CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

Waste Management and its Impact on the Environment

Case Study: Los Angeles County

A thesis submitted in partial fulfillment of the requirements

For the degree of Master of Arts

in Geography, Standard Program

By

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May 2016

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Acknowledgement

I would like to specially thank Dr. Regan Maas for providing guidance and helping me to complete this thesis. I would also like to appreciate David Deis, the department cartographer, who assisted me with the maps. Dr. Steve Graves, Dr. James Craine, Dr. Soheil Boroushaki and other faculty members of the Department of Geography for providing me with insight into the various sub-disciplines of geography during my stay in California State University, Northridge as I attained my Master degree. Finally, not forgetting all my love and gratitude goes to my family, parents, siblings, Petra Anagor and Jennifer Iroezi for encouraging me during this process. All honor still goes to Almighty God for his faithfulness.

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Abstract

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Landfills are the most common method for disposing of waste, but they present a number of challenges that political leaders and environmental managers must address. This study analyzes the atmospheric and hydrological effects of landfill sites and proposes a suitable location for a new landfill site in Los Angeles County. GIS and multi-criteria methods were used to analyze a number of variables in order to determine the suitability for an environmentally safe location for a new landfill. Nine factors, each with a unique map layer were used in the analysis, including current landfill sites, slope, forest, wetland, airport, road, highway, railway, and land uses. GIS was used to layer the raster based maps in order to create the final suitability map, which identified better suited and less well suited areas.

Chapter 1

Introduction

In 2014, approximately 350,000 tons of solid waste materials were delivered on a daily basis to all of the different landfill sites in Los Angeles County. The Department of Public Works (DPW) is one of the establishments which deals with waste management representing Los Angeles County and has collected and reported data on the generation and disposal of waste in the county for 30 years. According to the DPW's 2014 annual report, "From the year 1990 to December 31, 2013, the permitted in-County disposal capacity has increased from 98.7 million tons to 124.8 million tons" (2014, p. 15).

The landfill method of waste management is known to be the oldest form of waste treatment (burn and bury), regardless of the development (Donevska et al., 2013; Sumathi et al., 2008; Mahini and Gholamalifard, 2006; Leao et al., 2004). It is still the most common method of disposing of waste. Landfills are defined as the accumulation of waste in a particular area. Majid (2010), addresses how landfills are the most common method of disposing solid waste, even though there is a lot of improvement in the waste management system, "but landfill site selection is a serious issue in the urban planning" (see also: Hostovsky, 2000; Geneletti, 2010) because they can pose environmental threats including degradation of the water or soil, and air pollution. Improper selection of locations for landfills can be disastrous to the larger society in terms of health and environmental pollution and can also adversely affect the economy and the natural system if not properly maintained.

What will be the fate of the environment if there are no waste management systems or if there are no landfill sites to dump and dispose all the trash humans produce every day?

In everyday human activities, there are numerous wastes produced by harmless stuff such as paper, diapers, plastics, metal and food to toxic materials such as batteries, healthcare waste, paint etc. These waste products have no value to individuals or the environment because they cannot be used for any productive purposes and can only be disposed. Waste can be categorized into, household wastes; municipal wastes; commercial and non-hazardous industrial wastes; healthcare wastes; Hazardous wastes; incinerators wastes; construction and demolition wastes (Ali et al., 1999; Tchobanoglous et al., 1993), each category producing different type of wastes.

The majority of the waste dumped at landfill sites contain toxins which percolate into the soil, groundwater, and are also released into the air. Mwiganga & Kansiime (2005) described the danger surrounding landfill sites as generating nuisances such as bad odor, birds, mosquitos and flies, as well as health issues like cancerous illnesses, respiratory irritation, and central nervous system damage (Davoli et al. 2010; Durmusoglu et al. 2010) to residents living near landfill sites. Waste is usually considered irrelevant and useless to society and is only taken into account when it leads to air and water pollution, contamination of soil and atmosphere, and filling landfills, which affects people and society directly. In fact, waste is a risk to every living thing and natural resource that is important to human survival (Falasca-Zamponi, 2011; Hossain et al, 2011, DPW, 2014).

