# A Geo Model for Landfill Site Selection Process

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***Abstract*— *A serious and growing potential problem in large urban areas is shortage of land for waste disposal. An inappropriate landfill site may have negative environmental, economic and ecological impacts, which can be mitigated through locating waste disposal sites in suitable places by conducting precise and transparent land filling site selection. Globally, different tools and techniques are used to select suitable and sustainable land filling sites. Yet in Sri Lanka, proper practical mechanism is not seen. This study investigates using geo-informatics as a solution for enhancing success of land filling site selection process. GIS provides infrastructure for spatial data processing and analysis. Especially in spatial modeling GIS vitally helps to integrate spatial data and generate information. Moreover, it makes handling and analyzing massive amount of geospatial related information easier. Ultimate objective was to develop a geo model, with reusable Model Builder for land filling site selection process which facilitates Multi criteria Decision analysis (MCDA) where several criteria for coming to conclusion for selecting suitable and sustainable waste disposal site are compared. Model Builder can simplify diverse and dynamic inputs for complex analysis functions. Users can change governing parameter for data set in Model Builder according to expert knowledge and preference. Model Builder application for waste disposal can be used for site selection process in country as a standard way, applying few artefact modifications. Research was conducted within inductive research paradigm. Initial geo model was developed for North Central Province, Sri Lanka. To select suitable and sustainable locations, several criteria i.e. land use type, access roads, residential area, stream lines and catchment areas were addressed. Mainly distances from various sources to location play a vital role in this selection. With parameters and data layers provided by user, Model Builder generates most suitable land areas in the North Central province with the informative map. Furthermore this geo-model enhances capability of making prior decisions.*

***Keywords*— :** *Geo-informatics, Geospatial, Geo-Model*

## I. INTRODUCTION

Solid waste management is a key service or a facility provide by every government and the responsible authorities in order to make the lives of the people more comfortable. Increasing of the population and the advancements in technical industries related developments parallel to the rate of population growth is making the process of solid waste management worse by giving additional burn to the waste management criteria and more disposal to be managed. So the proper solid waste management process is vital to be come in practices in order to overcome the constraints arise though the waste disposal.

Waste is generated globally and make direct constraints to the lives of the people. The waste is usually categorized into main three as liquid, gaseous and the solid. Certainly wastes of the gaseous are expose to the atmosphere with or without treat them before discharge depend on the rules and regulation of the each states. And the liquid wastes are expose in to the water bodies or in filter to the ground. So many countries are using the various methodologies in order to mitigate the constraints occur due to the constraints in the waste management process.

Sri Lanka is a tropical country located in the Indian Ocean. It occupies the total land area of 65, 610 km2 and population of the 20.38 million (Wijerathna et al 2002) Moreover the urban population is around 16. 3 % .in the context of rural area statistics it is 83.7% and the population growth rate is 0.7%. Population and its growth is main factor that affect to the solid waste management process. With the increasing of the population, quantity of generating the wastes is increasing and on the other hand the suitable lands for the dumping waste is reducing due to the people are invading the lands for their living purposes. So Sri Lanka government together with the Waste Management Authority executing so many activities in order to proper management of waste. Among the Sri Lankan Strategy for waste management Landfilling plays a vital role as that is a one back end of the waste management process. So the process of selecting suitable landfilling sites for dispose the waste, should be conducted in a proper and transparent manner.

But in Sri Lanka it cannot be seen a precise mechanism for landfilling site selection process. As a solution for this it can be used conventional methodology or GIS like new technology for introducing new landfilling Selection standard. When switching between these two aspects, conventional methodology or the GIS it is better to choose GIS as conventional methodology is a very complex process and manually conduct this this process with conventional data management is very time consume and tedious. The following section will describes the reason for selecting GIS over the conventional methodologies.

*A. Issues with Conventional Methodology*

In the entire procedure of the landfilling site selection process since the beginning it happen to be managed massive amount of data and make predictions, go through a series of analytical criteria's to come to the final decision for select a suitable land for dumping site. There are basic methods that is considered as the origins of landfilling site selection processes as follows,

- Multi Criteria Decision Analysis (MCDM)
- Positive mapping
- Negative Mapping

When it is conducting the land filling site selection process it needed to be use these methods. But most probably when these methods are used in the site selection process manually, (normally named as conventional data management),as there are a massive and complex amount of data to be handled and decision making through them these manual methodology is very complex and tedious and most of the time the involve parities happen work hard time to time repeat with the same procedure when the input data is change with environment variables change. So in order to mitigate those common pitfalls of the manual process and easier the data management process, map creation, time saving it is better to go for an alternative solution (Ball, 2005). Below figure 1.0 depicts the generic site selection process in brief.

A GEO model can be introduced in order to enhance the efficiency of the existing landfilling site selection process in context to the Sri Lanka. GEO model is a model that is created with the aid of the Geographical Information System (GIS). GIS is defined as a system of computer hardware, software and procedures designed to support the capture, management, analysis, modeling and display of geographically referenced data for decision making. It is a way in which to begin to represent and model the real world. Geographic information system is one of the technology origin from the Geo informatics. Through the use of GEO model.it will be easier the process of multi criteria decision analysis, negative mapping and positive mapping as with the GIS infrastructure Through the use of GEO model.it will be easier the process of multi criteria decision analysis, negative mapping and positive mapping as with the GIS infrastructure.

It is providing the facilities for data management and decision making through the geodatabase facilities. Following factors will illustrate the need of shift from Conventional data management to the GIS, it will be proved that need of moving with the GIS than conventional data management methods for the landfilling site selection process.

