Urban Landfill Investigation for Managing Negative Impact on Geo Spatial Environment in the Context of Ethiopian GTP 2 Goal of Sustainable Environmental Management A Case of Woliyta Soddo town

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Abstract
As many scholars showed that the intervention of humans on the natural environment influences the nature of ecosystem processes by the rate at which they operate on environment . In addition to poor urban planning and management has always negative impact on environment, economy, ecology and heath problem in community . Therefore, landfill has to be selected carefully by considering both land use regulations and constraint in regarding to landfill site selection analysis in case of Wolayta Soddo town has been selected as case study. due to poor waste disposal and management system in the study area often end up in drains, causing blockages that result in flooding, unsanitary conditions and cause very effective vectors (flies) to spread disease like malaria, including acute water diarrhea and typhoid fever, which are current existing problems in Wolayta Soddo town due to inappropriate waste disposal site. and based on problem existence of Soddo town solid waste disposal system, the object was developed to conduct suitable solid waste disposal site and least cost path using Geographic Information System (GIS) and Multi Criteria evaluation (MCE). In addition, In order to active the objective of this research, eight very important factors have been used such are: land use, soil, ground water, drainage, road, slope, Aspect and population using the method of weighted overlay technique for all selected factors in Arc GIS 9.3 and IDRISI 32 software to generated Analytic Hierarchical Process (AHP) Eigen vector matrix value. In addition, as the finding of this thesis, it has been showed; a 6ha of land of the study area was selected among the 32.49 ha of very high suitable site
Keywords: Analytic Hierarchical Process (AHP), Geographic Information System (GIS)

1. Introduction

As many scholars showed that the intervention of humans on the natural environment influences the nature of ecosystem processes by the rate at which they operate on environment (*Mengiste Abate a, Jan Nyssen b,, Tammo S. Steenhuis a,c, Michael M. Moges a, Seifu A. Tilahun a Temesgen Enku a, Enyew Adgo d 2015*) . In addition to poor urban planning and management has always negative impact on environment, economy, ecology and heath problem in community (*Bereket G 2013*). Those are a growing problem for national and local governments to ensure effective and sustainable management of environmental sanitation and due to lack of controlled waste management (*United Nations Environment Program, 2009*). Also as per *World Health Organization* (WHO) estimations of 2003, the total health-care waste per person per year in most low income countries, is anywhere from 0.5 kg to 3 kg which is one of the case for increases in health problem to citizens of low income countries. (*Hassan, 2005)* and (*Lotfalian and Najafi Caspian, 2005*) According to the Health Minister of Federal Democratic Republic Ethiopian Annual Federal report of in Jun 2016, community in different area of the country like Addis Ababa 20,000 people, Arbaminch 10,000 people, Adama has been contaminated from acute diarrhea and exposed to flooding due to solid waste blocking of deranges Which are also current existing main problems in Wolayta Soddo town due to inappropriate landfill system, and Wolayta Soddo town is one of the 22 reform towns by Federal Minister of Constriction and town development and Wolayta Soddo town is one of Southern Nation Nationality of Region (SNNPR) of Ethiopia but it was the goal of Ethiopian government and urban planners to have sustainable management of environmental sanitation and suitable landfill Due to poor landfill system in the town, there is high rendering to pollution of land use, groundwater, surface water and cause for the main source of public health problem in the town. The objective of this study was to use Geographic information system (GIS) as a tool with integration Multi Criteria Decision Making (MCDM) in Analytic Hierarchy Process (AHP) for landfill site selection,. GIS overlay analysis with Multi Criteria Evaluation (MCE) performed to identify the optimum site for the disposal site, (*Ehrogott, 2005*). Therefore, the study focuses on an optimized land use site selection based on multi-criteria decision analysis and geo-graphic information system based (GIS) overlay analysis for an Investigation of Urban landfill site for managing negative impact on Geo spatial environment in the context of Ethiopian GTP 2 goal of sustainable environmental management A case of Woliyta Soddo town

2. A practice of poor landfill system of the study area

The common landfill system adopted in Wolayta Soddo town is unmanaged landfill system including waste disposing around derange areas and river (fig 1.1) open environment as tired to indicate in pictures below A, B, C and D , **A** indicates collecting solid waste from each house holed **B** transporting to disposal site ,**C** unmanaged solid waste left in the drainage system of the town **D** final disposal of solid waste .As a result, drainage, lands and rivers are highly exposed to contamination and land pollution from (*Wolayta Zone Soddo town Water development Agency 2015E.C*). and **28.5%** of people of the town has exposed to air born, severe of vectors born, typhoid fever, endemic typhus fever, malaria, including acute cornice diarrhea in (2016 E.C) disease (*Soddo town health Administration annual laboratory 2016*). In addition, some drainage system has a direct linkage to local river named "Kalte ". This resulted pollution in this river, surface water and ground water around this area. According to *Wolayta Zone Soddo town Water development Agency 2014*) " kalte " river has been using by 10 % of urban and 35 % rural people for drinking and home use purpose due to shortage of drinking water in town.

A B C D

Fig1.1 Solid waste mangement practice in Wolayta Soddo town (Source: by author 2016).

Current landfill site in the study area has been selected without any scientific method (*Soddo town beautification and sanitation agency as report in and study for Environmental protection by world bank 2016*). and due to all the listed problems environment of the study area is highly exposed water born, and air born disease

Data model for urban landfill site selection

GIS tool based data model technique has been developed with the Malti Criteria Evaluation (MCE) structure by different scholars of related studies *(Sani Yahaya, 2010).* The data Model utilizes various Geographical data layers and uses for GIS processes such as reclassification, buffering, raster calculation and 3D analysis tools to create data layers that represent the impacts on each criterion. The simple additive weight method used to combine land suitability factors with classification of factors was used to the least cost path map in this study *(McHarg, I.L. 1969)* . Then, a Boolean constrains equation is used to both land suitability and least cost path map to get the result map (Malczewski, *2004*). The results of the MCE is used to determine the suitable areas is study based on the modification and refining of the following flow chat in other related studies

3. Description of the study area and materials

Location

Soddo town is the capital of Wolayta Zone Administration of Southern Nations, Nationalities and Peoples Regional (SNNPR) State, Ethiopia (Figure 3.1). In addition, it has total area of 43.2072 km2 and It is located at about 396 km South west of Addis Ababa. Its geographical extent is between 364500 and 372000m N latitude and between 754000 and 760000m E longitude with altitude ranging from 1400 to 2140 amsl (Ethiopian demography and health organization institute 2005). It has three-kifle ketema and 11 kebels. Soddo is located from Northwest of "Boloss Sore" , from Northeast of "Damote Gale" , from Southwest in "Offa" and from South of "Humbo" in Wolayta Zone Administration of SNNPR of Ethiopia.

