

GIS Coursework

CS3210

Household waste dumping site selection

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**Background Research**

[1] Used GIS to tackle the problem of finding appropriate sites for solid waste landfills in densely populated areas. Considering the issues of disease, odour nuisance, atmospheric and water pollution that could affect the cities if landfill sites are not correctly chosen.

Using geographic information system and a proposed method of multi criteria decision analysis with respect to environmental, economic and ecological factors they were able to choose effective landfill sites for disposing of solid waste.

Method of approach was by first surveying the area for relevant data that will enable them to select the sites. Creating several maps featuring water bodies, agricultural land, structures etc. [1] To create context and understanding of the area they are dealing with, as well creating various buffer zones around residential, commercial, agricultural areas to identify exactly where proposed landfill sites could be placed.(USING GIS)

After this MDC (multi-decision-criteria) analysis was used [1], whereby the landfill sites are chosen based on several pre-determined factors. For example climate, wind direction and soil condition, including the fact the council prohibited filling any area greater than 0.5 acres and 300 metres away from ponds to further filter out the number of possible landfill sites based on the criterion.

This research has proven to be positively impactful, as it has aided by giving valuable information which is given to the policy makers within Chittagong. Highlighting their need for re-evaluating waste disposal sites.

However, a weakness of this study is, that it requires further analysis of the soil type to identify whether these landfill sites are truly appropriate. As one test result is not enough to justify whether that landfill site meets the requirements that have been set based on the constraints.

Overall, this paper has been effective in identifying suitable landfill sites of the given study area by using GIS alongside with an MDC model, that ensures possible sites meet the criterion.

[2] Also bases its study of choosing landfill sites in a densely and highly populated city in India known as Kolkata. The main issues this paper tackles in trying to select such sites, is the effect that these landfill sites will have ecologically, environmentally and accessibility of its inhabitants much like [1] did, which imply that these factors are imperative when choosing landfill sites for cities.

By using the powerful tool GIS in conjunction with the government policy of solid waste management CPHEEO, there is a set of criteria that must be met when choosing landfill sites which are based on accessibility, receptor, environmental, socioeconomic, waste management practices, and climatological and

geological criteria

[2] Uses GIS to create various layers and maps. For example, creating a map which displays vegetation, towns, water bodies and fallow land within the study area to create a composite layer from all of them to make easier visualisation and compare it to the possible landfill sites.

Many map layers made including wasteland, slope and elevation, forest, commercial areas etc. For the same reasons [1] did, to identify and separate specific areas and create buffers around them to find out where possible landfill sites can be chosen out of the proposed areas based on a set of criteria i.e. “no landfill site can be built within 20km of an airport”. Which is also known as spatial analysis [2]. And from the various maps created, with the given criteria the possible number of landfill areas are filtered out.

This research makes it a standing point that waste dump selection is crucial to the development of an area, as well as preserving its environmental structure. This paper proposes by using GIS and Remote sensing, they were able to choose appropriate landfill sites. Based on a Multi-Criteria-Evaluation (MCE) method similar to [1] and [2]’s MCD criteria and sensitivity index methods respectively.

By using GIS, the researchers were able to create various maps and layers consisting of important data which they then analysed based on their MCE method which took into account distance from centre of town and wind direction [3] for identifying and choosing various appropriate landfill sites which met the criteria that have been set.

Similarity between this paper and [1] and [2] is that they all survey the study area to create various thematic maps, which consist of important data that they need, when choosing a landfill site. By creating various map layers, they can analyse them and create composite layers such as buffer layers around certain map layers such as roads, agricultural land etc. to filter down possible landfill sites.

In addition, it takes into account population growth and the size of waste generation produced from the growing population much like [2] did based on a statistical analysis of populated areas, and rate of growth using data and map layers from the past of the study area. To find suitable landfill that will still be ideal in the years to come.

This paper based its site selection of landfill areas using a hierarchical decision model, which uses different categories and the various factors that could affect those categories which each have a rank and a weighting. Where lowest rank indicates that it is least suitable, and high indicates most suitable. (see Appendix C).

[4] proposes selection of landfill sites, in Lahore based on processing and analysing spatial information obtained by using GIS to create various and relevant map layers.

Creating raster layers such as water bodies, roads, “important places” and existing dumping sites [4]. Which has been done in all the aforementioned papers.