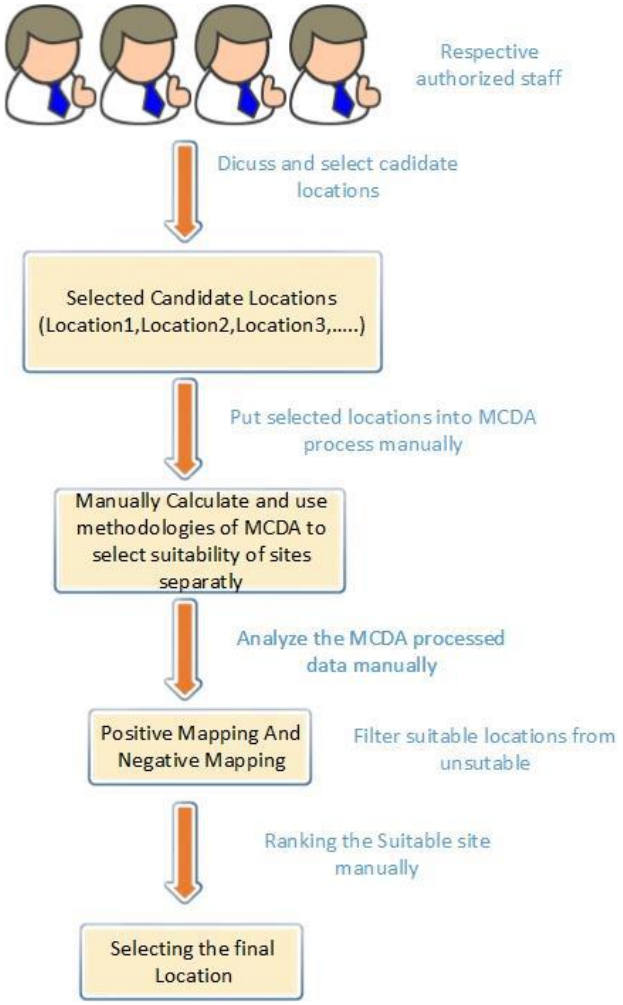


Figure 1. Generic site selection process

- In conventional data management when using multi criteria decision analysis, it happen to manage

massive amount of information about the criteria's. It is very tedious when performing these activities.

- In conventional data management spatial data is poorly maintained by with the GIS spatial data can be maintained in better manner with a standard formats.
- In conventional data management statics and the maps may be outdated and the updating process is very tedious, but with GIS updating the data is easier
- In GIS the operation of analysis, search data and represent them is very easier than conventionally processing them
- GIS data can be shared and exchanged among the users easily, but in conventional data management as there is no a standard the data exchange process are very complex.

Through data management over the GIS time and money can be save and make the progresses more efficiencies. But conventional data management will not save the time most probably.

As GIS provides the facility of decision supporting, in the process of massive data analysis in landfilling site selection it will be really helpful to come to final best decision. In conventional way it will be difficult the decision making than the GIS support. In conventional data management the data may be some times fall into inaccurate when processing if the human being make a mistake. But with processing data with GIS support once the all system is defined carefully, most probably it will not create the mistakes. As it illustrates in the above facts. It proves that enabling the Landfilling site selection process with the GIS can give the better solution in managing massive data and the decision making.

*B. An Overview to GIS*

Geographical Information System can be defined as a system of computer hardware, software and procedures designed to support the capture, management, analysis, modeling and display of It is a geographically referenced data for decision making way in which to begin to represent and model the real world. Geographic information system is one of the technology origin from the Geoinformatis. Geoinformatics is a science which provides the facility of combining geospatial analysis and molding and provide facilities with geo databases.

*C. Research Question*

The research question around which this research is based is presented below:

How can the GIS integrate with landfilling site selection process, mitigate the complexity of handling data relates to the site selection process and presenting the final result in a well understandable graphical format.

## II LITERATURE BEHIND ANALYSIS

As we discussed in the document so far. It was identified set of methods as multi criteria decision analysis, positive mapping and the negative mapping in order to reach the landfilling site selection process. As this processes takes much more time when performing manually, in similarly parallel several of steps combined with the GIS we can archive the same objective of selecting a land filling suitable as a dump site. In the process of site selection process combined with the GIS following main phases have to be pass through (Ball J 2005)

- Select the relevant map layers defined with the adequate criteria
- Creating the Raster maps.
- Executing the Mask operation
- Ranking the candidate sites through Analytical Hierarchy process
- Select most suitable site from the candidate site

The entire process can be summarized as in the figure 2. As the initial stage for input data for processing with the GIS, set of map layers defined according to the expected criteria's has to be introduced into the development infrastructure. These are the first input data and phase of the entire process. These maps should be define with the required usable criteria's used with the buffer zone rankings. Selecting process of the map layers depend on the conditions and the requirement depend of the each country or region. Sample map layers can be selected as

- villages,
- urban centers
- wet lands
- Surface water.
- Slope
- Flood plain
- Population
- Railways
- Roads (Ball., J ,2005)

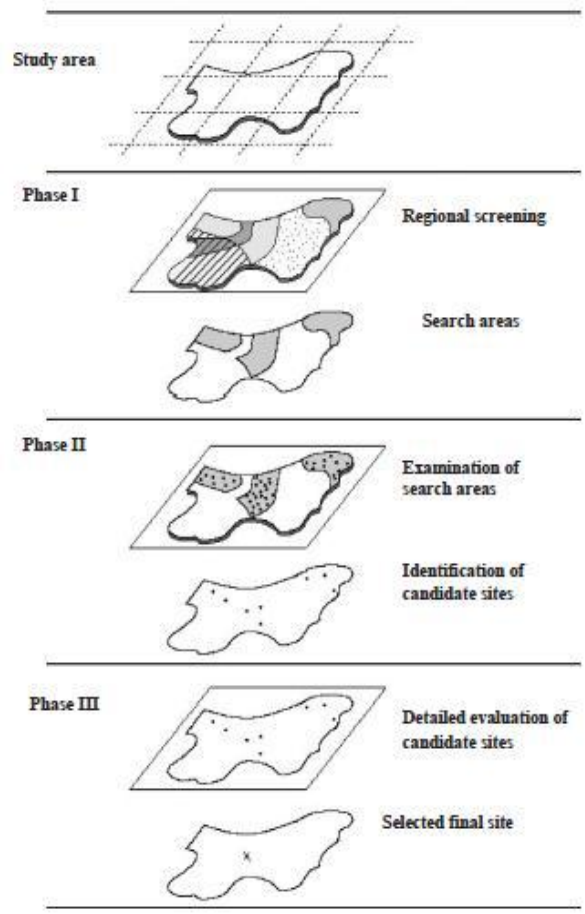


Figure 2. Phases of entire process in Brief (Bask & vadat 2006)

These all maps can be derived by digitalizing and geo coding the relevant data. A tool as ArcGIS (Esri) can be used for this. By using information collected from the relevant authorities it should be determine the buffer zones (the suitable distance) for each maps. Then each layer is converted into Raster maps. (Raster map is a data layer map consist of gridded array of cells can be represented in a 2D or 3D manner with small cubes in terms of digitalized maps. Simple buffer zone sample table will be as shown in the Figure 3 Then all of these digitalized maps or **Raster maps** will be layered one over one using the map overlaying technology. As demonstrated in figure 4.0.

