Spatial assessment and identification of suitable landfills for solid waste disposal in Madang Urban, Papua New Guinea

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Abstract

Change is inevitable in any society that is geared to improving themselves and their surrounding environment, and with that change comes its negative impacts. One such negative impact is solid waste management. The study seeks to identify suitable sites for landfills in the Madang Urban area. Landfill suitability criteria such as roads, rivers and environmental resources are criteria that must be considered in site selection of Landfill sites. A cost-effective measure involving Remote Sensing (RS) and Geographic Information Systems (GIS) is the approach that has been identified for this study. The Madang urban local government needs this technology to improve its decision making in areas of waste management. The township is fast becoming an industrial centre from its once small population that prides itself in its tourism and hospitality. In this study, seven landfill site criteria were investigated. They include the river zones, the commercial zones, the industrial zones, land use land cover, slope, soil texture, and major roads. The selected criteria were given distances that are favourable for landfill sites to be located from the urban centre outwards. Then the buffered landfill criteria were set weightage values against them by observing their characteristics concerning landfill site. From there a final output map was produced, laying out both suitable and not suitable landfill sites. The technology has been used by developed countries for making informed decisions. It is a decision-making tool that describes space with its location. In summary, seven landfill site criteria were investigated and mapped thematically, and an output map was generated for identifying suitable and not suitable landfill sites.
Keywords: *Landfill, GIS, Remote Sensing, Weighted Overlay, Madang Urban, PNG*

1. Introduction

The underlying cause of urbanization in Papua New Guinea is that employment opportunities are limited in rural areas, therefore, intensifying an urban migration that has led to a rapid increase in the quantities of waste that require disposal (Borden & Ward, 2006). According to Merz (2000), there is a lot of movements in Papua New Guinea between the highlands, outer islands, and urban centres, which has resulted in an increase in the urban population growth rate of 43 percent. The report further stated that the increase in urban population places more pressure on municipal solid waste management. Other urban areas such as Lae Urban are increasing their capacity for accommodating industries and their workforce as a result of mining, gas and oil boom in the country. In doing so the population has increased as well as waste from the population and the industries there. This is now a concern for Lae City Council. According to Wangi (2008), the management and authorities there are experiencing poor management standards due to insufficient funds or resources and no policy/strategy guidelines. Madang Urban is not that industrialized like Lae Urban, but the idea of health hazard preparedness must be considered now. We must be resilient in our designs and policies by learning from other urban towns and cities in our country and abroad. Madang town which is the capital of Madang province has one officially designated dumping site called “Mero Dump.” The site where the dump is located is unsuitable due to residential areas around the site, along the river banks and at the river’s mouth. Also, its proximity to the main road and the Madang airport can be a problem. According to Sulliman (2010), solid waste can cause harm or damage to people and the environment. Therefore, the right thing to do now in Madang town is to seek a highly suitable place that can accommodate solid wastes well into the future. The current study was carried out with the aid of GIS and RS tools. Respectively, GIS and RS are decision-making tools for the management of natural and manmade resources that when used properly the output gives in its entirety a view from above a picture that makes the user think spatially or the users think relationally to other features concerned.

The problem in Madang town in the future will be with the disposal of solid waste material in landfills. The existing facility that takes in the solid waste in Madang town area is an open landfill site. Though it is far from the main township there are now physical and socio-economic criteria, that, when considered completely disqualifies its very existence there. Parameters, such as the landfill site have residences surrounding it and a river that passes along the dumpsite which has a lot of people along the river bank and also it is near the Madang airport and the main highway to the north coast of Madang. The dangers which the dumpsite poses to the unsuspecting public is a health hazard that should be planned for in the name of health hazard preparedness. The sudden boom in economic prosperity has brought its share of challenges and one such challenge is accelerated waste production. This is an inevitability of urbanization, economic development, and a cultural norm of towns and cities.

Karani and Mutunga (2004) distinguished that the population increase in urban areas of Kenya resulted in a high rate of solid waste generation. Evidently, it shows in the 2000 to 2011 population census of Madang Urban. In the year 2000 Madang Urban had a population count of 28,547 and in the year 2011 the population count went up to 35,971 Urbanization and living standards in towns lead to an increase in the quantity and complexity of generated waste (Kansal, 2003). Though there is an official dumpsite managed by the Madang Urban local level government, it is not managed as expected. In most developing countries modern urban living brings on the problem of waste management, which increases in quantity and composition with each passing day (Sanjay, 2004). According to Sanjay (2004), Madang town is heading for a major disaster in waste disposal if drastic actions are not taken. Some approaches of research and findings are mostly needed to find solutions to this challenge, to at least plan for proper landfill location soon. Working with several environmental factors or parameters, we can be able to locate a scientifically suitable landfill site that is safe and far from causing harm to any human being and the towns, cities and the environment we live in. The present research seeks to identify suitable sites using RS and GIS technological tools for the area under study. With the help of buffer zones and weighted overlay analysis, potential landfill sites could be identified and used in the future. According to Chang (2010), proper landfill sites must be far from residential areas, environmental resources and settlements which is fundamentally the basis of solid waste management.