The paper similarly to all the others makes an important note of how densely populated the study area as, as well as the positive correlation between increasing population and waste generation.

Additionally, much like the other papers bases its site selection from the analysis of the various map layers created and a set of constraints which focuses on economic and environmental factors. Such as, sites are not able to be more than 300 meters in proximity to roads achieved by buffer zones.

This paper proposes a criteria index which uses a formula for deciding a suitability value of a site based on the constraints set using a Boolean restriction model [4] by only displaying suitable areas on the raster map as a 1 and non-suitable areas as 0 (blank space).

Conclusion of Background Research

All research papers address the problem of finding suitable landfill sites based on a set of constraints by using GIS, a powerful tool for creating various map layers allowing for analysis of data and gaining a better understanding of their given study areas which allow for them to identify the most efficient and effective (suitable) landfill site.

By using GIS and a pre-deterministic list or model of rules, they can find landfill sites that promote economical, ecological and societal development of the area.

Requirements:

Continuing from the conclusion of the background research. According to all the past studies and research discussed, their methods included creating base maps to create thematic layers which offer valuable information enabling for effective analysis.

This includes creating a topography and land coverage layer. Topography layer will consist of map features regarding roads, structures, motorways etc. As well as the land coverage map providing data including water bodies, forests, arable land, agriculture and such.

These map layers will form the foundation of this study as the base maps. By creating a composite map from these two layers, it allows for easier analysis to filter down possible landfill sites by looking at where the landfill is located. I.e. if a landfill is located next to a road, or water body it should be ruled out based on the constraint set keeping in mind it should be environmentally sound and avoid disruption to the scenery etc.

However, there are more maps to consider from the base maps generated as well as the data sets provided.

Firstly, extending from the topography and land coverage maps, it may be beneficial to create certain buffer layers from features within those maps using the default GIS raster maps. For example, buffer layers for water bodies or roads etc. By creating appropriate buffer maps, it allows for easier analysis and understanding of generally what landfill sites are most appropriate based on the constraint of being environmentally sound to ensure that landfill site is built beyond these specified buffer zones.

Additionally, there are various data sets that have been given to consider when choosing the landfill site. Many layers should be created from these and combined with others to derive very important data that will be crucial. One example is to re-class the soil layer to only indicate areas with a preferred soil type. As the desired soil type will be cheaper to build the landfill on that some others.

As well as this, there are various different layers that will be important to the analysis of this study including: Net Income Survey, Wind Speed, Days with Fog, Mean Sunshine Hours.

By using the Net Income survey map, it allows us to see the locations of the population throughout Leicester. Indicating general locations which should be avoided when choosing the landfill, attempting to disrupt the population as least as possible.

With the wind-speed layer, this information highlights the average annual wind speed within different locations. Using this map to reduce air pollution is possible if selection of landfill is not placed in areas with high annual wind speeds.

Including this, it is possible to preserve the beauty and nature of the environment further when choosing the landfill regarding Days with fog map which indicates the average number of days that are foggy in different locations. By analysing this map data, choosing the landfill to be in areas where it is most foggy will not dramatically affect the environment as well as it not disrupting the scenery very much.

Moreover, Mean Sunshine Hours map shows the average hours of sunshine of each location in the study area. Analysing this map, can enable choice of landfill to be placed in locations where the mean value is low therefore affecting the scenery as little as possible.

Using all these layers, it is possible to derive more data from combining certain layers together. For example, compiling all the buffer layers into one single layer allows easier analysis and comparison to other maps. Additionally, combining the mean number of hours map and annual average temperature map will give birth to a map that shows areas which tend to be colder which is good as hot temperatures will enhance the smell of the landfill and cause great air pollution. By combining these two layers it makes it easier to see which areas the least significant negative impact will have to build landfills by minimising air and scenery pollution.

Another potential requirement that could add value to the analysis is by using a form of classification model, or rule list. To filter out what sort of landfill locations should be more suitable than others which will aid creating the various different buffer layers. For example, in the background research [1] and [2] used sensitivity indexes and MCD to shape their maps by creating buffers of specific distances from water bodies and roads to ensure that their landfill choice does not negatively impact the environment and populace. Perhaps using a similar strategy to classify suitable landfills will provide for better results.