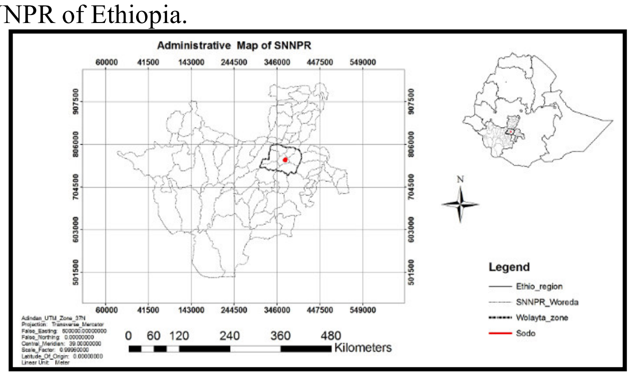

Fig 3.1. Location of study area

Relief and climate

Most of the land area of the Wolayta Zone Soddo town is found in the altitude range 1400 meter above sea level to 2140 meters above sea level of around Damota Mountain. The land area of the Woreda is dominated by rolling hills, plateaus and plains that extend into the low lands of Dallbo Wogen and Humbo taballa which are part of the lowlands of rift valley though the town that extend to lake Abaya. Most part of the Soddo town experience Woinedega (warm to cool) type of climate (SNNPR, Biro of Regional Metrology Annual report 2015). Except the

Mount Damota of Soddo town top areas that experience colder climate, some times. The South and south west peripheries of the town experience a transitional type of climate (warm to hot) (Woinedega to Kola) mainly due to the South east rift valley that cross the surrounding Woreda (Dallbo Wogen and Humbo Taballa) and run in to the low lands of lakes Abaya and Chamo which are rift valley lakes. Dallbo Wogen is the Northerly Boundary of Soddo town and humbo taballa is the southern boundary of the Soddo town Administrative.

Materials used

Table 3.1 Data and their sources

Data Types	Sources	Specifications of data	Use of the data
Master plan of the town	Wolayta Soddo Municipality	1:50,000	Use to generate shapefile layers such as land use, road, derange which is done by using digitization in GIS environment
Geological data; Soil infiltration and Ground water factor	Southern Ethiopian government Minister of Water and Mining agency	ESRI Polygon Shape File layout (*.shp)	To estimate infiltration rate of types of soil near the surface water and ground water used in designing solid waste landfill site.
Land use Factor	Wolayta Soddo Municipality	ESRI Polygon Shape File format **(*.shp)**	Used in selecting a solid waste disposal site based on MCE
Drainage factor	Wolayta Soddo Municipality	ESRI line Shape File Format **(*.shp)**	It was used to avoid risk flood in to selected site.
Elevation /slop factor	Wolayta Soddo Municipality	ESRI line Shape File Format (***.shp**)	Contour shape file is used to develop TIN and DEM for analysis aspect and surface water runoff for the study.
Road factor	Digitized from land Use	ESRI line Shape File format **(*.shp)**	Used to analyze proximity zone to major and minor road
GPS data (ground truth)	Filed Survey with GPS	Line ESRI Shape File format **(*.shp)**	for the evaluation of existing site
Population density	CSA (2005)	In number	To estimate service period of the selected sit

The specific data required for this study were collected from primary and secondary sources (table 3.2). Primary data of this study were field survey data's with hand GPS of the ground truth and secondary data has obtained from the local government Authority and SNNPR regional government offices. Analogue map of the study area has obtained from the local government of Wolayta Soddo municipality. A field visit has paid in order to determine the names of features on the analogue map in the attribute field of the digitized copy. The data and their sources used to generate land-use layer, road layer, deranges, for suitable solid waste landfill site selection analysis in the study area by using GIS with the integration of Multi-Criteria Evaluation(MCE).

Software

This study has selected based on the capability to work on the existing problems in achieving the determined objectives. Hence, software package like, Arc GIS 9.3 and IDRISI 32, Arc View 3.1was used for the processing activities on scanned map of the selected study area. And it was used to select suitable site for solid wastes dumping with the Analyses of lest cost path in case of Wolayta Soddo town by using GIS with the integration of Multi-Criteria Evaluation. The factor map development has carried out using Arc GIS9.3 software package. The factors that were input to for multi-criteria analysis should preprocessed in accordance to the criteria set to develop suitable site for solid waste dumping and least cost analysis. So using Spatial Analyst and 3D Analyst extension, some relevant GIS analyses has under taken to convert the collected shape files. Eigen vector for the selected factor has computed using Weight module in IDRISI 32 software. Arc View 3.2 software was also used (table 3.2) to identify characters soil and rock from the geological map of the study area

Table 3.2 Material lists used in this study

Soft ware	**Purpose**	**Hard ware**	**Purpose**
Arc GIS 9.3	Data Analysis	Computer (lap top)	For inscribe
Idriris32	Per wise mechanism Analytic Hierarchical Process (AHP)	Printer, Scanner	To scan map and print
Arc View 3.1	Geological data extraction	Global positioning system	To collate ground truth

4. Methodology of the study

Overview of conducted methodology

The objective of the study has improved by using Geographic Information System (GIS). In addition, GIS technique is a suitable tool for urban landfill site selection since it has the capability to manage large amount of spatial data that comes from various sources. Therefore, spatial and non-spatial data processed using GIS and Multi-Criteria Evaluation for the suitable site selection and least cost path analysis. Therefore, in this thesis GIS and Multi-Criteria Evaluation (MCE) have used to achieve the objectives of the study.