Most studies suggest that a good solid waste dumping site should be located within a 1km buffer from the roads and other transportation facilities. In the current research, a synoptic approach was taken by utilizing high-resolution satellite data to generate physical thematic layers. Site suitability analysis for urban solid waste disposal considered seven parameters such as road network, rivers, commercial zones, soil texture, slope and land use/land cover. The generated thematic maps of these criteria were standardized using the weighted overlay analysis method. A weight for each criterion was then generated and compared with others according to their importance. With the help of these weights and criteria, a final site suitability map was prepared and thus helped in determining the suitable disposal sites within Madang Urban and its nearby communities. The main analytical approaches in the present study were buffer analysis and weighted over analysis.

Buffer analysis is used in the modelling phases of urban planning and upgrading (Toosi et al., 2005). This is a spatial operational technique used in GIS to create zones within specific distances of selected features. For a buffer analysis to be effective, the buffer zone map generated must be overlaid with other layers. The weighted overlay is a spatial analysis tool in ArcGIS that is used to assess and analyze multiple factors and to derive the final output result in a single map. When performing a weighted overlay analysis, several factors with their classes are assigned weights as per % of influence to identify more suitable sites for waste disposal (Sekac et al., 2015).

2. Materials and Methods

2.1 Study Area

The study area (Figure 1) is Madang town and the surrounding area is the Madang Urban Local Level Government. The study is focused on identifying generally an aerial view of suitable areas of solid waste disposal or landfill sites. Also, a brief was prepared that considered the health hazards, which the dumpsite or landfill site has on the environment.

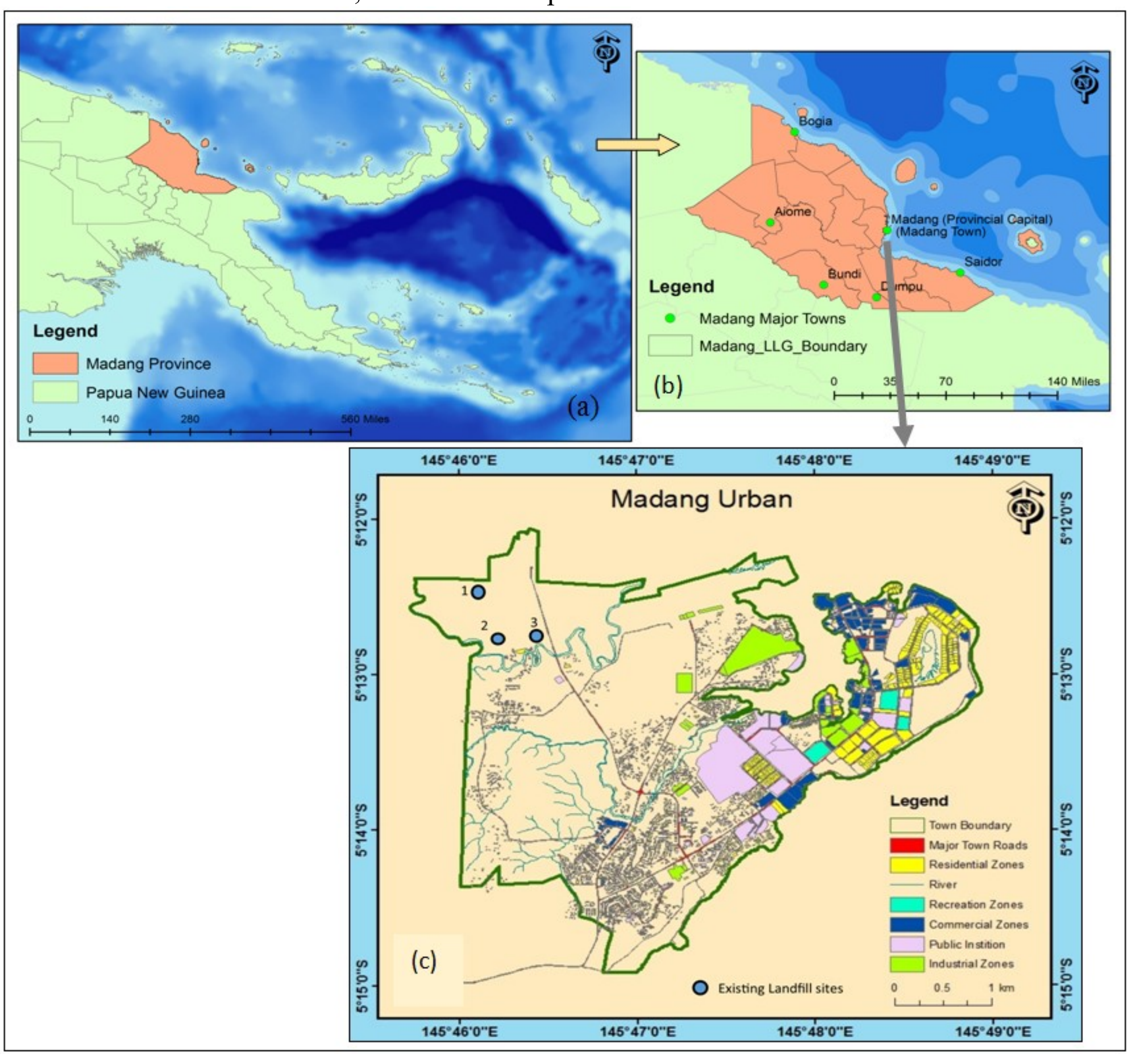

Figure 1: Location map of the study area: (a) Papua New Guinea (b) Madang Province (c) Study zone with existing landfill sites.