Conversely, perhaps adopting a similar approach to [3] by using a hierarchical model that gives weights to various different categories and calculates the weight of the potential landfill site based on what attributes it takes from each category i.e. type of soil can be weighted as 0.25, distance from water bodies = 0.35 etc. By doing this it allows for an objective analysis of which landfill is most suitable while keeping in mind the different factors it should uphold.

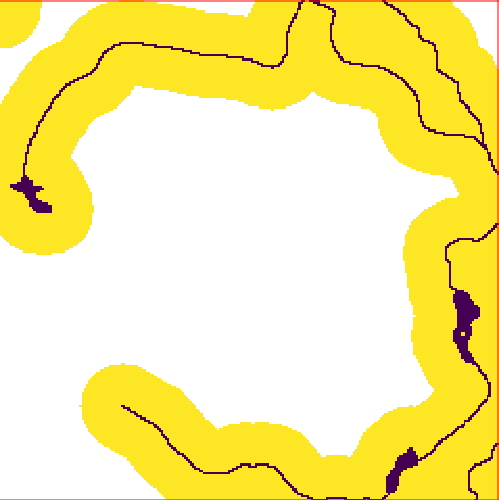
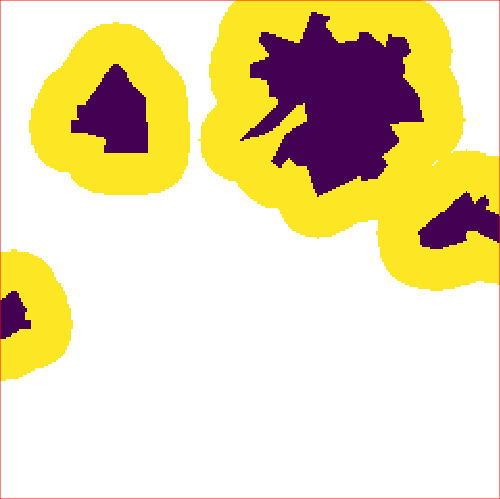
**Design and implementation**

The method used in Grass to answer this problem, was performing a survey analysis by studying the area via obtaining important and relevant map layers. This included creating ‘base’ maps which consisted of a topography layer which gave details regarding roads, structures, motorways etc. As well as the land-coverage map giving information such as water bodies, urban areas and the like.

These maps were then broken down and extended further into sub-set maps, buffer maps which were derived from features within the base maps (water) or available raster maps Grass has provided such as urban. This included creation of urban-buffer, water-buffer maps. In order to analyse and filter general areas where landfills could not be built via use of the r.buffer command within Grass, distances of buffers varied depending on the feature the buffer was applied to i.e. 300m for roads, 1km for water-bodies. Moreover, all the buffer layers created initially were combined into a single buffer layer by using the r.mapcalc command via if(isnull) to change the values to make it easier to analyse but also make it understandable exactly what positions were valid for the landfill. All these Buffer layers were necessary in order to filter out possible locations for the landfill based on the criterion, to maintain the local environment.

By creating a buffer map for the water bodies, the possibility of pollution in water areas becomes very unlikely.

In addition, buffer zones around the urban areas ensure that densely populated places won’t be disturbed by the landfill and the smell should be far enough away from them. Moreover, a buffer map was created for existing landfills as well since if the new landfill was built within near proximity of an existing one it would be inefficient as well as greatly impacting the environment and the people. As these already built landfills are within the buffer zones that have been created which is evident in the combined buffer layer.

Figure 1- Water buffer map (distance 1km) Figure 2-Urban area buffer map (distance 300m)