Can waste be prevented? Gentil, et al (2011) described how governing bodies, private firms and international organizations plan to decrease the impact of waste on the environment by making waste reduction a priority and seriously looking for a better solution (e.g., in 2015, California banned plastic bags). Such solutions include encouraging consumers to buy more durable products and to buy fewer products to recycle when possible. Regardless of

the effect of these solutions, the problem of landfill sites is there. In terms of business approach, irrespective of its size, there is profit from waste prevention. In a community, if all individuals work together towards waste prevention, it will actually prevent pollution and make the environment a better, less harmful place to live in (Salhofer, et al. 2008; Gentil, et al. 2011; Abarca, et al. 2013; Yano & Sakai, 2016). There are four areas of waste management namely; collection, recycling, incineration and landfills.

The landfill method is practiced in both urban and rural areas. This research will focus solely on the impact of landfills in urban areas and also consider a suitable place for a new landfill in Los Angeles County. Letcher and Vallero (2011) emphasize how the increase in population has affected waste production as residents produce more waste. Therefore there should be a high demand in developing competent waste management strategies. Proper waste management has contributed positively to the growth and development of communities and has also contributed to their financial growth. As more people move from rural areas to cities such as Los Angeles in search of a better life and greater job opportunities, waste generation continues to reach an all-time high (Yazdani, et al., 2015). With lots of research on waste management, it is acknowledged that urban growth has also had a direct influence on the urban waste generation (landfill) in the County of Los Angeles.

There are some challenges in the management of waste that keep occurring around the Los Angeles County such as: lack of proper waste collection coverage, inadequate use of recycling technology, landfill disposal and management of waste. Nevertheless, dumping of waste through the means of landfills is done all over world by both the developed and under developed countries. Lempert and Schwabe (1993), view the issues

of landfill waste management as related to the advance in population, which caused people to migrate closer to landfill site. Here in Los Angeles County, the control of materials used on the surrounding is the problem linked with the landfill method due to the increase of the population. When there is a discussion on waste generation in an area, there are three main explanations for it. These include urbanization, population growth, and industrialization, which create lots of environmental concerns and manufactures big problems in our society (DPW, 2014; Zhang et al, 2010; Zerbock, 2003; Zurbrugg, 2002; Boer, et al. 1997). Below is a table showing Los Angeles County's population growth in recent years.

People QuickFacts	Los Angeles County
Population, 2010 (April 1) estimates base	9,818,664
Population, 2014 estimate	10,116,705

Table 1: Estimate Population Growth in Los Angeles County.
Source Information: http://quickfacts.census.gov/qfd/states/06/06037.html

Because the landfill method is the most common means for the disposal of waste, an appropriate site selection will be quite a complex process and will need several criteria and procedures. Majid (2010) explains that Geography Information System (GIS) plays a significant part when it comes to the suitability analysis of a landfill site and how the software is efficient for such situations (Kontos et al., 2005; Sener et al., 2006). To ensure efficacious siting of a new landfill site in LA County, Multi Criteria Analysis will be used. The methodology allows for multiple effects on the environment to be considered simultaneously. Javaheri, et al (2006) specifically discuss the importance of using Multi Criteria Analysis when considering a suitable location for a landfill site, and how evaluation of the working criteria helps or impacts the result. Multi Criteria Analysis offers a way to rate the landfill sites according to their importance, and to ensure that the proposed

location is outside of the determined criteria. One way to address this issue is by using GIS and Multi Criteria Analysis to identify suitable areas for the sustainable landfill sites (Delgado et al. 2008, Tavares et al. 2011; Sharifi et al. 2009, Nas et al. 2008). GIS is also an excellent tool for information management and will be used to conduct a thorough analysis in order to find the best area for a new landfill.