After laying these maps together **Mask** methodology will be applied on the map layers to prepare a mask of unsuitable area. In this process as all maps are digitalized and is in the phase of raster maps using the aid of the pixels each map is multiplied together where any pixel has a value of 0 will be considered as that pixel is totally unsuitable. This is done with the aid of GIS technologies.

In the next steps relevant to the operations of the GIS it will be executed some mathematical based processes (Bosko & Maric) as simple additive weighting method.

| Feature | Description | Limitation or buffer size |
|---|---|---|
| Elevation | - | >2000 m |
| Slop | - | >15 % |
| Fault | major | >5km |
| | minor | >1km |
| | reverse | >2km |
| Earthquake spots | 5.5-6 mb | 1 km |
| | >6 mb | 2km |
| City | Large city | 20km |
| | Medium city | 10 km |
| Village | - | 2km |

Figure 3 Buffer zones defining example

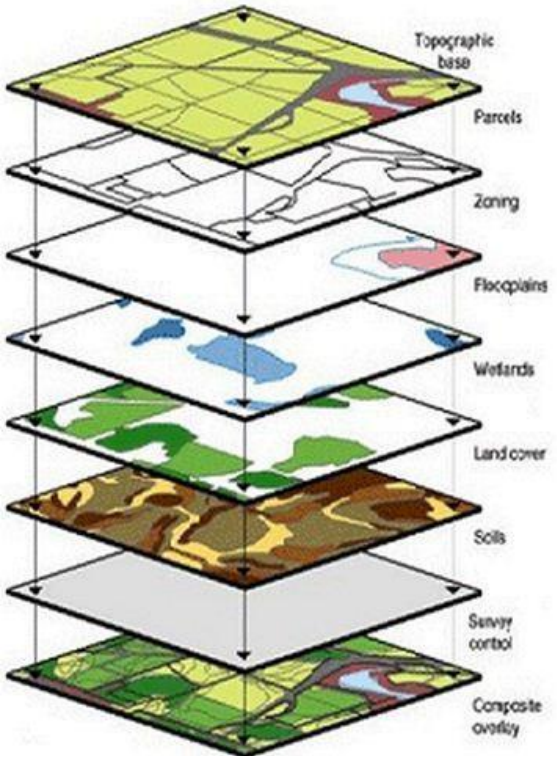


Figure 4. Sample map overlaying

Then go through an Analytical hierarchy process where a simple decision problem is decomposed into simpler decision to perform a decision hierarchy. Going through this the map pixels will be scored and ranked them in order to select the most suitable site among the candidate sites. These ranking graphs can be generated as the preference. It will support to categorize the site as suitable, least suitable, moderately suitable etc. as needed. In the final of each of these process suitable land for a dumping site can be selected easily, because as these tasks are performed with the aid of Geographical information system. It will easier the analysis process and the decision making process. Moreover because the stress-free of the working with performing these activities has become less complex.

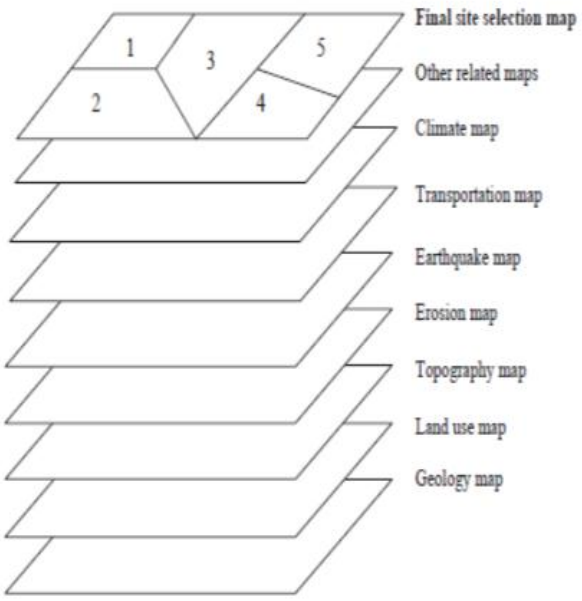


Figure 5. Map overlaying procedure (Irfan & Hasen)

As it is revealed by the Irfan and Cetin on their case study on landfilling site selection process executed in context to the Southeastern Anatolia Project (known as GAP in Turkey) in region of Turkey. They have conducted a survey in order to select a suitable location for landfilling covering “Adiyaman, Batman, Diyarbakir, Gaziantep, Kilis, Mardin, Siirt, Sanliurfa and Sirnak (Irfan & Hasen 2005) This area is a urban area with a high frequency of the population and number of main roads, agricultural lands. So they suggest that enabling the landfilling process with GIS is more suitable rather than manually conducting. In their methodology also they have used the same procedure of for the site selection process. Through MCDA process they have identified the criteria’s and then in three phases as regional analysis, examination of the search areas and evaluation of the candidate sites they have archives the final site selection process. So they create raster maps in order to represent the each respective layers need to use in the site selection process and also they have used the criteria as temperature, wind. The following figure demonstrate sample map laying they used.

So through following the GIS enabled services and technologies like MCDM and the Map overlaying technology they have archives their objectives in an easier manner.

## III METHODOLOGY

The research was conducted within inductive paradigm. The intention was to develop a geo model that consist of reusable ModelBuilder. The ModelBuilder is the component that includes all the selection criteria and the algorithms that execute the landfilling site selection process. As mentioned in the above the ModelBuilder is reusable, once it is developed the ModelBuilder it can be used by applying only several changes. And the advantage of this is as this is reusable once this is developed this can be used as a standard way of site selecting within Sri Lanka.

The Geo Model is developing using the ArcGis which provides facility of utilization of the GIS based components. So the development process consist of several Main steps as

- Selecting the geographical area to execute the site selection
- Defining criteria for determining the buffer zones
- Define and map layers and overlay them
- Integrate the maps and criteria’s in the model builder to execute the entire process

As the initial step North central province in Sri Lanka was selected to execute the landfilling site selection process. Then it was defined the geographic map layers to be used relevant to the North Central Province. For this, schools map layer, water and wet resources map layer, existing disposal site map layer, road map layer, railway line map layer, building map layer was selected. When it is needed to use this model for another area of the country it can be change the map layers related to the area and use again.