Madang town is the capital of Madang province and is a town with a population of 27,420 (2015) on the north coast of Papua New Guinea. There are ten local level governments, with elected ward councillors all resident in Madang Urban area. The area has coordinates of 5 degrees 13 minutes south and 145 degrees 48 minutes east with an elevation of 3m or 10 feet the above sea level. The road network is still the same as it was in the last five years, which is shown on the study site map. Vegetation is mainly shrubs, grassland, bare land and swamps and it is quite a distance from the mountains. The mountains are covered by tropical forests. Evidences of colonial housing are still there. The only later developments are the squatter settlements on State land in terms of residential zones. Also, on the study area map, two rivers run in the Madang Urban vicinity. These are the Mero River and the Wagol River. These rivers' zone has residents living along the banks, but they are categorized as squatter settlements. The northeast of Madang Urban is mostly sandy loam and silty clay loam. The north western part is mostly silty clay loam and sandy loam. Sandy clay is mostly found on the far western side of Madang Urban, while at the far southern tip of Madang Urban clay and silty loam can be found. The town is a tourist destination but is not as industrialized as Lae in Morobe province and Port Moresby in the National Capital district. However, recently, extracting industries are already operating in the province which in turn have attracted people from the rural parts of Madang province and other parts of the country to gain from the local economic boom. Commercial centres and new developments are springing up in this small urban area as reflected in the 2000 to 2011 population census of Madang Urban. In the year 2000, Madang Urban had a population count of 28,547 and in the year 2011, the population count went up to 35, 971. Current affairs on waste management are a concern right in Madang Province due to an incident earlier by a natural resource extracting company from China spilling chemicals from its tailing's facilities into the sea. That is a different subject altogether, but the concept of waste management is intertwined.

The current study is intended to identify a suitable landfill site for solid waste disposal in the vicinity of Madang Urban. According to Orathinkal (2010), the Health and Social Services Coordinator, the dumpsites 1, 2, and 3 (Figure 1c) had already reached their maximum limits covering six hectares of land with a life span of 24 years in operation. These limits are a contributing factor to water contamination and air pollution caused by poor management, dust, fumes, smoke, and particles from open burning, which also causes poor visibility for civil aviation and motorists, apart from being an ugly problem visually. Since the landfill sites have reached their maximum life span, it is advisable to locate a suitable site for a new landfill to avert the looming serious health hazards. At present, landfill 3 is close to the main highway (Figure 1c) to the north coast of Madang, which is near the airport. Hence, landfill 3 is the most used zone for waste disposal, as there are residences located near and around that landfill. This landfill is named by locals as Mero. Landfill sites 1 and 2 are not used that often because people tend to discard their wastes, not at the designated sites that the urban authorities had ordered. Ground truthing was not done here in this study but the use of google earth including the literature and previous experience have brought us to these conclusions about each landfill.

2.2 Methods

2.2.1 Data Inputs

Factors used in the investigation also depend on the localities' characteristics to form relevant thematic layers. For the study area, 7 criteria were designated and considered. These criteria include: Slope, Major Town Roads, Commercial Zones, Industrial Zones, Land use Land cover, River, and Soil Texture. The data used for criteria preparation are from Papua New

Guinea Resource Information System (PNGRIS) and Geobook obtained from PNG UOT, Quick Bird 2.8m resolution satellite image, Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM), and LiDAR Orthophoto (Table 1).

Table 1: Data layers used in this study

Data layers	Description	Data Source
Land use Land cover factor/layer	Generated from Quick bird satellite image (28.5m spatial resolution)	PNG University of Technology Department of Surveying and Land Studies
Slope Factor	Extracted from PNG SRTM DEM (90m spatial resolution)	Open Topography via the internet
River Layer	Digitized and extracted from LiDAR Orthophoto (20cm spatial resolution)	Office of Climate Change Port Moresby
Major Roads Layer		
Commercial Zones		
Industrial Zones		
Soil Texture	Shape flies extracted from Geobook (2008)	PNG University of Technology Department of Surveying and Land Studies
Madang Urban town boundary	Cadastral map shape files	

2.2.2 Analysis

The method illustrated in Figure 2 below forms the background knowledge of the analysis carried out. Erdas Imagine 9.8 and ArcGIS 10.4 software were used to extract the required information to prepare a general site suitability landfill map of Madang Urban. To achieve the objective of the study, the data identified in Table 1 were collected. The datasets were prepared in MapInfo TAB formats, which were later converted to ESRI shapefiles using the Universal Translator tool in MapInfo.

Two high-resolution images were opened in ArcGIS and every individual feature needed for criteria or thematic layer preparation was digitized and extracted. Using the LiDAR orthophoto image four (4), feature layers were digitized using the polygon creation tool in the ArcGIS work environment. The four features were the river zone, commercial zone, industrial zone, and major road zone. After digitizing the four feature zones, each digitized zone was multi-buffered using the ArcGIS buffer tool. The buffered zones were prepared because landfill sites must be situated at certain distances from the feature zones for health hazards control.