Factors and analysis

Taking urban landfill site selection for Municipal Solid Waste Management(MSWM) as critical current issue of the local and federal government as one of GTP 2 goal, this study has been putted and developed factor and parameters to indicate suitable landfill site using Geographic Information System and Multi criteria Evaluation by (*Sani Yahaya, 2010*), the six parameters (i.e. suitable urban landfill site selection and sustainable environmental management) were developed and analyzed in GIS environment. The contributing factors for suitable landfill site selection analysis were developed to a common rescaling option from 1 to 5, based on AHP and it has be as follow 1 very low , 2 low, 3 moderate, 4 high, and 5 very high respectively for conducting suitable landfill site by Multi-Criteria Evaluation. Experts, decision makers considering the previous related studies, assigned the weight of identified criteria (*Baban and Flannagan*, 1998). it potentially saves time that would normally been spent in selecting an appropriate site, while claim that GIS is an ultimate method for preliminary site selection as it efficiently stores, retrieves, analysis and displays information according to user-defined specification. However, GIS has limited by the existing sources of data needed in sitting analysis of this study. To run MCE, the following selected parameters can be contributing factors were reclassified and weighted. Then weighted overlay technique was computed in ArcGIS9.3 to generate suitable solid waste disposal site based on Analytic Hierarchical Process (AHP) Eigen vector matrix value that are generated by IDRISI 32 software.

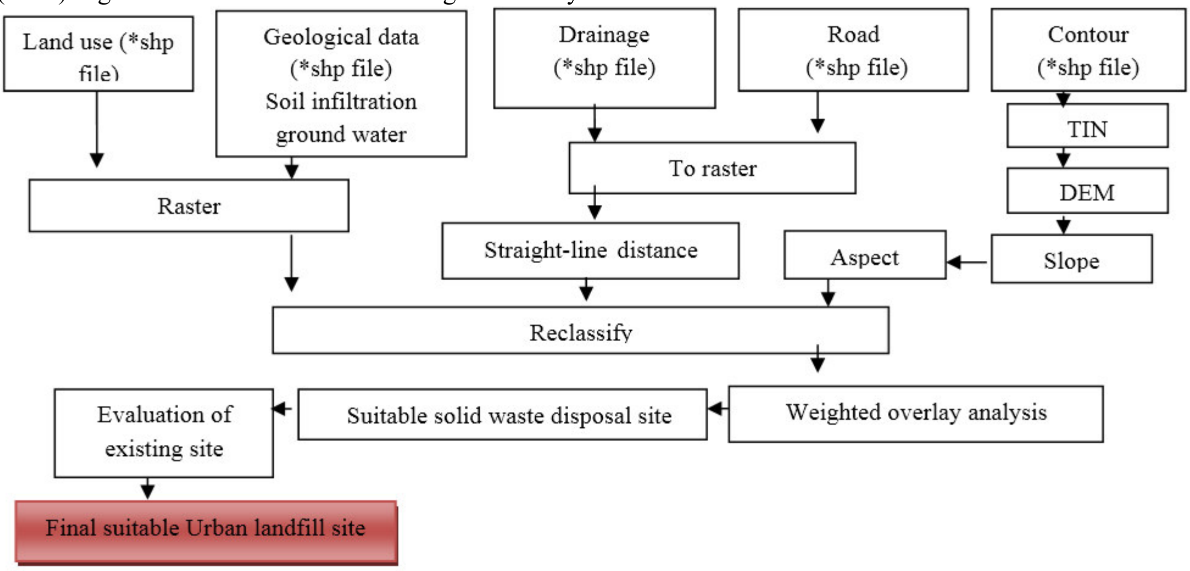

Fig 4.1 Technological scheme of data analysis

5. Data analysis, results and discussions

Data analysis and results

This study has been incorporate Geographic Information System (GIS) with Multi Criteria Evaluation (MCE) for the selection of suitable landfill site in case of Soddo town. And as the different studies shown in literature review, solid waste disposal site selection has been used geographic information system as a key tool for the reduction of environmental and geographic related problems (Baban and Flannagan, 1998). Parameters those are essential for this study has derived from master plan and local government office . Accordingly, land use and road network drainage , slope and geological data (soil infiltration rata, groundwater) were used in order to achieve the goal of the study. To assess suitable landfill site selection , GIS and MCE have used. It was depends on the nature of geographic extent and Spatial Multi Criteria Evaluation (SMCE) involves evaluation of geographical events based on criterion values and the decision making preferences to a set of evaluation criteria. In this study, Weighted Linear Combination (WLC) were used for continuous criteria (factors) with standardized common factors rescaling option (table 5.1) model with raster layer resolution of 30 m cell size, used and then combined by means of a weighted overlay analysis.

Table 5.1 Used description of spatial data analysis

No.	Elements used	Descriptions
1	Spatial reference system	Adindan UTM Zone 37N
2	Projection	Transeversal Mercator
3	Scale factor	0.999600
4	Linear unit	Meter
5	Datum	Adindan
6	Rescaling Option (1 to 5)	5= Very high suitable 4=High suitable 3= Moderate suitable 2=Low suitable 1= Very low suitable
7	Cell size	30m
8	Extent	Top =365006.583m Bottom=371563.689m Left =760373.228m Right=753581.826m

Criteria for selecting landfill site

Criteria used in this study for selection techniques of suitable solid waste disposal site and least cost path has been generated depending on Ethiopian town level solid and liquid waste landfill standard criteria which was taken from (S/N/S/P/R Bureau of Urban sanitation and Beautification office 2004) (table 5.2) below

Table 5.2 Selection criteria for solid waste disposal site

No	Criteria for selecting solid waste disposal site
1	Landfill site should utilize for a minimum of 10 year without any exposures of natural failure
2	The optimal road to final dumping site must be selected with 30 min transportation rout to reach the site with car solid holding capacity of 20 tones.
3	Dumping site must be free 1km from mining activates .
4	Geologically, the final site of soil depth not to be less than 35-65 cm and infiltration rate must be low.
5	Proximity to the wetland, park and forest is 5000m.
6	Dumping site should be located at a distance of 1km far from residential area.
7	Dumping site must be far from green areas.
8	The site should not be located at steeps slope.
9	Public service area like schools must be 1km far from the final solid waste dumping site.
10	Dumping site must be 1000m far from major road without any traffic crowed.
11	Proximity to river, derange and water body should be in range of 1500m -1700m.

Data analysis

The developed factors that have been used in study are very important for the achievement of the objectives this study. As model land use map, displays the land utilized by the human and the natural cover .It is the basic map of the study area and helps in generating thematic maps required for overlay analysis. The land use map indicates the areas of commercial, residential grassland & forest built up area, urban farmland, proposed land use and bare land. The majority of this land use is used to selected proper solid waste disposal site; slope, geological data, road drainage and population have also developed by taking into account as a key factor to achieve the goal. The infiltration rate plays an important role in determining potential risk of contamination of the groundwater and hence is a key criterion for the development of a solid waste disposal site selection at a particular site.

