers have a higher discharge and greater downstream influence, no landfill should be sited within the floodplains of major rivers. Hence, buffers of 200 m and 100 m for permanent and temporary rivers are applied respectively. However, in the vicinity of the town permanent rivers are hardly found.

and a buffer zone of 300 m around these areas are considered.

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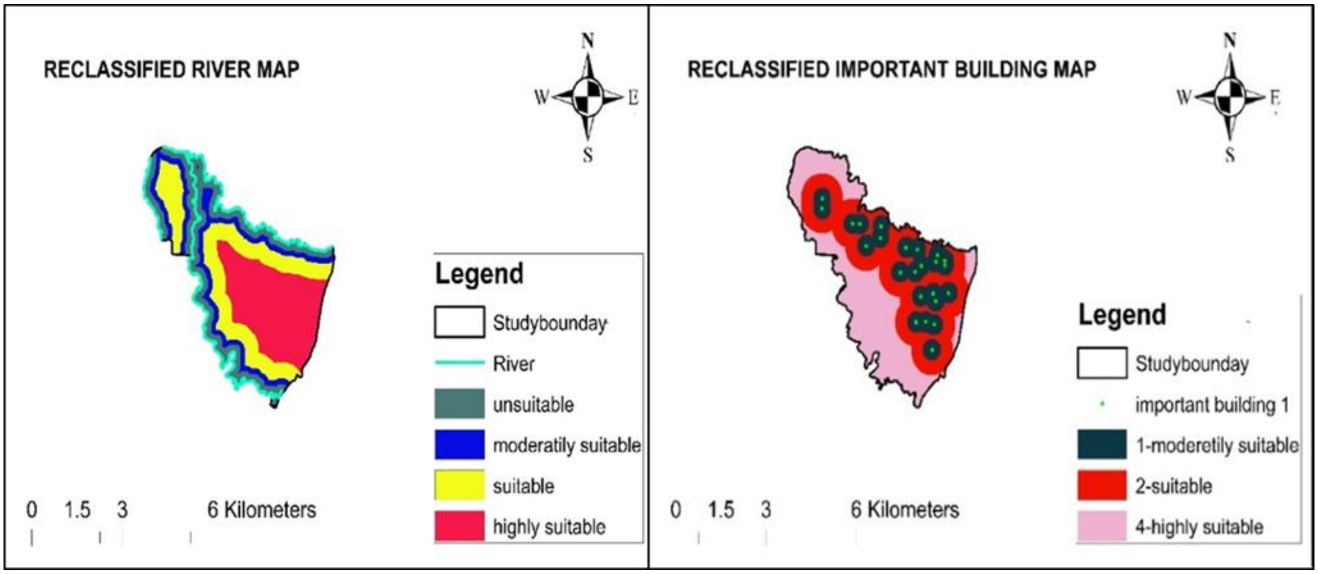

Figure 4: River buffer and important building Map

The road networking the town consists of main roads, secondary roads and pedestrian roads. The waste disposal areas should not be too close to the road networks. Therefore, a 100 m buffer zone is applied to these networks, **Figure 5** shows as road networks constraint and borehole (BH) Buffer Map.

The waste disposal areas should be away from boreholes otherwise it can have irretrievable human and environmental effects. All of the boreholes in the town are entered into GIS system and a buffer of 400 m is considered for them

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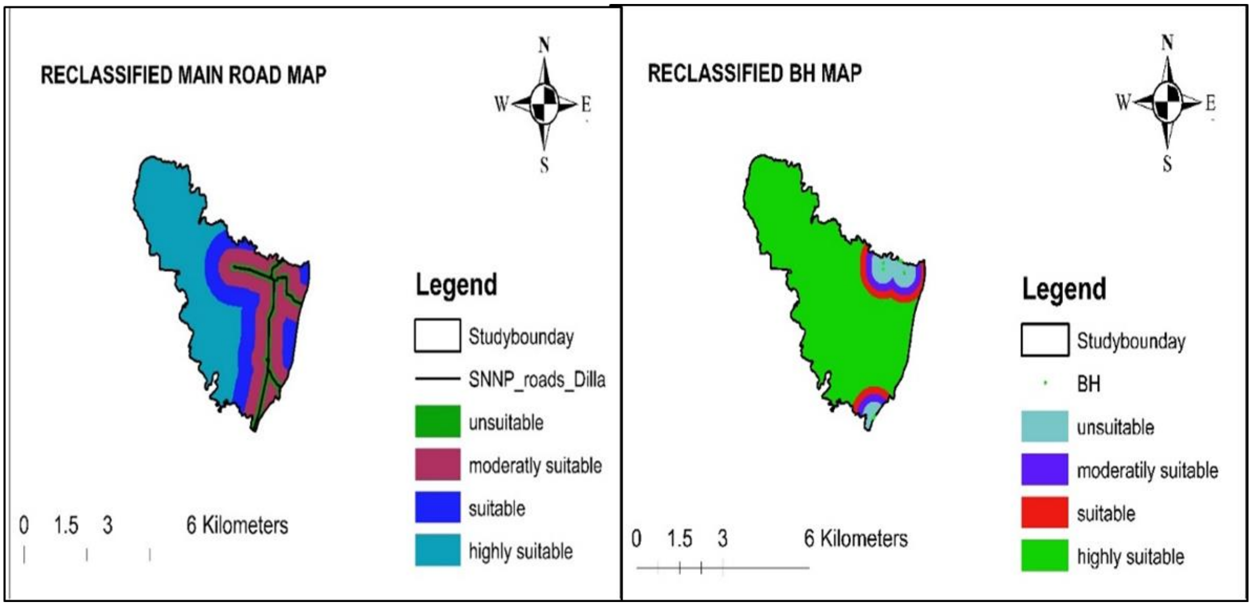