### A. *Developing the ModelBuilder*

As it was defined in the previous sections of the paper ModelBuilder plays the main role in the GeoModel. In ArcGis, Generating of the ModelBuilder consist of few main steps.

- Creating a Geodatabase that store all the components relates to the ModelBuilder.
- Selecting each the map layers that satisfy the each criteria.
- Defining buffer zones for each criteria
- Using The UNION function to overlay all the map layers.
- Using ERASE function
- Using Select Function
- Use ADD FIELD and CALCULATE FIELD to Rank
- final selected scrub land.
- Using MAKE FEATURE LAYER function
- Convert final out put the KML version that opens with the google Earth.
-

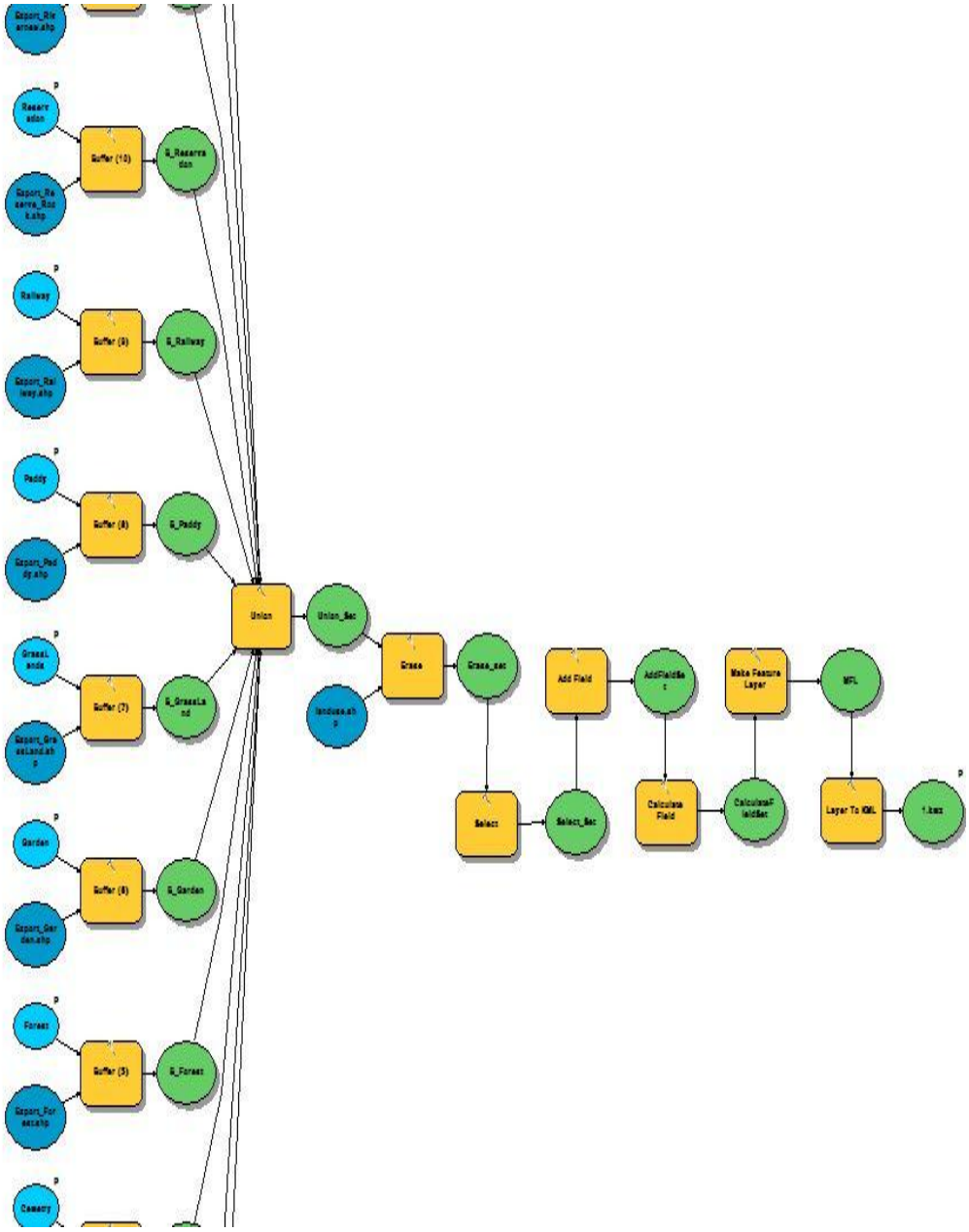


Figure 6. The Entire Geo Model

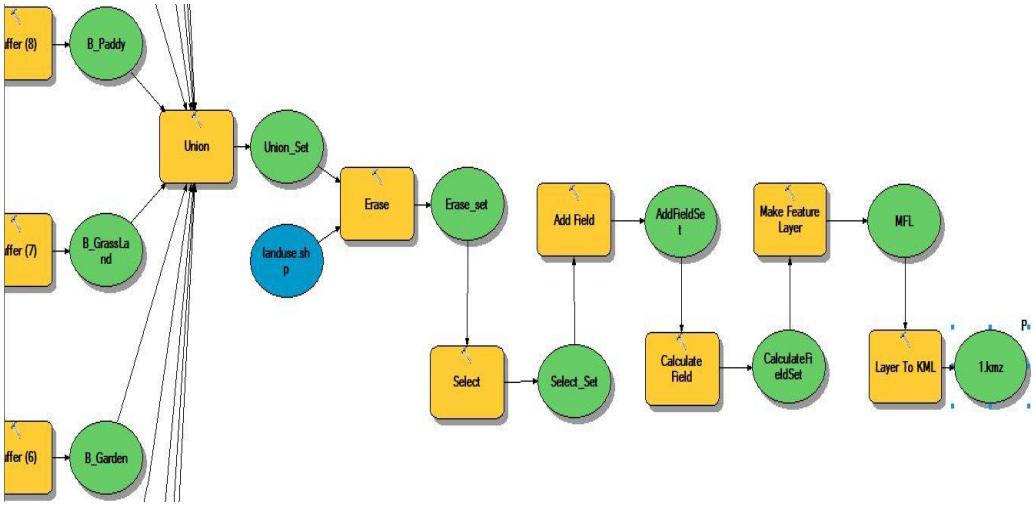


Figure 7. Magnified view of a Portion of the Model

*1) Geo Database:*
Geo Database store all the components related to the Geo model. It helps to store the all related data in organized manner. The data that is used in the development can be stored in featured data sets.. In the development it has been used two feature datasets as, working data and output data. All the map layers or the shape files are imported and store in the working feature data set and the all generate outputs of them will be stored in the output data set. This will enhance the easier of the data usability.