Classification of LULC was done using the quick bird image. The classes specified during classification were built-up areas, bare land and grassland, shrubs and bushes, inland rivers and lakes. The buffer zones of the river network, industrial zone, commercial zone, and major road zone were rasterized. The slope was prepared from the SRTM 30m resolution DEM. The SRTM DEM was then inputted into the slope tool for slope generation. The soil texture was prepared from shapefiles from PNGRIS and Geobook (2008) by laying the shapefile for the Madang Urban boundary on the soils texture shapefiles and clipping them off using clip tool in the arc toolbox. All projections were projected to WGS 1984 UTM zone 55S for weightage overlay analysis. No ground-truthing was done on the area of study since two high resolutions aerial images were used. This is not to say that ground-truthing cannot be done but is advised to be done to accurately locate suitable landfill sites. Figure 2 illustrates the Methodological Flow Chart used for the study.

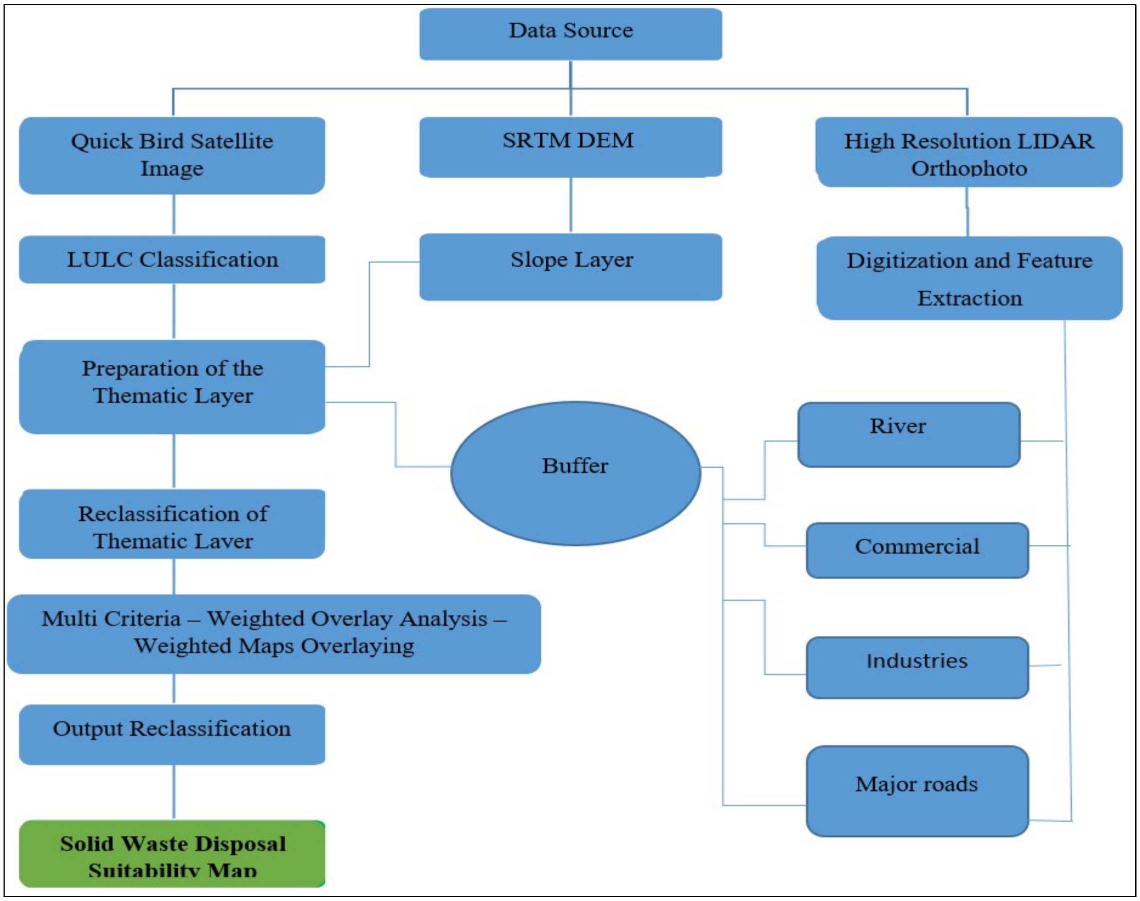

Figure 2: Methodological Flow Chart

3. Results and Discussion

Within the study region, various important criteria are usually adopted for purposes of landfill site selection. These criteria are extracted and prepared from various data sources as discussed in the second section above. Each criterion or thematic layer is individually examined below.

3.1 Slope

The slope is important in determining a landfill site for it describes changes in elevations in degrees. Madang Urban slope factor (Figure 3a) where the numbers represent the ranges of slope from less steep to more steep slope: 1, 2, 3, 4, 5. The higher the number, the steeper the degree and the less suitable a location is for a landfill site. Thus, the lower the number, the less steep is the slope, and hence the more suitable a location is to be a landfill site. Steeper altitude locations tend to let the water runoff quickly so it can wash down wastes effectively from the site. For example, “5” has a higher value, so its degree is higher the steeper the slope. In contrary, “1” has a lower value and its degree is lower, so it is unhealthy for the environment especially for people, flora and fauna living within the vicinity of the landfill sites or further down. Also, there is the possibility of the run-offs contaminating water tables since Madang Urban's elevation is 3m above sea level; as such, contamination of water table is possible. Fortunately for Madang Urban, water supply is gravity-fed meaning that it is sourced from high altitude rivers further inland. As a result, the slope factor was considered one of the seven landfill site criteria for this study. Rainfall data will highly give good standing on the slope criterion selection, but due to data availability problem, this was not included in this study.