1.1 Geographical Background of Los Angeles County

This research only considers ten active municipal solid waste landfills sited in: Calabasas, Pebbly Beach, Scholl Canyon, Antelope Valley Recycling and Disposal Facility, Sunshine Canyon City/County, Chiquita Canyon, Lancaster, Savage Canyon, City of Burbank landfill #3, and San Clemente. Out 0f 10 active landfills, the research will be model 8 active landfills of the site city such as Los Angeles, Burbank, Palmdale, Sylmar, Agoura, Castaic, Whittier and Lancaster; as areas to avoid when looking for a suitable location for a new landfill site. Table 2 below will show the site name and its city, while Figure 1 below will show the Landfill site area, some Cities and Los Angeles County.

Figure 1: Los Angeles County and its Landfill.
Source information: https://dpw.lacounty.gov/epd/swims/OnlineServices/search-solid-waste-sites-esri.aspx (Landfill sites, 2015); ESRI Data 2013 (LA County and Cities).

The location of a landfill ought to meet the terms that will be provided for this research in order to get a suitable landfill site guiding principle and criteria. Chang et al. (2008) explained that landfill siting is a very challenging procedure which involves assessment of many different criteria, including urban centers, active landfills, transportation network, slope, water resources and land use. However, looking at the current landfills in Los Angeles County, they no longer meet the appropriate landfill siting criteria thanks to the county's rapid population growth. The existing landfills are located near residential area, transport modes and water bodies (Ball & Novella, 2003 ; Blight, 1995 ; Christensen, et al. 1998 ; Christensen, et al. 1994 ; Douglas, 1992 ; Papadopoulou, 2007 ; Boer, et al. 1997 ; Vrijheid, 2000). These areas are susceptible to environmental pollution and the proximity of the landfill to residential areas could pose serious hazards to residents. For that reason, a proper landfill site selection will be needed to ensure sustainable development.

1.2. Purpose of the Research

This research will focus on choosing a suitable location for a landfill in the County of Los Angeles. Its principle aim to find a site that minimizes environmental destruction and avoid harmful effects on human health. This research looks at the impact of waste management, specifically landfill waste management sites, and how to propose a suitable area for a new landfill. The best area for a new landfill in Los Angeles County should not be in close proximity to residential areas. A suitable place for a landfill site should be an isolated area, away from population centers, water resources, and airports, but not too far from access roads and railway lines.

There have been several studies on waste management. The Los Angeles County Department of Public Health has examined the solid waste management implications on health for individuals living near landfills. Its goal is to protect community health by ensuring that all residential, business, and commercial solid waste is stored, collected, transported, processed, and disposed of in a safe, and environmentally suitable way.

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Chapter 2

Literature Review.

2.1 Introduction

Our everyday lives revolve around waste, but the important thing about waste is how it is handled and disposed of, because if not done properly, it can pose risks to human health and the environment. While the focus of this research paper will be on Los Angeles County, this chapter will highlight past studies focusing on problems in the management of waste in developed regions, such as New York, New Jersey and Montreal. These problems surrounding the environmental effects of landfill sites are both atmospheric and hydrological.

2.2 Waste management

The management of waste is based on the collection, transportation, disposal, handling and monitoring of waste materials to facilitate the cleanliness of our environment. Within the years of development, many changes have occurred in the waste management model (Tanskanen, 2000; Morrissey & Browne, 2004; Berger et al., 1999). One of the simplest and most crucial services provided by waste management experts in order to preserve the cleanliness of the environment is controlling waste (collecting and transporting it out of neighborhood). According to Asnani (2006), the management of waste is provided by the county and some private firms in order to keep the county and subsequently the whole country clean (Seadon, 2010; Costi et al, 2004). Apart from the beautiful constructions in the cities, keeping the environment clean is also a big attraction in an area. Even if a community is known for its incredible architecture or flora, it would

not be desirable if it were filled with trash. In this paper, the waste management method focused on is the landfill, which is known as a site where waste materials are being disposed of by burning and/or burying.