Land use

Land use of the study area has been reassigned by categorizing land use types using Query builder into seven general classes (table 5.3), and converted to raster layer. Further, existing land use types of the town reclassified into seven groups in order of their suitability to solid waste disposal site it has also used as main source of factor development of this study (Appendix 1) information in factor-developed map is indicates only five classes. However, during field observation to reality of that information, grassland and urban farmland have collected by hand, GPS as additional ground truth (see in Appendix 2) of GPS data. In addition, new values has re-assigned depending on their land use/land cover types giving with the rank for suitable analysis (figure 5.1)

Table 5.3 Rank of land use factor for suitable site analysis

Land use factor	Land cover	Ranking
	Commercial area	Restricted
	Residential area	Restricted
	Grassland and forests	1
	Built-up area	2
	Urban farmland	3
	Proposed _land use	4
	Bare land	5

Suitability score of land use reclassified has been according to rescaling option in (table 5.1), the highest suitable value rank of 5 and very low suitable score value of 1 grassland and forest having with commercial and residential areas are restricted area for the suitable solid waste disposal site selection

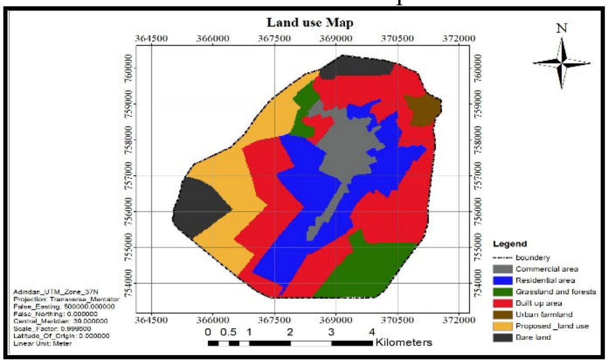

Fig 5.1. Reclassified land use map of the study area

Land use map in Boolean standardization reclassified to the types of land use that available for evaluation of existing site and new landfill site. Therefore, this reclassified area (table 5.4) contains listed types of land use/land cover that each of them has a different level of ranking for the selection of suitable site of solid waste disposal for analysis

Table 5.4 Land use area coverage

Land use factor	Suitability scale	Cell count (cell size 30)	In m^2	In (ha)	In (%)
Commercial	Restricted	3856	3470400	347.04	8.032
Residential	Restricted	9727	8754300	875.43	20.2612
Grass land & forest	Very low suitable	4478	4030200	403.02	9.32761
Built up area	Low suitable	16327	14694300	1469.43	34.0089
Urban farmland	Moderate suitable	3274	2946600	294.66	6.8197
Proposed land	High suitable	6920	6228000	622.8	14.4143
Bare land	Very high suitable	3426	3083400	308.34	7.13631
	Total	**48008**	**43207200**	**4320.72**	**100**

Slope

Slope factor of Soddo town has developed from contour data of the study area. In addition, use to produced Triangular Irregular Networks (TIN), Digital Elevation Model (DEM) and then to slope an elevation of the study area range from 1400 - 2140m, and resigned in percent with this regarded slope from 1-2.6(%) percentage was taken as flat and gentle that derived from the DEM for suitable location of solid waste disposal site. And slopes used to identify the maximum rate of change in surface value over a specific distance . In actualizing the slope map from the DEM required for the final thesis analysis, the spatial analyst tool in Arc Map 9.3 was used in the slope map calculation (Jay L. and Mandy J 2002). Calculated slope as function of many in spatial analyst tool and this function was used to derive the slope map from DEM. The Boolean aggregation demands all criteria has standardized to the same values. Slope data was effectively reduced to these values, areas where the slope that was between 6.4 % to 8.2 % was taken as steep (table 5.5) 8.2% to 10 % were not recommended and was taken as very steep.

Table 5.5 Rank of slope suitable analysis

Slope factor	Slope in (%)	Ranking
	1- 2.6	5
	2.8-4.8	4
	4.6-6.4	3
	6.4-8.2	2
	8.2-10	1

The reclassified slope was the values into equal intervals. The values was assigned suitable analysis (fig 5.2) accordingly to select flat slope, a value of five to the very high suitable, four is high suitable, three is moderate suitable, two is low suitable and one to the very low suitable in the above table.

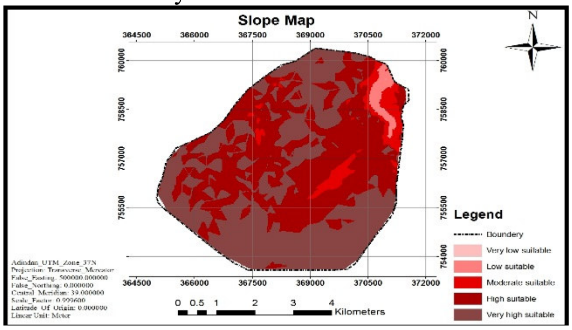

Fig 5.2. Reclassified slope map of the study area

This has been reclassified in five sub groups which is very steep (8.2-10 =very low suitable), steep (6.4-8.2=low suitable), moderate steep (4.6-6.4=moderate suitable), gentle (2.8-4.8=high suitable) and very high suitable (1- 2.6 =flat)

Table 5.6 Slope area coverage

Rank	Suitability scale	cell count (cell size 30)	In $(m)^2$	In (ha)	In (%)
5	Very high suitable	16511	14859900	1485.99	34.39218
4	High suitable	13216	11894400	1189.44	27.52875
3	Moderate suitable	11292	10162800	1016.28	23.52108
2	Low suitable	5251	4725900	472.59	10.93776
1	Very low suitable	1738	1564200	156.42	3.62023
	Total	**48008**	**43207200**	**4320.72**	**100**

Aspect

As one of the required factor, aspect for this study has identified from down slope direction of the maximum rate of change in value from each cell to its neighbors to indicate the wind direction. The values of the output raster will be the compass direction of the aspect. A new landfill should not be located within a distance of a housing area because of the dust and odor emissions. Dependent of the local wind direction and speed (*SNNPR, Bureau of Regional Metrology Annual report, 2016*) (table 5.7), the safe distance necessary to locate a landfill site should be determined to prevent sensing dust and odor.