In above figure 6.0 it present the entire geo model generated for the landfilling site selection process, and in the figure 7.0 it display a magnified view of the essential functions of the model

*2) Selecting the Map Layers and Defining Buffers:*
Map layers should be selected according to the defined criteria used. Maps will be imported to the ArcGis infrastructure in the in the type of shape files. Then it will be defined the buffer distance for each criteria using the buffer Analysis tool. This tool consist of the buffer defining function. (Aminda, 2012)

As the Sri Lanka already does not have a precise mechanism for defining buffer distances, in the developed geo model it was used internationally recognized and research based distances for defining buffer distances. Following are the criteria and the distances used in the Geo model.

- Railway : 500 m
- Roads : 200 m
- Plantations : 100m
- Built up areas : 600 m
- Cemetery 100 m
- Forests : 600 m
- Gardens : 600m
- Paddy Fields : 500 m
- Rivers : 300 m
- Water Sources : 500 m
- Reservations : 300 m
- Well :500m (Balasooriya., et al)

Furthermore in order to facilitate the user to define their own buffer distances. The distance component have been defined as a model parameter. Which is mutable or can be changes when it is needed. The following figures show each separate map layers.

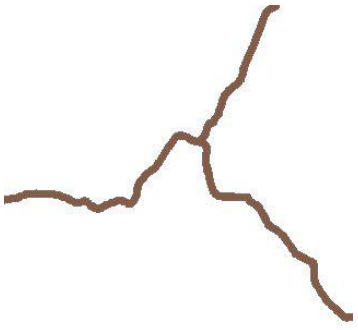

Figure 8. Railway map layer

Figure 9. Roads map layer

Figure 10. Cemetery map layer

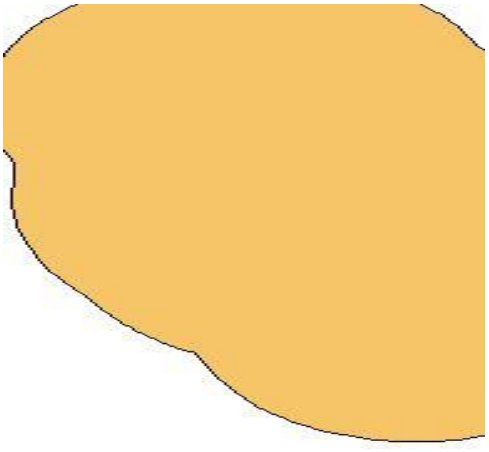

Figure 11. Built up areas map layer

Figure 12. Cannels

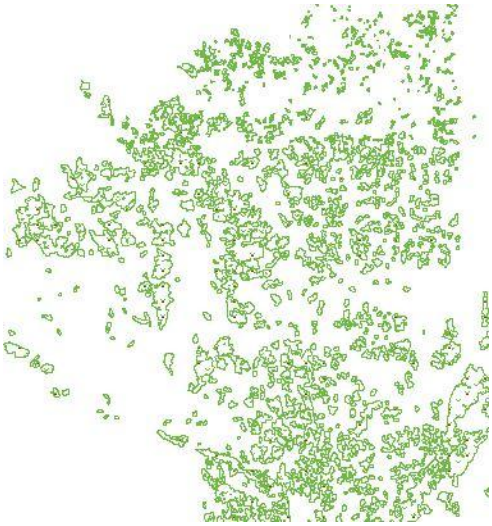

Figure 13 Plantation map layer

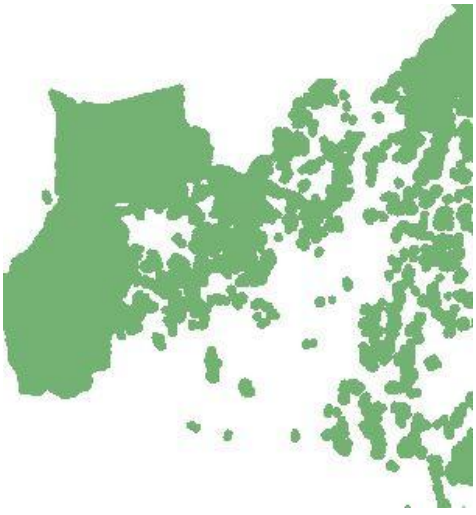

Figure 14. Forest map layer

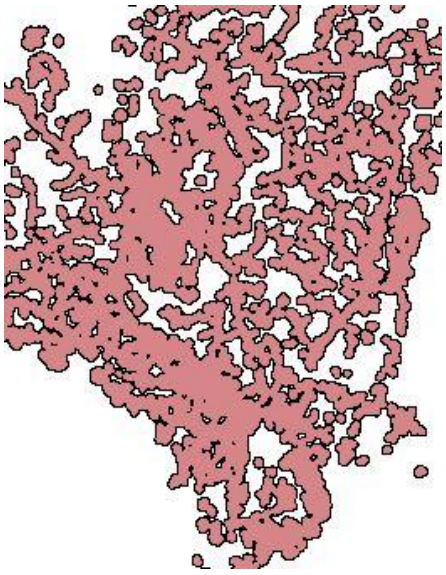

Figure 15. Gardens map layer

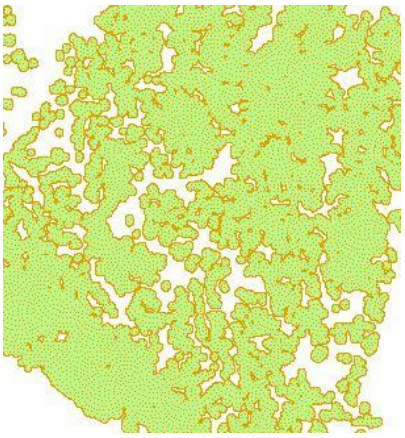

Figure 16. Paddy fields map layer

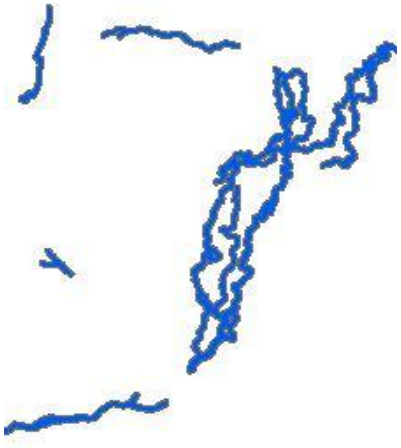

Figure 17. Rivers map layer

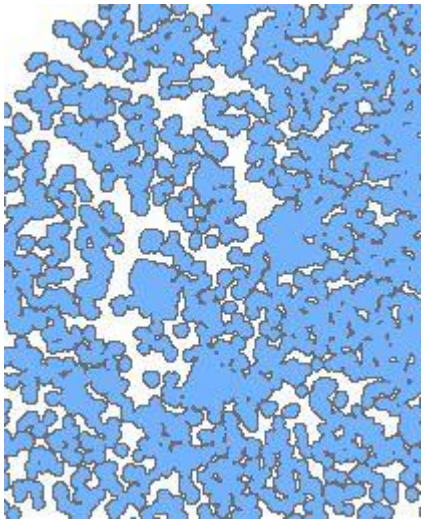

Figure 18. Tanks water Sources map layer

Figure 19. Reservations map laye

Figure 20. Well map layer

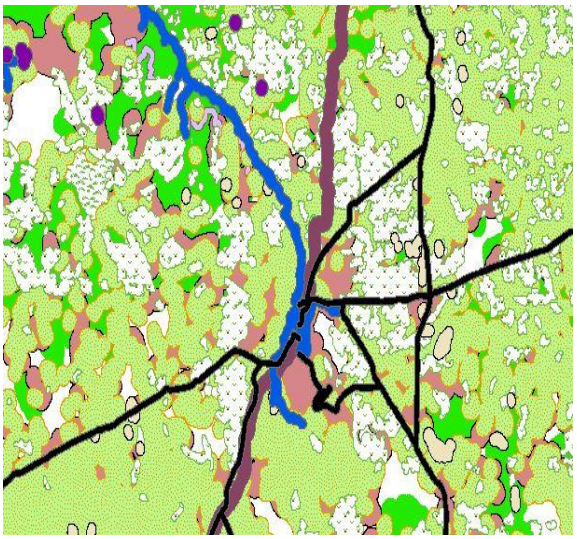

Figure 21. Collection All maps after overlaying

```
# Script arguments
Built_Up_Areas = arcpy.GetParameterAsText(0)
if Built_Up_Areas == '#' or not Built_Up_Area
    Built_Up_Areas = "600 Meters" # provide a

Plantations = arcpy.GetParameterAsText(1)
if Plantations == '#' or not Plantations:
    Plantations = "100 Meters" # provide a de

Cemetry = arcpy.GetParameterAsText(2)
if Cemetry == '#' or not Cemetry:
    Cemetry = "200 Meters" # provide a defaul