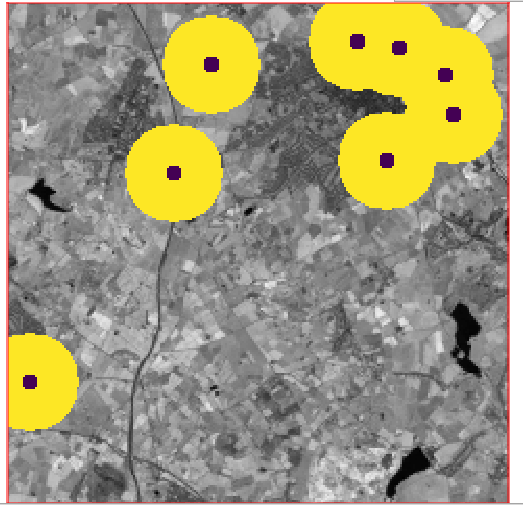
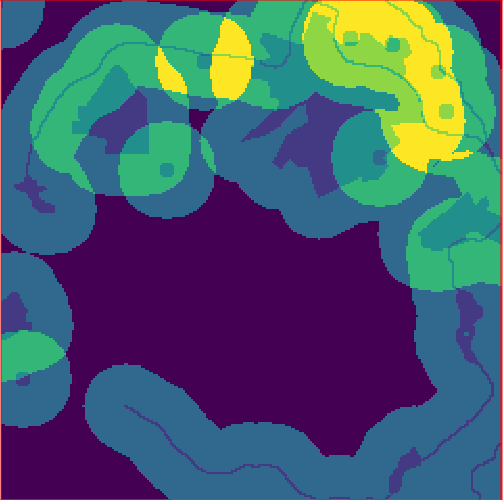
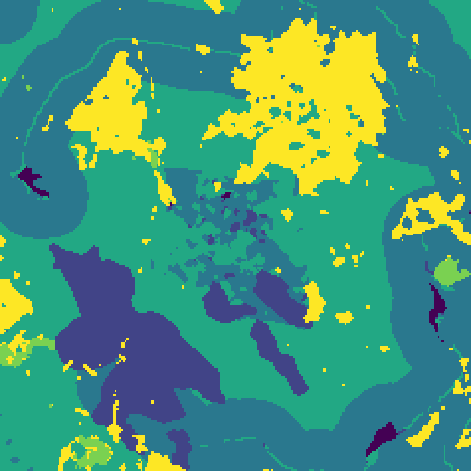


Figure 4- Combined buffer map layer from urban, water and waste site buffer maps

From the combination of all buffer maps, a spatial analysis makes it clear to see the general areas that the landfill should be built (in purple zones) to ensure that the landfill does not pollute nearby urban areas affecting the local people as well as contaminating the water bodies which was enabled by setting specific buffer ranges around these land coverage features.

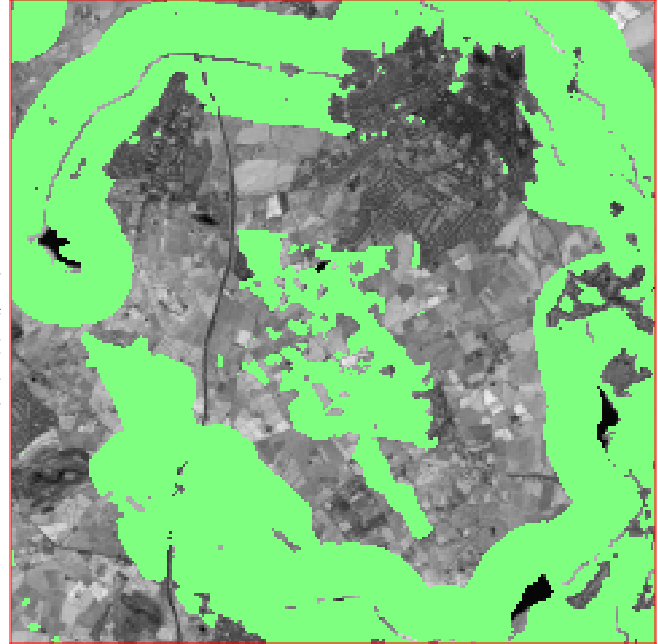
Figure 3- Buffer Zone map on Existing waste sites



Created a soil map, to identify areas that would be the easiest areas to dig, in respect to the council’s budget. As finding areas such as sand and clay, are much more convenient and cheaper to place landfill sites as opposed to a built-up area.

Looking at the soil map it indicates different features of soil type. 1 = sand, 2 = clay, 3 = loam, 4 = exposed rock, 5 =built up area.

Figure 5 - Soil Raster map indicating the various soil types



Reclassification of the soil map, to indicate areas which only contain values 1 to 3 which are set to 1. And any other value is 0 (invalid).

Allowing, easier identification for suitable areas for the landfill based on the type of soil.

Figure 6- Reclassified Soil map

Then a grade map was created from the reclassifying the landcov map by converting pasture and scrub areas to 1 and every other type to 0, as they are the only areas that are best suited for the landfill with regards to the environment and budget criterion. For example, placing water into the grade map is redundant as we want to place the landfill in areas that will not pollute the water, like-wise woodland areas being removed harms the environment too. Also, impractical and economically infeasible to place the landfill in residential areas.