2.2.1 Landfill

A landfill occupies a large area (hectares) of land, which is specifically designed and built to receive waste. The United States Environmental Protection Agency (2003) explains how even though with the knowledge of reduce, reuse and recycle, there is still around "56 percent" of waste left that is being cast off at dump sites in the country. At these landfill sites now, the land area has an artificial liner to detach the waste from the environment, and is covered daily to keep it from scattering (from air, rain, animals). Landfills are known to be the most common, oldest method of waste disposal and are an essential part of an integrated waste management system in every part of the world (Sener, 2006; Khateeb, 2013; Renou et al, 2008; Majid, 2010). In developing countries, landfills are considered a dependable and cost effective method of waste management when sufficient land is available.

For a better knowledge of what happens in landfill site, it is compulsory in Los Angles that the county arrange and administer a Countywide Integrated Waste Management Plan annually, which enables them to keep records of solid waste reduction, and the amount of tons produced daily from the different landfill sites.

According to the Department of Public Works, solid waste facilities are permitted in Los Angeles County, although some are closed landfills, and historical dumpsites. The site types are:

Site Types	Active	Closed
Hazardous Waste Landfills	0	3
Designated Waste Landfills	0	52
Municipal Solid Waste Landfills	10	79
Inert Landfills	1	22
Inert Debris Engineered Fill Operation	11	3
Unknown	0	14
Composting Facility	10	2
Chipping and Grinding	13	0
Transfer/Processing Facility	54	8
Transformation (Waste-to-Energy) Facility	2	0
Out-of-County Facility	75	0
Waste Hauler	99	10

Table 2: Solid Waste Facilities in Los Angeles County.
Source Information: Department of Public Works.
https://dpw.lacounty.gov/epd/swims/OnlineServices/search-solid-waste-sites-esri.aspx

Out of all the facilities mentioned above, this research work will be focused on Municipal Solid Waste Landfills (shown in figure 1).

2.2.2 Environmental Effects of landfills

The landfill sites used to dispose of unwanted items are also affecting the air, water and land through environmental pollution. These problems can be generally categorized into two different classifications: atmospheric and hydrological effects (Rao & Shantaram, 2003; Vrijheid, 2000; Sutton, 2011; Kampa & Castanas, 2007).

i. Atmospheric Effects

The burning of landfill waste releases toxic gases that discharge into the environment, with citizens paying little or no attention to health risks associated with constant exposure to waste (Olorunfemi, 2009; Efe, 2013; Ogbonna et al., 2002; Aderemi

& Falade, 2012). Most waste dumpsites are located at roadsides, close to residential areas, markets, and farms.

With these wrong and unpleasant management and operation of waste, nuisance odor generates in the environment. The odors from landfills significantly affect the residents living near the site. As Sutton (2011) emphasizes, residents report more respiratory problems and irritation of the eyes, nose and throat, where there is significant landfill odor, pests, polluted water and traffic.

The foul odors generated from landfill sites are strong and measured by the "hydrogen sulfide" content, a toxic gas created by decaying waste, and can cause organic damage to human (Ramke, 2009; Sutton, 2011). These gas generated in MSW landfills, during the natural process of decomposition of bacteria is known as landfill gas. According to the United States Environmental Protection Agency (2014, n.p) "Compounds found in landfill gas (LFG) are associated with strong, pungent odors." These aromas spread out to neighboring homes and business; and this can be offensive to human health and the environment as well as these nasty odors can lower the value of people's lives who live near landfills site and reduce the value of the properties around that zone (Hamer, 2003; Olorunfemi, 2009; Aderemi & Falade, 2012).

ii. Hydrological Effects

The unsuitable placement of waste in landfills or open dumps generate groundwater pollution through runoff or infiltration from precipitation. If solid wastes are placed directly into ground water, or if leachate is permitted to drain straight into the surface water, it can produce severe harm (Amokrane et al., 1997; Aziz et al., 2007; Christensen et al., 2001).