Table 5.7 Average wind speed in m/s in case of Wolayta Soddo

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	AAWD
2014	1.87	2.65	2.22	1.55	1.34	1.23	0.78	0.93	1.5	1.83	SW to NE
2015	1.05	1.06	2.01	0.5	1.02	1.32	1.1	0.78	2.1	2.01	SE to NW
2016	1.25	1.02	1.27	1.36	2.05	1.75	1.03	1.56	2.02	1.09	SE to SW

Based on the aspect derived from the slope and average annual wind direction, the suitable score has generated by reclassifying in to three classes.

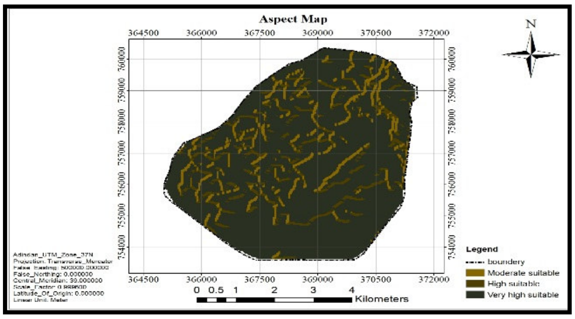

Fig.5.3 Reclassified aspect map of the study area

Soil infiltration

Soil infiltration rate plays an important role in determining potential risk of contamination of the groundwater, surface water and land pollution hence it has been a key criterion for the development of landfill site at a particular area (*Baban and Flannagan, 1998*). Infiltration maps (Fig.5.4) have taken from Wolayta Soddo town water and mineral office to analyze suitable solid waste disposal site.

Table 5.8 Rank of infiltration rate of soil suitable analysis

Soil factors	Soil depth	Infiltration	Rank
	55-65cm	Medium	3
	45-75cm	Low	2

As shown the study area, soil range in medium and low infiltration. In addition, new values re-assigned in order of selecting suitable site with the above ranked value. Value three of to the moderate suitable range of infiltration rate of soil and two is low suitable range of infiltration rate of soil.

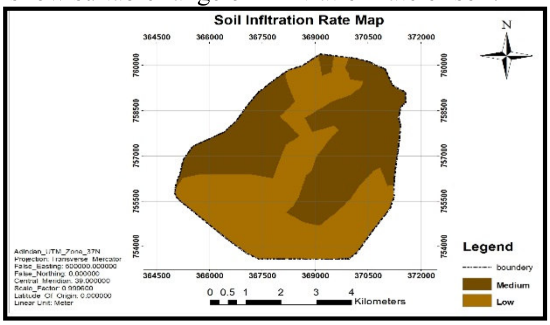

Fig 5.4. Reclassified soil infiltration rate map of the study area

As the infiltration rate of the region has divided into medium/low zones, medium infiltration rate (table 5.9) has made for suitability site. It was fond in the eastern and western part of the study area with thick clayey soils that has predominantly medium infiltration rate and from the southwestern, and southeastern across to the north the central part of the study area has clayey and black cotton with mostly low infiltration rate.

Table 5.9 Area coverage of soil infiltration factor

Rank	Suitability scale	cell count (cell size 30)	In $(m)^2$	In (ha)	In (%)
2	Low suitable	22480	21290850	2129.09	49.2762
3	Moderate suitable	23175	21916350	2191.64	50.7238
	total	**45655**	**43207200**	**4320.72**	**100**

Ground water depth

The depth of the ground water plays an important role in determining the contamination risk of ground water in regard of risk of landfill site selection. It was found (fig 5.5) that ground water depth of the study area as shown shallow in the southwestern part of the study area has ranges of (**20-35m**). In addition, some of northeastern part of the study area has shown between 46-65 m and more of the study area shows (**36-45m**). (*Wolayta Zone Soddo Water development Agency 2016*) (table 5.10) below has been reclassified based the standard criteria of suitable selecting solid waste.

Table 5.10 Rank of ground water for suitability analysis

Groundwater factor	Reclassified Sub-factors	Rank
	20-35m	3
	36-45m	4
	46-65m	5

New values re-assigned in order of selecting suitable site with the ranked and five is the very high suitable range four is high suitable range of and 3 is moderate suitable of ground water factor of the study area according to rescaling

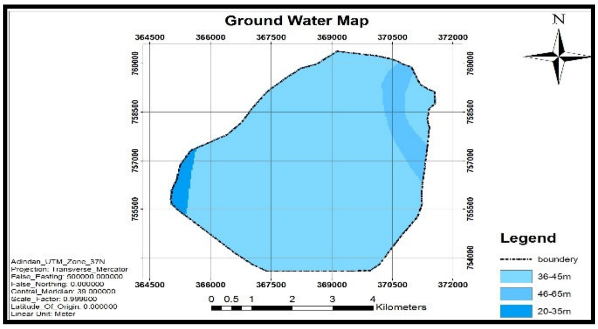

Fig 5.5. Reclassified ground water map of the study area

Table 5.11 Area coverage of ground water factor

Rank	Suitability scale	Cell count (cell size 30)	In $(m)^2$	In (ha)
4	High suitable	37001	33300900	3330.09
5	Very high suitable	9501	8550900	855.09
3	Moderate	1506	1355400	135.54
	Total	48008	43207200	4320.72

Road

Road factor of the study area for this study has digitized from the town master plane using line shape file in Arc catalog. The road layer was further calculated Proximity to roads of disposal site according to the selected criteria (see table 5.2). And reclassified (table 4.12) in five sub groups using standard classification schemes namely equal interval. This classification scheme divides the range of attribute values into equal-sized sub ranges, allows specifying the number of intervals While Arc Map determines where the breaks .

Table 5.12 Rank of road for suitable analysis

Road Proximity factor	Rank
0-199 m	1 Very low suitable
199-399 m	2 Low suitable
399-599 m	3 Moderate suitable
599-799m	4 High suitable
799-999 m	5 Very high suitable

And new values re-assigned in order of suitable site for the suitable solid waste disposal site in Wolayta Soddo town. The highest suitable value ranks of 5 and the least suitable ranks scale values of 1 were assigned (Fig 4.6).