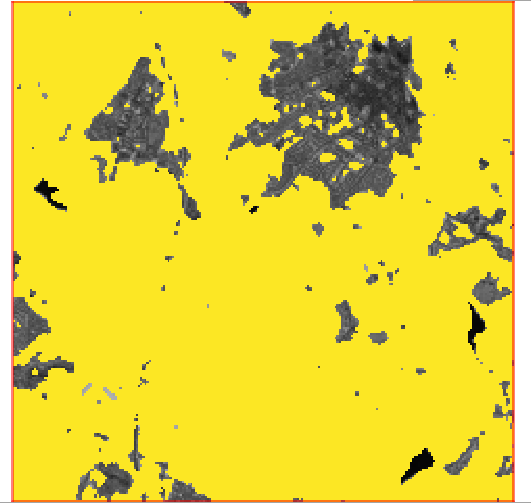


Figure 7 - Map showing areas which contain pasture or scrubs only

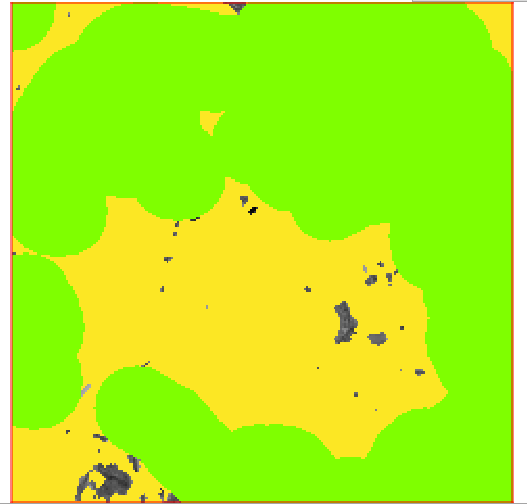
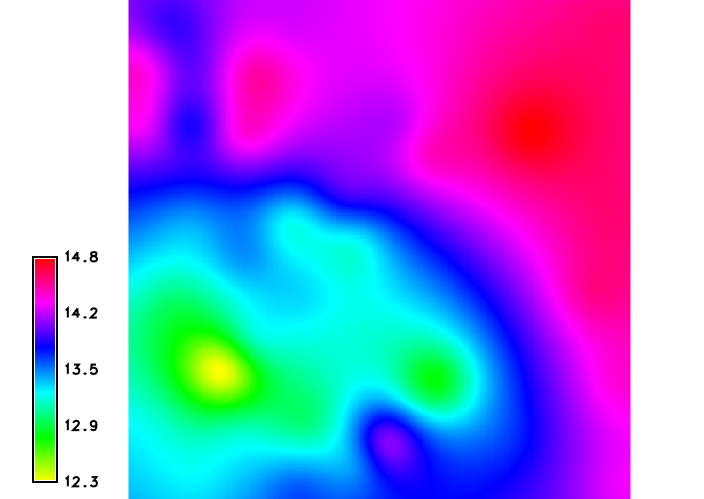


Figure 8- Map layering buffer layer over grade map

For analysis it was imperative to layer the combined buffer map on top of the graded areas, to locate general areas for where the landfill should be placed. Yellow indicating possible locations while the green areas act as exclusion zones.



Annual average temperature map was created from importing vector points which provided a select few sample locations. Therefore, in order to generalise that data on the entire study area interpolation was used. By first creating a raster map version of the vector data, and then using the B-spline method which gives estimates for raster cells which contain no data based on nearby data.

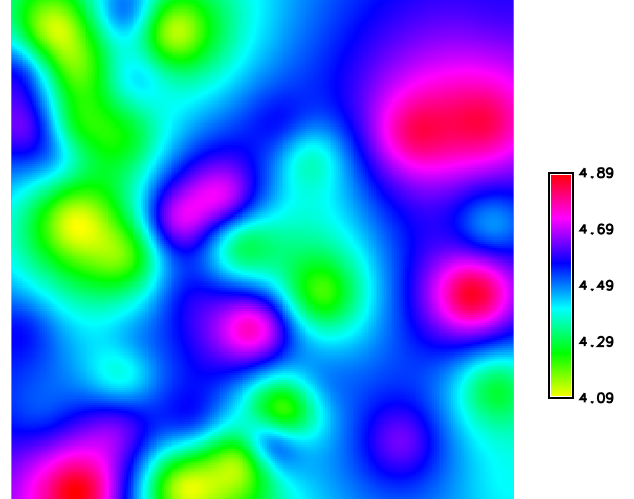
Figure 9- Interpolated map from sample vector data of annual average temperature



Then from the interpolated map, a reclassification of it was performed in order to find areas which had low annual average temperatures.