The water bodies that are extrapolated from environmentally hazardous waste are commonly known as leachates. Osterath (2010) explains that leachate is the flow of liquid generated by precipitation penetrating through waste deposited in landfills. When the wastes in landfills decompose, certain chemicals discharge into the soil such as chlorides and heavy metals, which pass through rainfall and end up in our drinking water.

El-Fadel et al., (1997) explained that solid waste disposal sites are amongst the causes of local water resource contamination because the generation of leachate which is triggered by water percolating through the solid wastes. This leachates affect humans by causing serious health problems such as mercury and lead poisoning; with animals, chemicals such as ammonia react with the water to reduce oxygen levels, which can cause suffocation of aquatic life (Kirkeby et al., 2007; Gailey & Gorelick, 2005; Vrijheid, 2000). Although, Ramke (2009) suggests that environmental pollution can be avoided if there is a well-constructed and operated landfill designed to collect and treat the emissions of leachate and landfill gas.

2.2.3 Effects of Landfills on Health and Well Being of Local Residents

Research have been carried out on the residents near landfill sites (Closed and Open) and with reports on the odor, health, and contamination of water. Driving through a landfill site is not a pleasant situation because of the odor, but what really happens to the people living near these sites? Vrijheid (2000) argues that hazardous waste disposal may be harmful to the communities and environment that are proximal to such dumpsites. Even though there have been numerous studies focusing on the health of the overall population, particularly those residences near landfill sites. Kampa & Castanas, (2007) added that industrial waste might cause more harm to nearby communities, due to accidental discharge

of hazardous waste into the atmosphere. There are increasing concerns about the health conditions of people residing close to landfill sites as they are exposed to large amounts of possibly hazardous chemicals. (Rushton, 2003; Jarup et al., 2002; Elliott, 2001)

In New York State in 1977; the toxic materials dumped at the Love Canal landfill during 1930s and 1940s leaked and chemicals were detected in the nearby neighborhood (schools and residential area), which caused adverse health effects (Vrijheid, 2000). In addition, there were objections from residents near Lipari Landfill in New Jersey around the late 1960s and 1970s about the heavy pollution that caused low birth weight babies, which triggered the closing down of the site in 1971. Studies show that the dangers of landfill gas emissions span reproductive effects on humans these include but are not limited to low birth weight, fetal and infant death, unprompted abortion, and also manifestation of birth defects among the residents living in close proximity to landfill sites (Vrijheid, 2000; Rushton, 2003). Meanwhile, the residents living nearby landfill sites are increasingly worried about health outcomes, based on the disposal of wastes around them.

According to UNEP (2012), fluorescent lights, batteries, electrical switches, which are dumped on landfill sites also generates pollution which also causes harm. Chemicals such as chloride, benzene and dioxin are harmful substances, which are carcinogenic, and cause liver, lung, and nervous system damage. Also, the gas from the landfill site (Miron Quarry) in Montreal, caused a main environmental and health concern and a range of volatile organic compounds (VOCs), including some suspected human carcinogens, which were detected in the gas (Goldberg et al., 1995; Hester & Harrison, 2002; Johnson, 1999; Drumm, 2006).

When a landfill site is located near aquifers providing community drinking water, movement of hazardous matters into groundwater is a major environmental worry, because it may represent a public health problem. The complex connections between the environment and health have been generally stressed, and studied by many researchers. Therefore, to better protect human health and ensure environmental safety, suitable waste dumping is an important module.

Chapter 3

Methodology

Previous research has shown that there is pertinent information to be acquired on the impact of landfills on environment and humans. To minimize future negative long term effects on the environment, a comprehensive landfill site selection procedure needs to reflect on specific criteria to detect the best accessible new landfill sites in Los Angeles County, California.