3.2 Soil Texture

Soil texture (Figure 3b) consists of constituents of particles of certain dimensions that make up the soil and these are: Clay, Sandy Clay, Sandy Clay Loam, Sandy Loam, Silty Clay, and Silty Clay Loam. The concern here is the water absorption rate, permeability rate, swelling rate, and how the soil textures can support micro-organic life. Thus, a value of 1 to 3 was assigned to observable traits possessed by the soil texture relative to the landfill site being considered for selection. Clay for example was given "3" meaning highly suitable as it can hold water for a long time. It can help in keeping the leachate until the natural breakdown of chemicals into neutral substances can take over from there on its slow draining process to release neutral compounds into the environment. Sandy loam is given "1" for its inability to hold leachate for that long for natural breakdown to occur.

3.3 Land use land cover

Land use land cover (Figure 3c) is very important in determining a suitable landfill site. Shrubs and bushes, and bare land and grassland, are suitable locations for a landfill site compared to rivers, built-up areas, lakes, or water bodies. Within the study region, there are 6 classes of land use land cover identified and analysed; and these are Inland River, Lakes, Sea, Built-up Area, Shrubs and Bushes, and Bare land and Grassland. Shrubs, bushes, bare land and grassland are highly suitable whereas inland rivers, lakes, and seas are not suitable. This is done when weightage overlay analysis is done and values are put against each land use-land cover depending on its importance.

3.4 River Network Buffer Zone

River buffer zone (Figure 3d) is another landfill criterion that is of concern due to human habitation. Most settlements are found along rivers so buffering such places is vital to investigate distance away from landfill sites. The buffer zones created in meters were 100m, 300m, 500m, 700m and >900m. Buffers having a value of 100m is considered unsuitable whereas a buffer having a value of > 900m is very highly suitable. Depending on liability to the municipality and the limit demarcated, five (5) buffer zones were generated to identify the most suitable areas for solid waste dumping. A buffer zone surrounding a river zone at 0 - 100m distance was rated an unsuitable site, 100 - 300m was considered less suitable, 300 - 500m was considered suitable, from 500 to 700m was considered moderately suitable, 700-900m was considered highly suitable and 900-1000m was considered very highly suitable.

3.5 Road Buffer Zone

Road buffer zone (Figure 3e) is also another criterion having a huge bearing on landfill site selection. Road buffer zone was created in meters to investigate possible sites for selected landfills. The buffers created are 100m, 300m, 500m, 700m, and >900m. Buffers having a value of 100m are considered unsuitable whereas a buffer having a value of > 900m is very highly suitable. According to Ebusti (2013), landfills or dumping sites shall not be located within 100 m of any major highways, city streets, or other transportation routes. Solid waste dumping sites must be located at a suitable distance from the road network to enhance smooth transportation and reduce relative costs. In accordance with how far Madang Urban borders are, five (5) buffer zones were created to identify the most suitable areas for solid waste dumping. Buffer zone surrounding a major road at 0 - 100m distance was considered an unsuitable site, 100 - 300m was considered less suitable, 300 - 500m was considered suitable, 500 to 700m was considered moderately suitable, 700-900m was considered highly suitable, while 900-1000m was considered very highly suitable. A buffer too far from the road will increase costs; too near health hazards will be a health hazard to the traveling public.

3.6 Commercial Zone

Another criterion having a huge bearing on landfill site selection is commercial buffer zone (Figure 3f). Given the extent of the jurisdiction of Madang municipality and the limit delineated, five (5) buffer zones were considered to identify the most suitable areas for solid waste dumping. The buffer zone surrounding the major road at 0 - 100m distance was considered an unsuitable site, 100 - 300m was considered less suitable, 300 - 500m was considered suitable, 500 - 700m was considered moderately suitable, 700 - 900m was considered highly suitable, and 900-1000m was considered very highly suitable. The economic boom in the province has made this criterion to be considered in terms of traders' connections/links to the big natural extracting companies.

3.7 Industrial Zone

Other criteria having a huge bearing on landfill site selection are industrial buffer zones (Figure 3g). Buffers assigned are 100m, 300m, 500m, 700m, and >900m. Buffers having a value of a >500m are considered suitable whereas buffers having a value of < 500m are not suitable. According to the extent of the city and the boundaries demarcated, five (5) buffer zones were created to identify the most suitable areas for solid waste dumping. The buffer zone surrounding a major road at 0 - 100m distance was considered an unsuitable site, 100 - 300m was considered less suitable, 300 - 500m was considered suitable, 500 - 700m was considered moderately suitable, 700-900m was considered highly suitable and 900-1000m was considered very highly suitable. The latter zone was included since it produces a significant urbanization impact for a society that needs to develop at a fast rate but with immense waste generation.