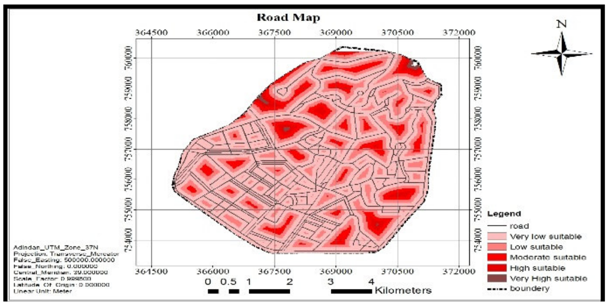

Fig 5.6. Reclassified road map of the study area

Table 5.13 Area coverage of road factor

Rank	Suitability scale	(cell size 30)	In $(m)^2$	In (ha)	In (%)
1	Very low suitable	991	891900	89.19	2.064239293
2	Low suitable	2466	2219400	221.94	5.136643893
3	Moderate suitable	4432	3988800	398.88	9.231794701
4	High suitable	10283	9254700	925.47	21.41934678
5	Very high suitable	29836	26852400	2685.24	62.14797534
	Total	48008	43207200	4320.72	100

Drainage

Drainage factor is one of important factor used in this study and there was two types of drainage line have conducted in this study. The lines that was conducted were river line and natural drainage line but natural derange line was not compiled in a way that is usable for the user to digitize from master plan of the town. Hence, in the field survey, spatial point locations on local open and closed natural derange line were collected using hand held Global Positioning System (GPS) receiver, which was listed table in (table 4.14) blow. These spatial points have digitized into a line feature to create a natural drainage line feature for limitation distance to final disposal site as one of important factor. In addition to natural drainage line, river line have digitized in Arc GIS9.3 from the master plan of the town. And integrated together in Arc GIS topology of personal Geo-data base for further analysis of drainage factor for selection of suitable solid waste disposal site. Moreover, those spatial point locations of the study area collected by Global Positioning System (GPS) were the major natural drainage line of the town, which has connection to the river line in the town (Appendix 2).

Table 5.14 Ground truth points of closed and open drainage in Soddo town

Points	Easting	Northing
1	36 50 18	75 60 02
2	36 52 76	75 61 75
3	36 55 67	75 62 68
4	36 57 94	75 53 65

According to selected criteria, any construction like a water pipe line, derange line and river should provide protection of water from pollution. In order to avoid of this case and according rules, disposal site should be located with minimum distance of 1500m from rivers(table 4.15)

Table 5.15 Rank of drainage for suitable analysis

Reclassified drainage factors	Rank
0 - 641m	1 Very low suitable
641 - 770m	2 Low suitable
770 - 898m	3 Moderate suitable
898 - 1026.m	4 High suitable
1026. - 1160m	5 Very high suitable

Spatial Analyst calculated this straight-line distance before reclassification, it was extracted using extraction by mask overlaying by study area boundary and the distance displayed on layer was 1155.22m this was reclassified five class to equal interval by new values re-assigned in order of selecting suitable site for solid waste disposal fig 5.7 site

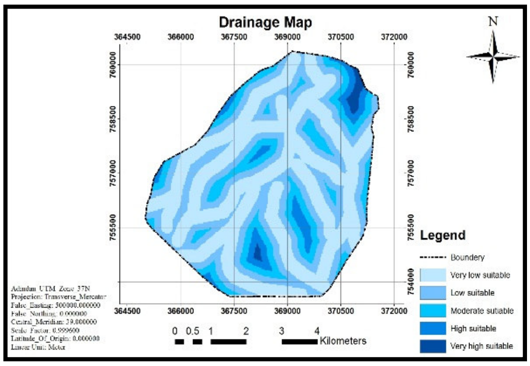

Fig 5.7 Reclassified drainage map of the study area

The value ranks of 5 highest suitable and the least suitable ranks scale values 1 were assigned. Accordingly this was reclassified in five sub groups using layer property standard classification in 5 is very high suitable, 4 leas suitable, 3, moderately suitable, 2 is low suitable and 1 is very low suitable (fig 5.7) above.

Table 5.16 Area coverage of drainage factor

Rank	Suitability scale	(cell size 30)	In $(m)^2$	In (ha)	In (%)
1	Very low suitable	3198	2878200	287.82	6.661389768
2	Low suitable	6998	6298200	629.82	14.57673721
3	Moderate suitable	7191	6471900	647.19	14.97875354
4	High suitable	13311	11979900	1197.99	27.7266289
5	Very high suitable	17310	15579000	1557.9	36.05649058
	Total	**48008**	**43207200**	**4320.72**	**100**

Development of the pair wise comparison matrix

The standardized raster layers were weighted using Eigen vector that is important to show the importance of each factor as compared to other in the contribution of site selection. Accordingly, the Eigen vector of the weight of the factors has computed in IDRISI 3.2 software in analysis menu decision Support/ weight module. The Analytic

Hierarchical Process (AHP) method employs an underlying scale with values from 1 to 9 to rate the relative preferences for two criteria (table 5.17).

Table 5.17 Scale for Pair wise comparison (Saaty, T, 2004)

Intensity of Importance	**Definition**
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance

This scale consists of a 9-point continuous scale so that an individual can simultaneously compare and consistently rank. The Weight module has combined with the pair wise comparison matrix file of the factors in a pair wise comparison continuous scale is as shown (Fig 5.8) below.

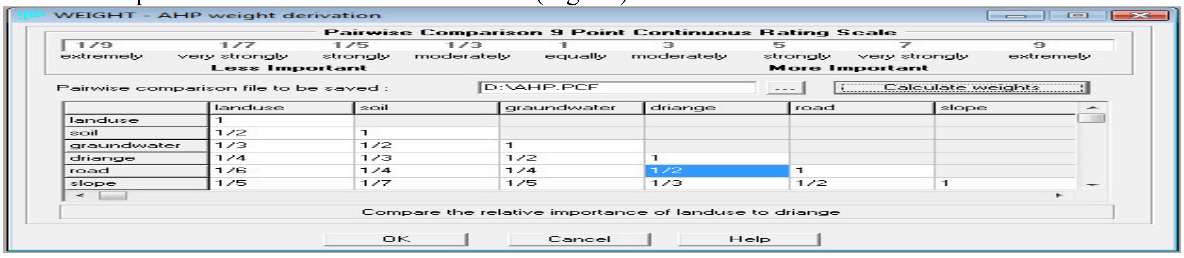

Fig 5.8. Pair wise comparison

Computed Eigen vector, which is an output of the pair wise comparison matrix to produce a best-fit set of weight module was in (table 5.17) below

Table 5.18 Weighted Eigen vector for suitable solid waste disposal site selection