Figure 5: Road networks constraint and Borehole (BH) Buffer Map

According to if the regional drinking water is supplied by surface water impoundments, it may be necessary to exclude the entire watershed that drains into the reservoir from landfill sites. A high groundwater level or a nearby high river level will cause more risk to pollute the groundwater or river water, Figure 6 shown that reservoir buffer and residential map. The potential landfill location with the lowest groundwater or river level is more suitable for a landfill. All of the reservoirs in the town are entered into GIS system and a buffer of 400 m is considered for them as indicated in Figure 4-11.

After identifying restricted area to selecting for landfill site each criterion reclassified according to their range categories.

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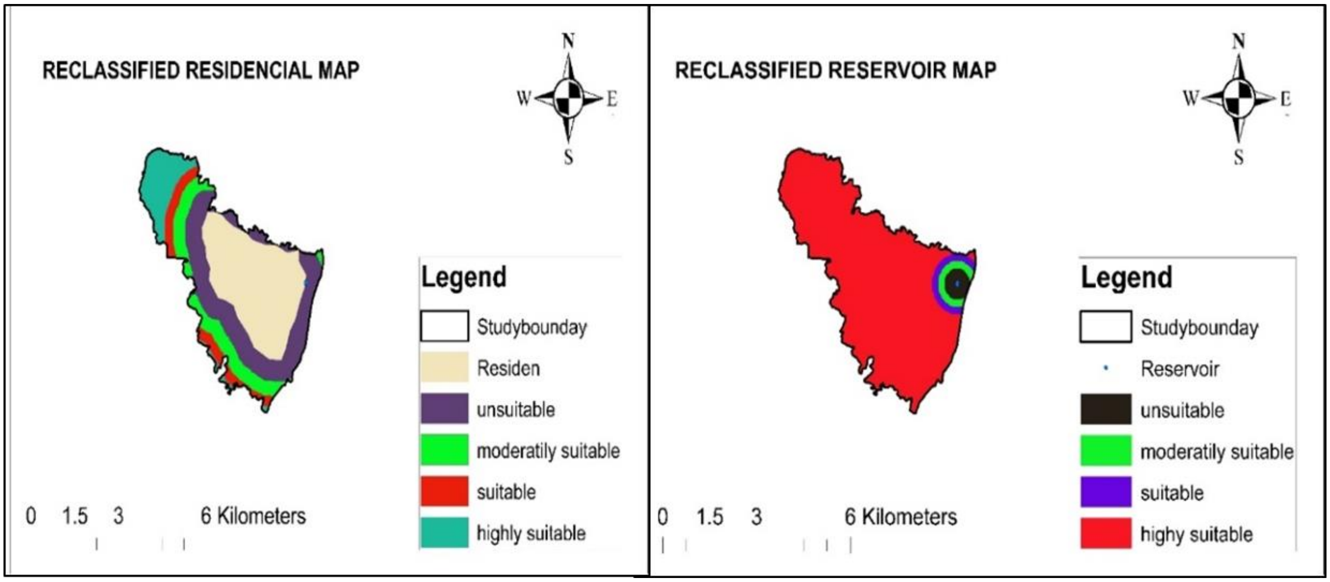

Figure 6: Represent reservoir buffer and residential map

The area coverage of each suitability index of the sites was calculated in ArcGIS environment showed that 7.58 ha (0.354%) of the total study area was unacceptable for landfill site as the areas are environmentally unfriendly, socially unacceptable and economically impracticable to be proposed as a solid waste disposal site, as shown in **Figure 7**, solid waste disposal site suitability of town. This unsuitable (restricted) area include close to surface water (river) (area with a 200m buffer zone), dirking water sources (area with a 400m buffer zone), areas with close to road networks and far from road networks with a 100m buffer zone.