3.8 Preparation of landfill site criteria thematic layers and output results

As mentioned earlier, seven (7) landfill site criteria were investigated in this study. Thematic layers were formed by re-classing the criteria in agreement with their perceived liability. Every weight assigned is tabulated in Table 2. The final output was prepared, which highlights the suitability of solid waste disposal as illustrated in Figure 4. Seven thematic layers, namely river buffer zones, road buffer zones, land use land cover, slope, commercial, and industrial buffer zones, were reclassified using the "reclassify" tool in ArcGIS 10. 4 that agrees with the weights scale range of 1 to 5. The weights were assigned to each class, subject to their relative significance in support of pinpointing suitable sites for waste disposal. To distinguish between the suitable and the unsuitable, numbers were assigned to the weights. Here, a weight of 5 indicates "high suitability" and a weight of 1 indicates "not suitable". For example, the landfill site criterion "bare land and grassland" in the landfill criterion LULC is given the weight of value "5" because this class was identified as a very highly suitable area for solid waste disposal. Water, on the other hand, is given the weight of "1" the lowest value due to its vector-borne disease capability. With that said, Madang Urban's water supply is collected outside the boundary where the study is concentrated on.

Table 2 indicates all weightages assigned to each criterion. Buffer zones, for example, the class “100-meter buffer zone" in the landfill site criterion river buffer was assigned the weight of "1" which is the lowest value because it is the zone that was identified as a very unsuitable area for solid waste disposal. The class ">900 m buffer zone" was given the weight of "5" because this zone is identified as highly suitable zone or site for solid waste disposal. The weightage was assigned to each landfill site criterion class and a % of influence was assigned to each criterion. The same was done for all landfill site criteria selected. Table 2 shows the weightage and % of influence assigned to each factor and their class.

Table 2: Ranking and Percentage Weightage of Landfill Site Criteria

Criteria	Percentage	Sub-criteria	Weightage	Level of Suitability
Slope	10%	Very Low (1)	5	Very high
		Low (2)	4	High
		Medium (3)	3	Moderate
		High (4)	2	Less suitable
		Very High (5)	1	Unsuitable
River Zones	16%	100m	1	Unsuitable
		300m	2	Less
		500m	3	Moderate
		700m	4	High
		>900m	5	Very high
Industrial Buffer Zones	16%	100m	1	Unsuitable
		300m	2	Less suitable
		500m	3	Moderate
		700m	4	Highly
		>900m	5	Very highly
Major Town Roads	16%	100m	1	Unsuitable
		300m	2	Less suitable
		500m	3	Moderate
		700m	4	Very highly
		>900m	5	Unsuitable
LULC	10%	Sea	1	Unsuitable
		Inland river	2	Unsuitable
		Lakes	3	Unsuitable
		Bare land grassland	4	Very Highly
		Shrubs & bushes	5	Highly
Soil Texture	16%	Silty loam	2	Unsuitable
		Clay	3	Very Highly
		Silty Clay loam	3	Highly
		Sandy loam	1	Unsuitable
		Silty Clay	3	Moderate
		Sandy Clay	2	Unsuitable
Commercial Zones	16%	100m	1	Unsuitable
		300m	2	Less suitable
		500m	3	Moderate
		700m	4	Highly
		>900m	5	Very Highly