Factor	**Eigenvector of weights**
Land use	0.3502
Soil	0.2454
Ground water depth	0.1715
Drainage	0.0996
Road	0.0616
Slope	0.0420
Aspect	0.0297
Consistency ratio	**0.03**

These resulting weight sums to one, as required by the weighted linear combination procedure. The consistency ratio (CR) indicates the probability that the matrix ratings has randomly generated. As a rule, a CR larger than **0.10** should be re-calculated and the result is a CR of **0.09**, which indicates a reasonable level of consistency in the pair wise comparisons (Saaty, T, 2004). The critical ratio of the calculated Eigen vector in this study was **0.03**, which is acceptable. The computed Eigen vector has used as a coefficient for the respective factor maps to be combined in weighted overlay in Arc GIS environment, where as in selection of suitable solid waste disposal site. Those factors has been reclassify the distance to layer, and assigned a value of 1 up to 5, 5 is to areas farthest from buffer center of road and drainage factor, buffer center of drainage (very high suitable) and assigning a value of 1 to areas near to center of buffer which is (the very low suitable locations). and ranking the values in between linearly. With this, Arc GIS 9.3 spatial analysis, tools determined which areas are near and which areas are far from solid waste disposal site.

Suitable urban landfill site selection analysis

In order to select the suitable site for meaningful and consistent map, weights have added up to 100% and the attribute scores had chosen using a scheme that was the same for each map. Each of the six constraints maps have considered as importance according to their computed Eigen vector weight score of each reclassified maps. This Attribute scores were assigned with respect to their scores ranged from 1 to 5, where a score of 1 indicated no constraint and a score of 5 indicated a total constraint. As the overlay operation is algebraic, the constraint score of a cell on the output map was equal to the total of the corresponding cell scores from each constraints map that were combined to produce it. Once the conversions had been completed for each file, the attribute scores were assigned to those reclassified maps and suitable site of solid waste disposal were created (fig. 4.8) there by using weighted overlay of spatial analysis (table 5.19)

Table 5.19 Scores and weights for the maps used in the landfill site selection.

Factors	Reclassification	Weight	Score
Land use	Commercial area	0.3502	Restricted
	Residential area		Restricted
	Grassland and forests		1
	Built-up area		2
	Urban farmland		3
	Proposed land use		4
	Urban farmland		5
I Infiltration rate	Medium	0.2454	3
	Low		2
Groundwater	20-35m	0.1715	5
	36-45m		4
	46-65m		3
Drainage	0 - 641m	0.0909	1
	641 - 770m		2
	770 - 898m		3
	898 - 1026.m		4
	1026. - 1160m		5
Road	0-199 m	0.0616	1
	199-399 m		2
	399-599 m		3
	599-799m		4
	799-999 m		5
Slope	1-2.8%	0.0420	5
	2.8-4.8 %		4
	4.6-6.4%		3
	6.4-8.2%		2
	8.2-10%		1
Aspect	SE to NE	0.0297	5
	SE to NW		4
	SE to SW		3
Weighted sum		1	

Based on the above weighted sum, a final composite map was produced using Weighted Liner Combination (WLC) the following post suitable site has been generated depending on the criteria with weighted overlay.

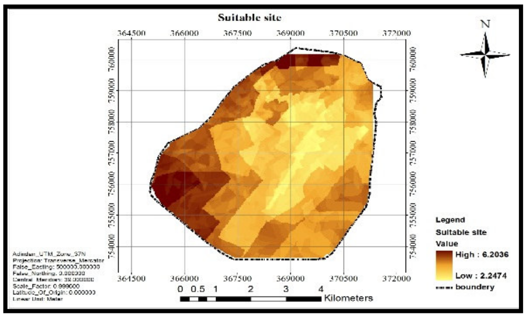

Fig 5.9. Suitable solid waste disposal site for Wolayta Soddo town

On the layer of the output raster, each pixel has a value that indicates how suitable that location for the suitable site of solid waste disposal site. And Pixels with the value of 6.2036 are very high suitable, and pixels with the value of 2.2474 are very less suitable. But it has not been finalized with this output it was evaluated with other used factors to finalized the site

Evaluation of optimal sites for final solid waste disposal site

Since suitable site has selected generally in pixel values of very high suitable and very low suitable, it was not comfortable for decision - making; therefore, a conditional expression in the con tool has been used to extract only the optimal sites from (fig 5.10). The finalization stage of the decision making to final suitable site was done through the process of overlying suitable area and existing site of Soddo town solid disposal site to the reclassified factors that are : land use, road, slope, and derange type and geological factors and extraction by mask had been used to the actual choice based on selected criterion. And Proximity to river, derange and water body should be in range of 0-1160 m , the buffer distance in with suitable site was become **1155.22**m after clipping the boundary area over it and evaluated optimal site can be seen in similarly for other factors. After all the evaluation has made between selected site, reclassified factors and existing site, the final suitable site was mapped (fig 5.11). And the suitability score for this final site has been made which indicated with approximate location. In the table (table 5.20), suitability score of 5 indicates the very high suitable area and 1 is very low suitable area among the evaluated layers.

Table 5.20 Suitability scores for evaluated factor

Factor	Suitability scores		Proximity	
	New site	Existing site	New site	Existing site
Road	5	1	1000m	25m
Land use	4	1	Proposed land use	Grass land & forest
Soli infiltration	5	1	Low	High
Ground water depth	3	3	36-45m	36-45m
Slope	4	4	2.8%-4.8%	2.8%-4.8%
Aspect	3	1	SW to NE & SE to NW	NW to SE
Drainage	5	1	1600m	15m

After evaluation con tool in Arc GIS 9.3 has used for extraction of final suitable site (fig 5.11) for output raster map of optimal sites of solid waste disposal in the study area has used.