Forest = arcpy.GetParameterAsText(3)
if Forest == '#' or not Forest:
    Forest = "600 Meters" # provide a default
```

Figure 22. Python Script for buffer Criteria Defining

In figure 22.0 it demonstrate the python script that can be used to customize the parameter values use for define the buffer values. By using the python script without using the tool for determining the buffer criteria's it can be achieved through customizing the code.

*3) Using UNION Function:*

After defining the buffers for the each map layer, in order to get a final analysis these separates maps should be overlaid and generated a one entire Map. The union function helps to integrate and overlay the each separate map layers. The out put of the UNION has been named as the Union set this union set will be then pass to the erase function figure 23.0 shows the UNION map.

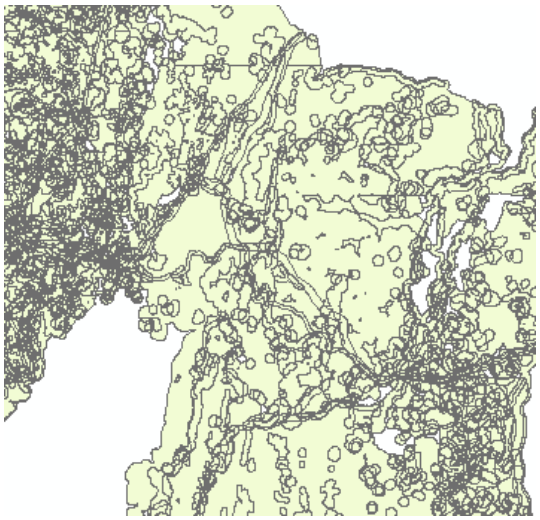

Figure 23. Union maps

*4) Using ERASE Function:*

Erase function is used to extract the needed map layer from the entire map. In erase process as the input layer we use Entire Land use Map that consist of all the layers that we used. From that it is erased the union set we generated. Then it will be able to get the rest of the available lands out of the buffer scope. Map generated after Erase is shown in the figure 25.0

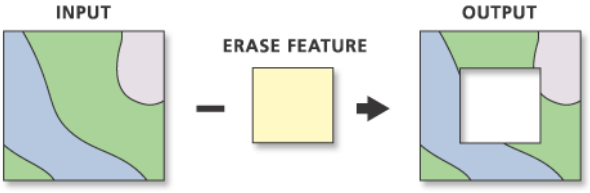


Figure 24. Illustration Of Erase Process (ArcGIs)

Figure 25. Map after Using Erased Function

*5) Using select Function*

Select function is used to select the Scrub Lands over the entire available Lands. In Select function the sql query is used to select the Scrub lands. Scrub lands are the places where suitable use as landfilling sites. Figure 26.0 shows the final output selected as scrubs land that suitable for using as the disposal sites

Figure 26. Final suitable Scrub lands for landfilling

As it is mentioned in above the figure 26.0 shows the scrub lands selected. This are the land available out of the buffer area defined by the user as the need.

*6) Ranking Process*

After selecting the Scrub land over the UNION maps, identifying the most suitable site over the all scrubs land can be a difficult process. In order to mitigate this constraint it can be used the ranking process. For ranking process it can be used mechanism of giving marks to the scrub lands, then the user can clearly identified the most suitable land among the locations shows on the maps. When designing the Ranking process it has used the Add Field and calculate field functions to archive the preferred target.