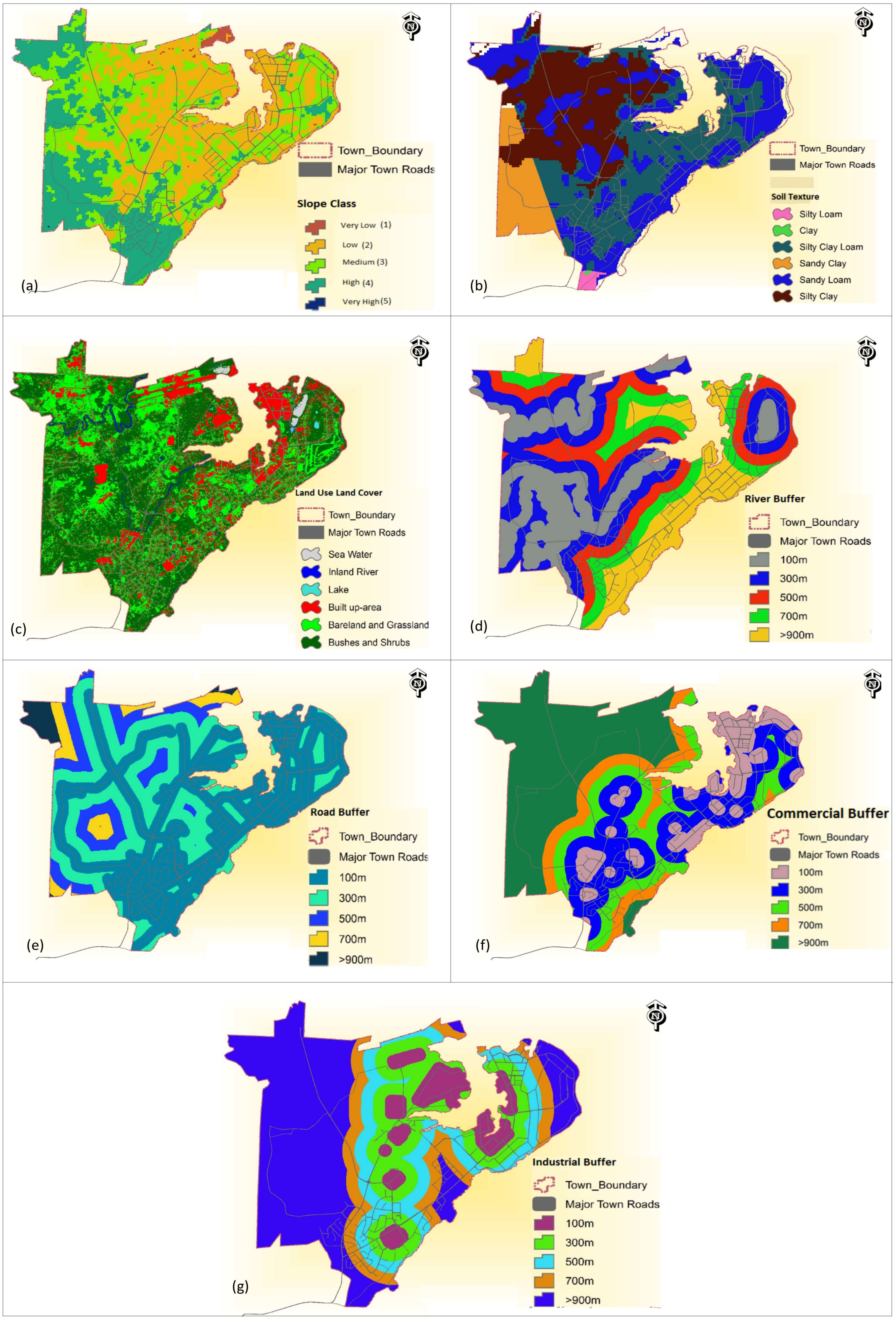

Figure 3: Madang Urban (a) Slope (b) Soil Texture (c) LULC (d) River buffer zones (e) Road buffer zones (f) Commercial buffer zones (g) Industrial buffer zones

Figure 4 illustrates the final output laying out suitable and not so suitable locations for landfill sites in Madang Urban. The colours in the legend give colours of suitable and not suitable areas. Figure 5 illustrates the percentages (%) of area coverages of levels of landfill suitability.

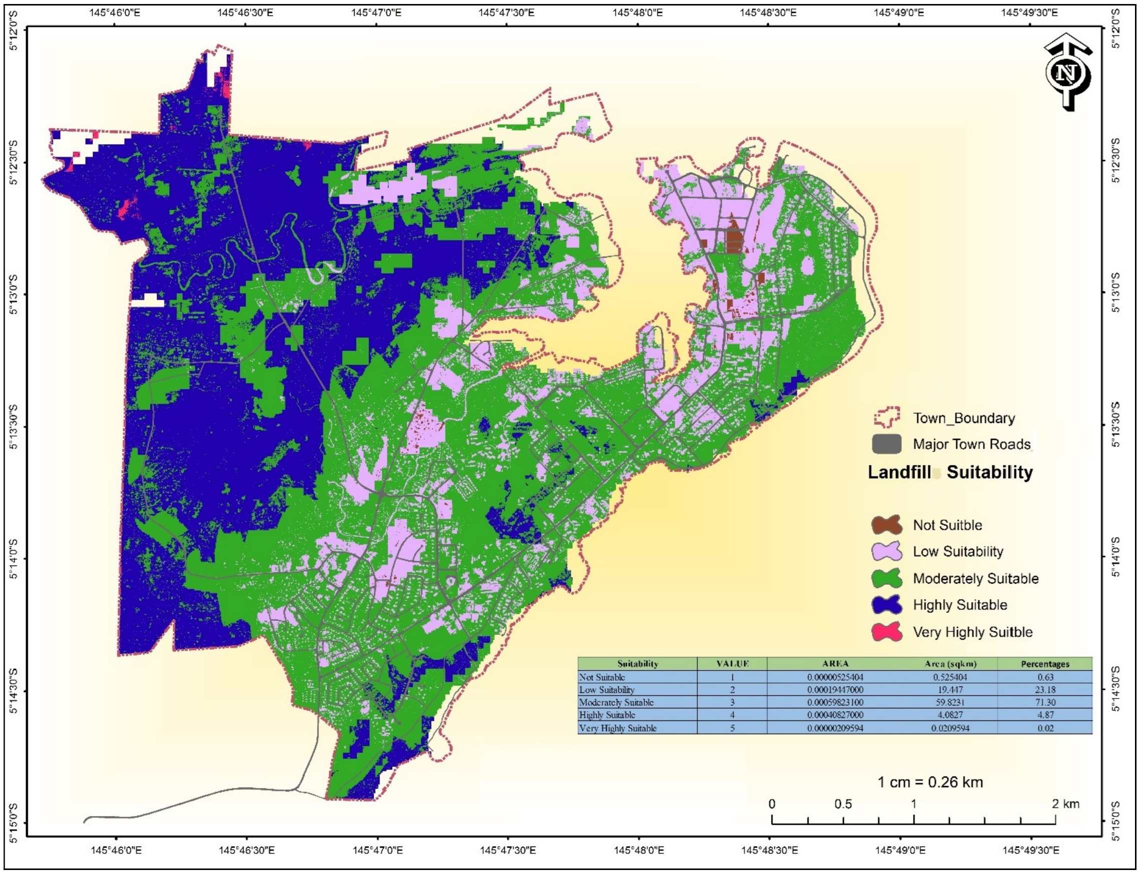

Figure 4: Madang Urban Landfill Suitability Sites.