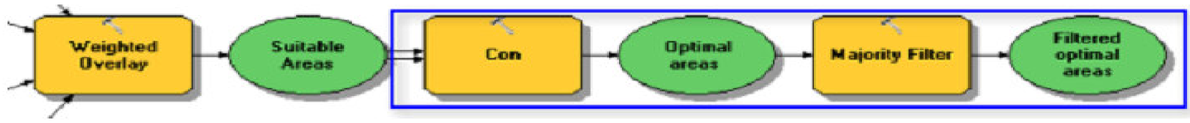

Fig 5.10. Final suitable sites selection model

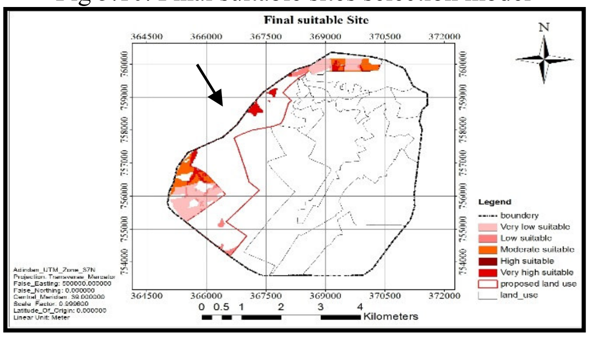

Fig 5.11. Final suitable solid waste disposal sites for Wolayta Soddo town

Table 5.21 Area coverage of final suitable site

Score	Scale	cell count	cell size 30	hectare	In %
1	Very low suitable	1170	1053000	105.3	49.40878
2	Low suitable	228	205200	20.52	9.628378
3	Moderate suitable	592	532800	53.28	25
4	High suitable	17	15300	1.53	0.717905
5	Very high suitable	361	324900	**32.49**	15.24493
			2131200	213.12	100

Durability of the selected site utilized for a minimum of ten year according to the site selection criteria used. Therefore, waste generation rate (Kg/head/day) and Population parameter has used to estimate how much area in hectare is need (see Appendix 4). According to literature review (Rwanda Environment Management Authority, 2010) 5m landfill depths have selected for the area in 6 hectare (2.1%) among 32.49 ha of the selected site for the minimum period of ten-year service.

Discussion

This paper examines an approach for identifying the optimum site for the construction of a landfill in a typically urbanizing town. A multi-criteria approach was employed in conjunction with GIS-based overlay analysis to identify the most suitable site for landfill development in the study area. The study attempts to minimize the problems listed in the current solid waste disposal system management of the study area such as illegal solid waste disposal site, and describes the capabilities of GIS and multi criteria evaluation for the choice of better solid waste disposal site in land use planning Spatial Multi Criteria Evaluation (SMCE) process based on GIS techniques and capabilities were main task of this thesis work and in such a way, land use planners can propose suitable solid waste disposal site and evaluate the geological, environmental and economical impact.

Conclusion

Final suitable landfill site has selected based on the criteria set and selected factor with final evaluation to reach the objective of this study. Moreover, these factors were converted into raster cell values based on the basic selected parameters, which resulted as final suitable urban landfill site. The analyzed landfill factors were then each assigned a relative importance by Analytic hierarchy process (AHP) to reflect in the overall scope of the study with acceptable Consistency ratio 0.03 for selecting suitable site of solid waste disposal in Wolayta Soddo town. (AHP) has been integrated into a decision making process with geographic information system (GIS) to achieve the objective of this study and to answer the study questions. In general, the study revealed that 5m landfill depths has selected for final disposal of solid waste in Soddo town. And 5m landfill depth has been taken for 20 year utilization depending on the population growth rate 1845 and waste generation rate (Kg/head/day =0.31) of the town and resulted 6 ha (2.1%). Therefore, the output of this study can be used as for minimization of environmental related problems due to uncollected solid waste disposal in the town.

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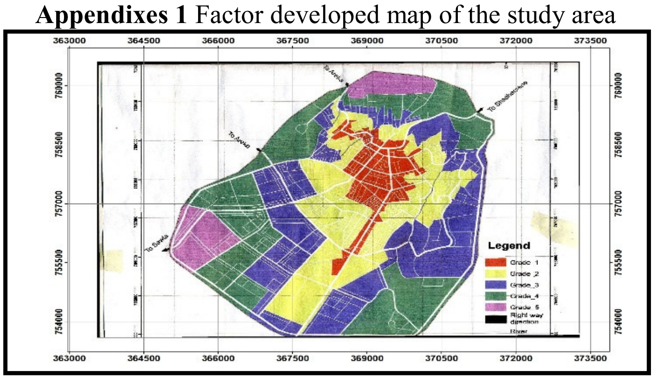
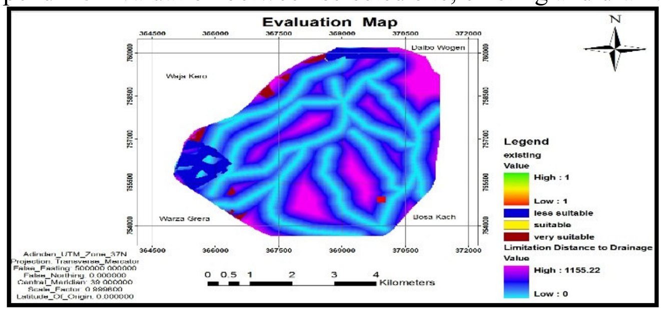
Appendixes 1 Factor developed map of the study area



Appendix 2 GPS point of urban farmland and grassland

Spatial pointes	Easting	Northing	Remark
1	37 0627	759259	Urban farm land during check to land use land/cove in the fled survey
2	370747	759041	
3	370885	758804	
4	370776	758429	
5	371023	758380	
6	371398	758557	
7	371546	758784	
8	371536	759100	
9	371230	759337	
10	371023	759209	
Spatial pointes	**Easting**	**Northing**	**Remark**
2	368206	758084	Grassland during check to land use land/cover in th fled survey
3	368434	758119	
4	368531	758347	
5	368100	758522	
6	368574	758803	
7	368574	759172	
8	368416	759680	

Appendix 3 Evaluation between selected site, existing and drainage



Appendix 4 Population vs waste generation rate

Population	Year	year	Population	Rate
62750	**2005**	2005	**62750**	1845
105627	**2023**	2006	64595	1899
Waste Generation rate (Kg/head/day)	0.31	2007	66494	1955
Density (kg/m^3)	370	2008	68449	2012
Volume (m^3)	**318593**	2009	70461	2072
Mass of SW (Kg)	117879553	2010	72533	2132
Depth (landfill Site)	5	2011	74665	2195
Minimum area (ha)	**6**	2012	76860	2260
Trend	**2.94%**	2013	79120	2326
	0.0294	2014	81446	2395
Rate	1845	2015	83841	2465
		2016	86306	2537
		2017	88843	2612
		2018	91455	2689
		2019	94144	2767
		2020	96912	2767
		2021	99680	2930
		2022	102610	3016
		2023	105627	3105

Appendix 5 Container sites