After executing the SELECT function by using the ADD FIELD the Designer can use a new variable or field to execute the Ranking, In the development it has been used a field named as “Rank”, Then depend on this it can be programmed the module, Using VB or the python, So in the CALCULATE FIELD provides the interface for writing the VB or python script, In here it has been used the VB to write the algorithm. The following set of code demonstrate the VB script use for ranking process.

```
dim n

if  [AREA_HA_]>= 0.6 AND [AREA_HA_]<=50 then
n="1"

elseif  [AREA_HA_]>50 AND [AREA_HA_]<=250 then
n="2"

elseif  [AREA_HA_]>250 then
n="3"

end if
```

As it is shown in the above code the Ranking has been done depend on the AREA of the selected scrubs lands. It depicts by the [AREA_HA_],As the minimum value for locating a sustainable and suitable landfilling site it has been limited the minimum value as 0.6 hectares this is same roughly to the 1.482632 Acre, The values less than 0.6 range have been considered as out of scope as it is less than 1 ACRE. In order to determine the maximum values and the minimum values of the land it can be checked the attribute table of the selected scrub land map layer. So by using a control flow statement as IF/ else if it has been defined the conditions to be used for selecting the site. The range between the [AREA_HA_]>= 0.6 AND [AREA_HA_]<=50 it has been assigned a value or have been given marks as “1”, then the range between [AREA_HA_]>50 AND [AREA_HA_]<=250 then have been assigned a values as “2” and the values than [AREA_HA_]>250 then have been given marks as “3” 250 hectares is nearly 617.763 Acres.

So the best site or scrub land depend on the size have been given the marks as 3 and the lowest suitable site has assigned the value “1”, so depend on the users perception which capacity of areas is to be used for the landfilling site can select 1,2 or 3. In order to easier the process of identifying the various category out of this 3 those have been separated by assigning the preferred colour for those separate values. It has been used the customization of the category. The following figure 27.0 will demonstrate how the colures have been assigned for marks or ranking values a 1,2,3. The purple color has been assign to represent the valuse “1” which has low values of acres , dark red has been used to represent the value “2” and orange colour has been used to indicate the best site with larger values of the Acres.

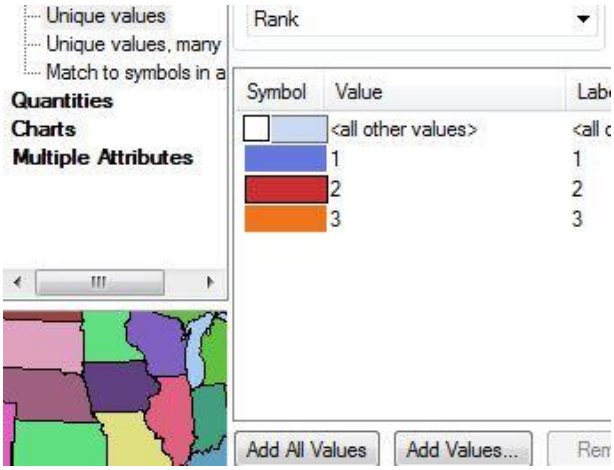


Figure 27. Assigning symbols for clearly identifying the locations

The Following figure 28.0 represent the map after executing calculate field function and assigning the colours for ranking

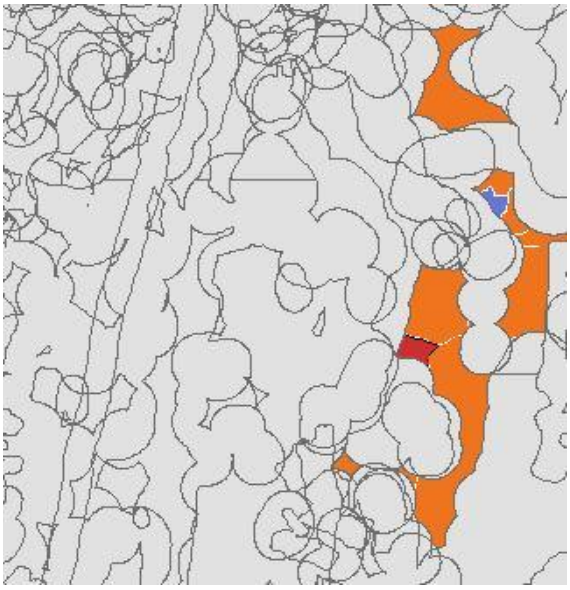

Figure 28.0 map after executing Ranking process

*6) Using Make Feature Layer tool:*
In order to get the final output as a KML file that executed with the *Google* Earth. It is need to give the input to the layer to KML tool as layer. So after erase function by the Make feature layer tool it is converted the Erased Maps to a layer. Then this can be put in the Layer to Kml Tool.

*7) Using Layer to Kml tool:*
Layer to Kml tool help to generate the final output as a KML that executed with the google Earth.

IV. RESULTS AND DISCUSSIONS.

After Developing the Entire ModelBuilder and run it the user can see a GUI as reflect in the following figure. As it display on the above figure the Model facilitate the user to change the parameter values that use to define the Buffer distances. In order to allow users to change the parameter values for the buffer distances those field should be made model parameters, in figure 6.0 and 7.0 by "P" it indicates the parameters made as model parameters.

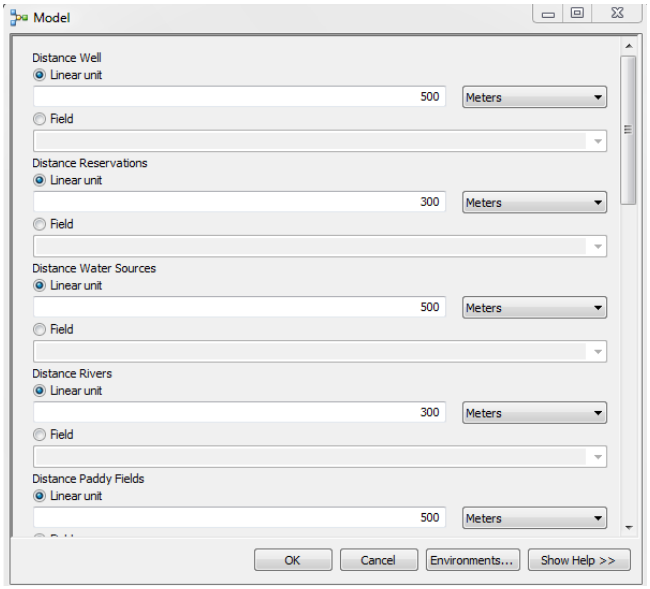


Figure 29. GUI Of the Application (ArcGIs)

In figure 30.0 and 31.0 it depicts the scrub lands which are considers as the suitable and sustainable locations for implementing the waste disposal sites. In the color of gray represent for the union map or the collection of the maps after overlaying as mentioned in the above and in colors of purple, dark red and the orange represent the suitable scrubs land after ranking process . In there it can be seen few amount of suitable lands are extracted from the model considering the defined criteria's by the user. Following figures which is the final out put open with the google earth will give a better understanding of the locating of the scrub lands.