0 to 13 degrees being ideal (set to 1) and anything beyond that invalid (0).As stated before, hot temperatures can drastically enhance the odour of landfills and cause significant air pollution to the area.

Figure 10- Reclassification of interpolated annual average temperature map



Additionally, an interpolated map of average hours of sun a day was creating from the given vector data set. Via the same method before (B-Spline). This map was needed in order to find locations in Leicester that had low number of hours of sun, so that when selecting locations for the landfill, there is less chance of it being put in an area with lots of hours of sunlight limiting the effect to the scenery.

Figure 11-Interpolated map of Daily Hours of Sunshine



Composite layer from sieve mapping the low temperature and low sun hour maps together to identify area in Leicester that has lowest temperature and lowest sun hours. To place landfill site in order to minimise air pollution as hot temperature enhances smell, and low sun hours to reduce impact on scenery of area.

Figure 13- Composite Map combining Re-classified Annual average temperature and Daily Hours of Sunshine



The LowSunandTemp map was merged with the good soil map to locate areas that meet all 3 criteria’s from each map i.e. yellow locations indicate areas which have good soil, low annual average temperatures and low average daily sunshine.

Figure 14- Composite map merged with good soil map



Merged grade3 map with the goodsoil and LowSunTemp map to identify areas which all fit into these different constraints of, good-soil, low annual average temperature, low annual hours of sun and low cost to build land.

Figure 15- Grade3 Map combined with goodSoil map, LowSun and LowTemp map



The combined buffer layer was then merged with the previous map to create a new layer which indicated areas that had low hours sunlight, low temperature, good soil and that are outside the given buffer zones to avoid polluting water and disturbing the urban area. Including the identification of the grade land (pasture or scrubs)

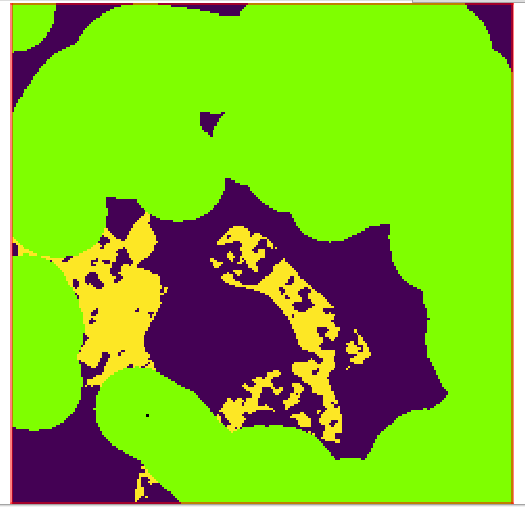


Figure 16- Buffer map layered over newly created composite map

Figure 17- Buffer map combined with composite map



Figure 19- Reclassification of clumped map to only show areas which are 2.4 hectares or greater

Figure 18- Clumping of the previous map to find size of areas



Figure 12- Reclassification of interpolated Daily Fours of Sunshine map

Afterwards, the map was reclassified in order to find areas deemed ‘suitable’ (areas which consisted of 0 to 4.30 hours) of sunshine converted to value of 1 and anything else is invalid (value of 0).

Afterwards, clumping the map was needed to find out the size of each area in hectares (figure 18) look at appendix A for detail. Then reclassified that layer to only show areas which are 2.4 hectares or greater, as according to NASA the average landfill size is 2.4 hectares [nasa??]

**Evaluation**

From an objective standpoint, there are many strengths to the methodology that was implemented in identifying and choosing a new landfill site in Leicester.

Mainly, identifying and creating ’base’ layers from the landcov raster map to survey the area for map features such as water bodies, urban areas etc. In order to extend from this map and derive further information for spatial analysis. In this case, the features extracted were then converted into buffer layer maps to ensure that the landfill site was placed in an area that could potentially adversely affect the people and the environment.