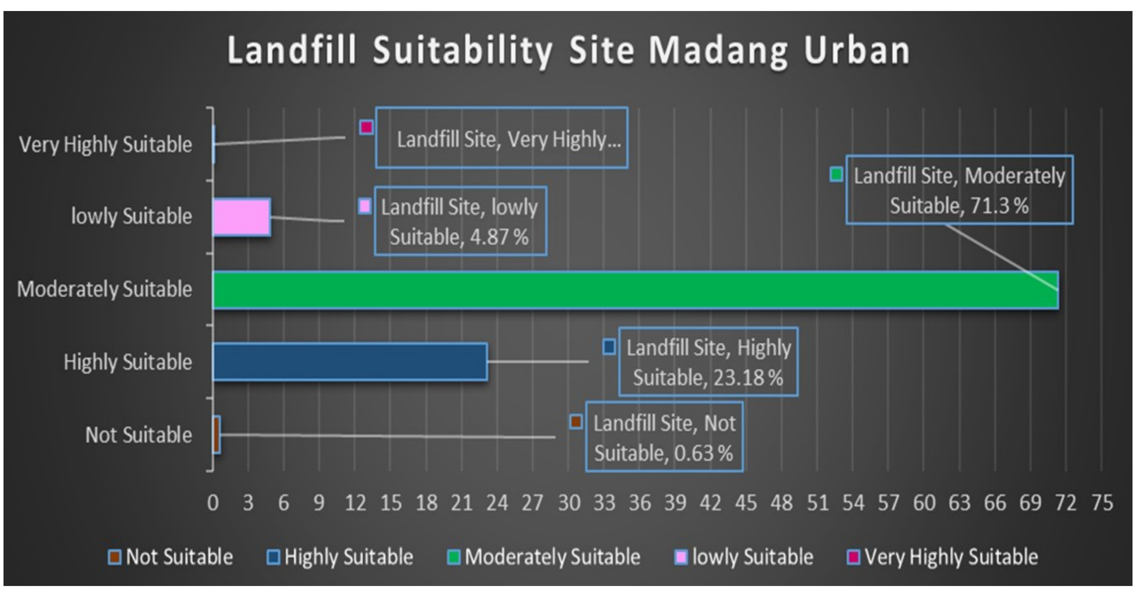

Figure 5: Landfill suitability zones in percentages (%)

It can be seen from Figure 5 that 71 % of the areas in the Madang Urban zone are moderately suitable for a landfill site, 23.18% are highly suitable, 4.87 % lowly suitable, 0.63 % not suitable, and 0.02% very highly suitable. This analysis is the result of the weighted overlay analysis from the incorporation of the seven landfill site criteria. The actual charts were created from the tabulated results generated from the final output map. Table 3 reflects and is related to Figure 4, tabulating the output of the landfill site suitability of Madang Urban. The colour shadings depict the legend of the final output map itself.

Table 3: Site suitability values of Madang Urban landfill sites reflecting Figure 4.

Index	Suitability	Value	Area in sq. km.	Percentage
	Not Suitable	1	0.525404	0.63
	Lowly Suitable	2	19.447	23.18
	Moderately Suitable	3	59.8239	71.30
	Highly Suitable	4	4.0827	4.87
	Very Highly Suitable	5	0.020959	0.02

4. Conclusion and Recommendations

The study was designed to identify suitable sites for Madang Urban solid waste disposal through the application of Remote Sensing and GIS technologies. The Remote Sensing and GIS approaches have proven to be successful with regards to the two objectives of the study, namely: to identify appropriate landfill site criteria, and then to apply those criteria in the GIS platform to produce an output. The applications of the multi-ring buffer tool and the weighted overlay analysis tool have been utilized as they are helpful in producing desired outcomes. The buffer tool in GIS was used to create zones within specific distances of selected features. For a buffer analysis to be effective, the buffer zone map generated must be overlaid with other layers.

The weighted overlay was used to assess and analyze multiple factors and to derive the final output result map. When performing a weighted overlay analysis, several factors with their classes are assigned weights as per % of influence. More criteria can be incorporated; however, in the current research, the researchers selected seven criteria based on what they thought was important of all or others. Furthermore, availability of data and processing tools was considered. As mentioned earlier, the existing landfill in Madang Urban area was disregarded due to the fact the study seeks to examine generally where suitable and not suitable landfill sites can be in Madang Urban. More emphasis in the current research is to produce a general synoptic view of the whole of Madang Urban area’s suitability sites for landfills, disregarding the existing landfill site. Any later research can use the current research background information as a stepping stone to identify more suitable sites for selection as landfill sites. The current research was done solely remotely meaning there was not any ground-truthing involving the usage of GPS, interviewing people on the ground, or completion of questionnaires.

Ground truthing, such as administration of on-the-ground interviews, collecting GPS points, and filling out questionnaire forms, is advisable when doing a detailed constraint mapping of suitable sites generated from the landfill site criteria described in this paper. Generally, the output map can be used simply as a start baseline to accurately produce a landfill site map in the future. Using this landfill suitability map as a guide to do more detailed studies of the

Madang Urban area is a step forward in realizing the approach of how Remote Sensing and GIS can revolutionize decision-making in the area of solid waste disposal management.

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