In figure32.0 show a scrub land located in considerable distance from water sources "Nacchaduwa wewa".when consider the area it should be a value among the [AREA_HA_]>50 AND [AREA_HA_]<=250 as it is shown in the colour of the red as defined in the desigining

Figure 30. Comparison and view of Scrub lands and the union map Layer.

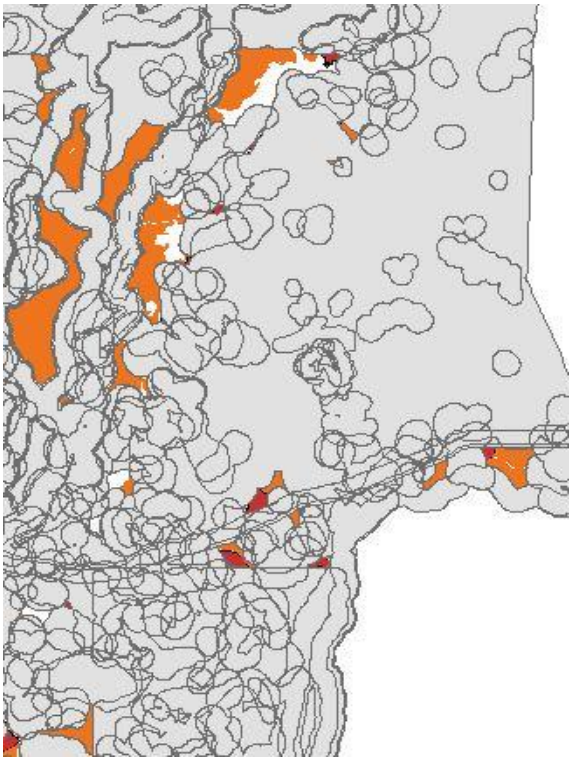

Figure 31. Partial view of Scrub lands and the union map Layer


Figure 32. Scrub land located away water source

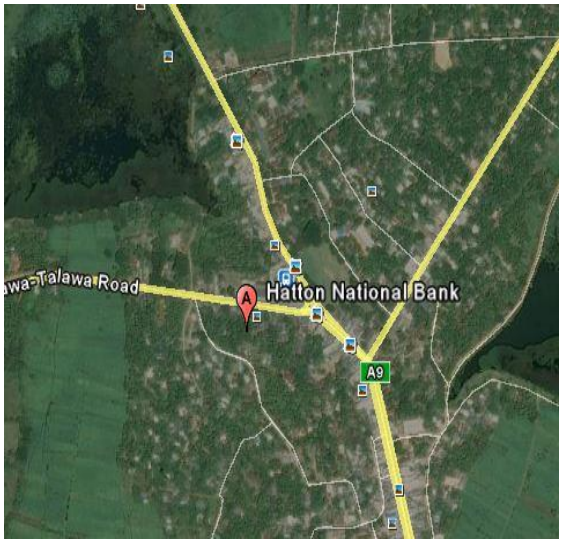


Figure 33. No site is indicated near the Urban areas

In Figure 33, 34 it demonstrate that no suitable scrubbed land is located nearby urban areas or the plantation areas, And in the Figure 35.0 It represent two category of scrub lands in orange color and the red color depend on the heaters in size.


Figure 34. No site is indicated near Paddy

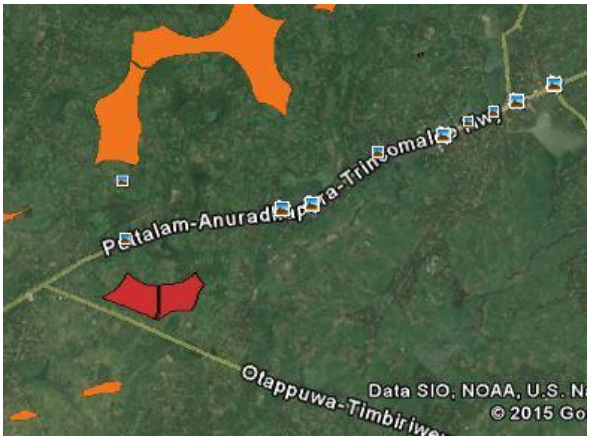


Figure 35. Scrub lands located far from the main Roads

As the limitations of developing the model it can be identified the accuracy of the map layers. If the data set or the accuracy of the map layer is not in precise level the final output generate by the model can generate the location with errors. As the input data set or the map layers have been not mapped up to the precise level or accurately.

## V. CONCLUSION

In Sri Lanka it is not practiced a proper mechanism for selecting suitable and sustainable lands for the waste disposal. Due to this reason it have been occurred negative environmental, economic and ecological impacts. As a prcise solution for that it can be conducted the Landfilling site selection process using conventional methodologies or GIS like new technological solution which provides the infrastructure for spatial related data analysis. But when it is comparing the efficiency and the easier of the process, using the GIS based solution is more effective than the conventional methodology. In traditional landfilling site selection process it happen to be handled the massive amount of data. This is very complex and take considerable time. More over graphically representation of the final out put using the conventional Maps is not a better user interactive method, as a solution for that GIS provide the basement for developing, customizing and overlaying and analyzing the maps in easier manner. The geo model developed using the GIS infrastructure, consist of the ModelBuilder which is a reusable component that can be apply for various areas of the country by applying only few changes to the artifacts. The initial geo model have been developed to cover the North Central Province. So the ultimately the Geo model designed for the landfill site selection process covering the North central area provides a precise way to conduct the waste disposal site selection process

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