Additionally, the combining of map layers through a GIS technique known as ‘sieve’ mapping proved very useful, to collate all the maps together in order to break down the information for easier visual understanding. By, doing this as seen in figure [] it is clearly visible what areas are valid locations for the landfill while keeping the criterion of environment and population disturbance into account.

In addition to this, a widely known technique ‘Interpolation’ was crucial to the analysis of this task. By taking vector data which gave a sample of a select few locations, by interpolating with GRASS it was made possible to generalise that sample of data to all the raster cells to give a realistic estimation of the entire area using the B-Spline interpolation technique.

Moreover, the reclassification of these interpolated map layers allowed for filtering out specific areas to build the landfill based on the requirements for easier visual understanding. i.e. in figure [] this map indicates clearly what areas contain low or high temperatures.

However, there are some weaknesses to the methodology used in order to determine a valid location for the landfill site. The analysis section is greatly limited due to the amount of data used, despite using various different maps to ensure the landfill was chosen based a set of criterion (environmental, urban population and scenery).

The study lacked a cost analysis in order to determine the most economically feasible locations. The only map that was used to analyse the cost was through re-classification of the soil to identify what areas are easier to dig up which associates itself with cost and environmental benefits. An improvement for this study would be to reclassify the landcov layer and change the values of the types to ones which are implicit of its cost. i.e. changing 2 (Residential areas) to 10 as tearing up residential areas for a landfill would carry a huge cost.

Also, another weakness is that there was no decision model to assess the cost-benefit between various factors much like in the studies in the background research. [3] uses a MCE method for assessing the different categories and each requirement has a weight. i.e. if a location chosen has bare land, but its topography slope is greater than 25% despite it having a bad incline the type of land it on weighs more and thus can be considered as a suitable location meaning there is more flexibility and choice for “suitable” landfills. In comparison to the methodology used for this study where the decision criteria is binary, i.e. if the land is not pasture or scrub it is considered invalid.

Conclusion

Overall the methodology used to solve this task was effective and efficient, through surveying the area for valuable information which acted as the foundations for analysis of this entire study to further derive data and extend these given maps to create additional ones which offer a different perspective of information such as buffers in order filter out areas the landfill cannot be placed ensuring the environment, and urban population are not adversely affected. Through the use of modern GIS techniques such as sieve mapping of various layers and interpolation, possible landfill sites were able to be identified based on the set of criterions.

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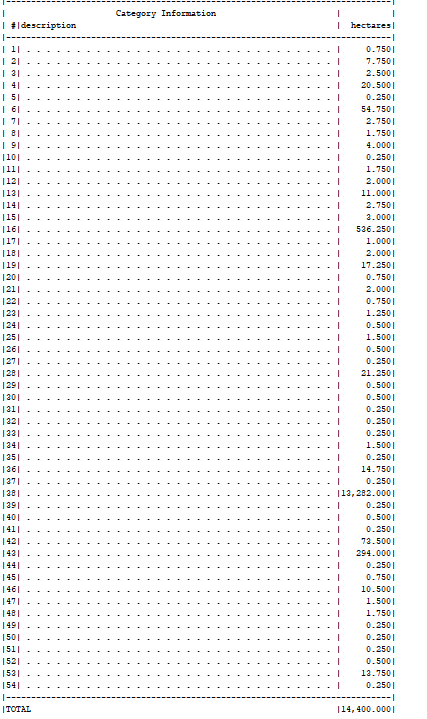
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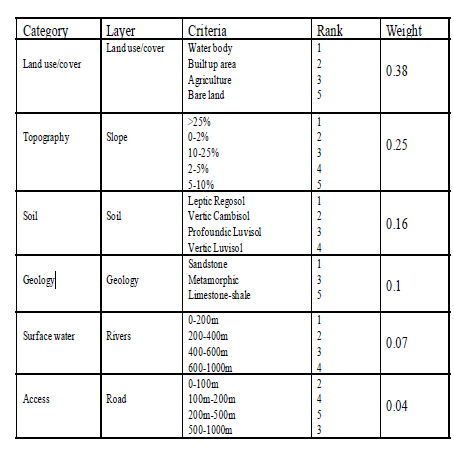
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Appendices

Appendix A – Legend for clumped map of suitable landfill sites.

Appendix B- Table indicating the clumped map and the size of each area in hectares.



Appendix C – Table from [3] showing the MCE model