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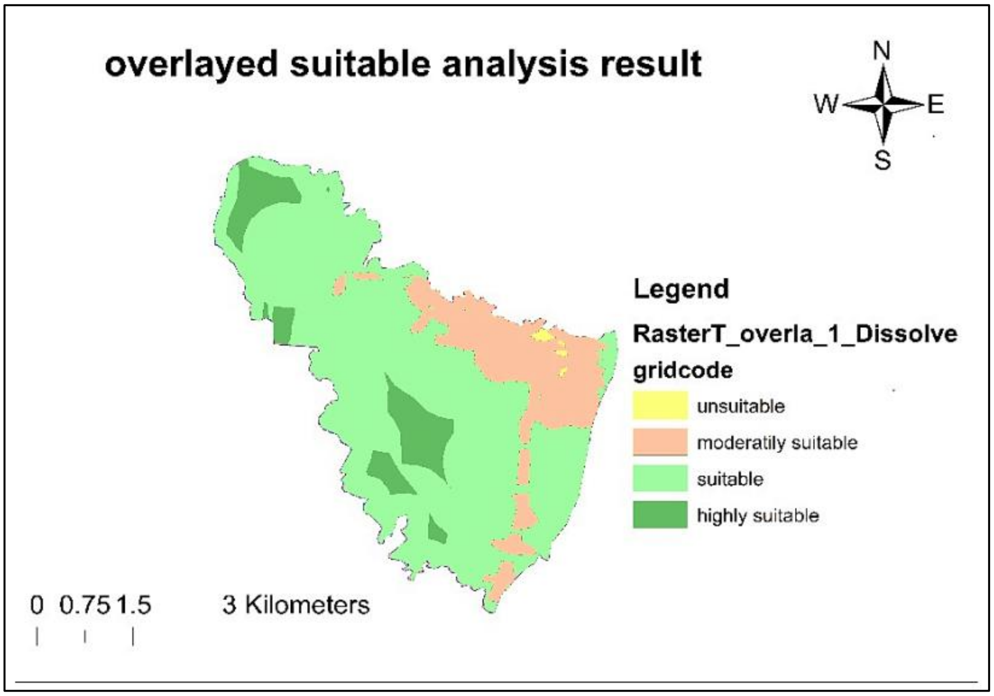

Figure 7: Solid Waste Disposal Site Suitability of Dilla Town

The main advantage of these areas restriction was to minimize their negative effects of on environment and public health as well as to minimize the cost of construction and maintenance of the solid waste disposal site. However, the area of 398.77 ha (18.65%) moderately suitable. 1525.04 ha (71.34%) suitable, but when comparing with geological formation of this site all most it composites of alluvial deposit of rock type. It consists of silt, sand, clay, and gravel, as well as much organic matter usually most extensive in the lower part of a river's course.

CONCLUSION

Solid waste composition and characterization analysis are critical in resource recovery in management of municipal solid waste. The first step to solid waste management is to gain an understanding of the waste types being generated in order to design appropriate collection and disposal strategies. As the study results revealed that the town has been unable to carry out sustainable SWM system especially at household level in line with the ever-increasing number of population and economic growth. The Characterization analysis results identified 85.69% organic waste, 8.02% package waste, 3.77% metals and 2.52% burnable wastes in solid waste of Dilla town. The per capita waste generation rate was found 0.17, 0.13 and 0.08 kg/capita/day from high, middle and low income households respectively. In this solid waste 59.69% is compostable, 3.95% is recyclable and 10.36% only disposable. This indicates that the solid waste management practice in Dilla town is very poor. It was due

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to lack of knowledge as well as awareness to handle the waste. Solid waste disposal system in Dilla Town is open dumping without discriminations. As the result, there are environmental and social problems facing the community from the dumping sites. All types of solid wastes from household, light industries, and commercial are dumped together which may contain leachable toxic compounds that are harmful to the environment and human health. The present landfill site is not suitable so that in this research found the best suitable landfill site based on the 7 factors like Proximity to slop, surface water (rivers, boreholes and reservoirs), residential areas, Important built up areas, road networks by using ArcGIS at study area of Dilla town. The result of the final landfill suitability map showed that 207.26 ha which is 9.69% of the entire study area is categorized as suitable landfill site based on various suitability indices. The proposed landfill site is economically feasible, environmentally safe as well as convenient to transport solid waste from Dill town.

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