3.1 Suitability Analysis

To find the best site for a new landfill in Los Angeles County, nine criteria were used, including proximity to current landfill site, urban center, forest lands, wetlands, selected transportation systems (including airport, road, and railway), as well as terrain slopes and land use/zoning classifications. Data layers were modelled using a 4-level suitability score and overlaid to create a cumulative multi-criteria suitability model (Table 3).

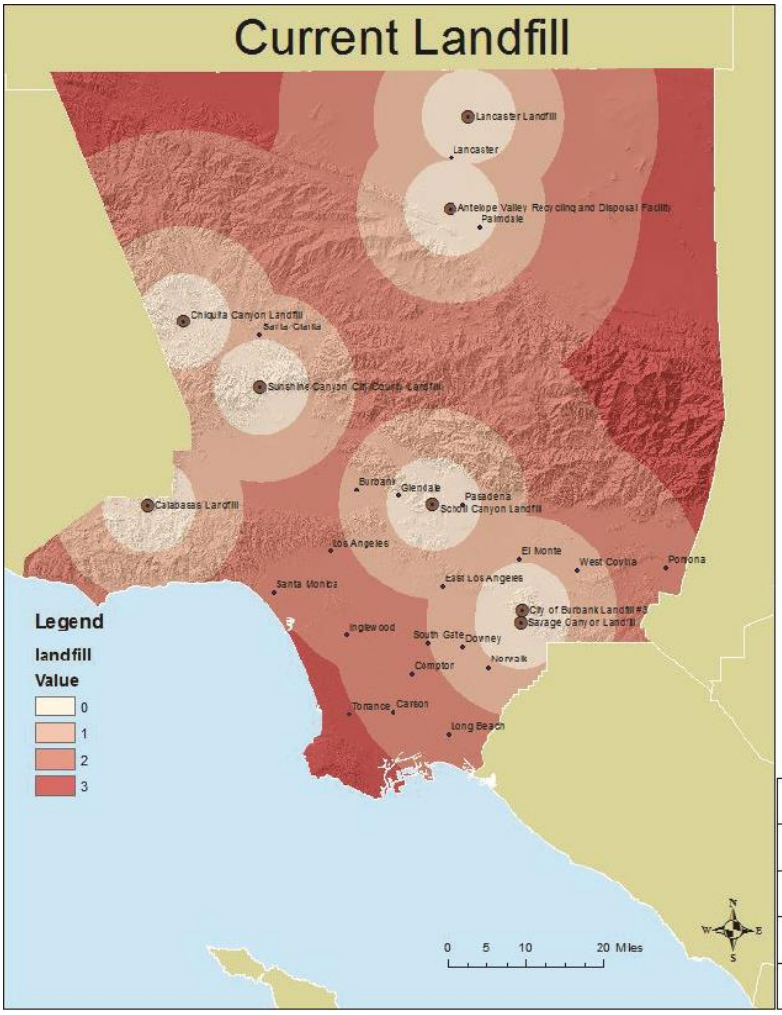
Model Level	Score
Suitable	3
Good	2
Fair	1
Not Suitable	0

Table 3: Overall suitability analysis model applied to each of the nine individual criteria across Los Angeles County.

3.1.1 Proximity to Current Landfills

In order to obtain landfill point locations in Los Angeles County, the Solid Waste Information Management System (SWIMS) data were explored. The relevant data was then compiled in ArcMap.

Eight active municipal solid waste landfill sites were focused to capture areas currently served, which will be avoided in the new landfill location analysis. These facilities include the Antelope Valley Recycling and Disposal Facility, City of Burbank Landfill #3, Sunshine Canyon City/County Landfill, Chiquita Canyon Landfill, Calabasas Landfill, Scholl Canyon Landfill, Lancaster Landfill, and Savage Canyon Landfill. Distance to the nearest current landfill for all pixel areas in the County were calculated (Figure 2). Areas within 16,093.47 meters (or 10 miles) were considered not suitable. Distances progressively further from current sites were given increasingly suitability scores (Figure 2).



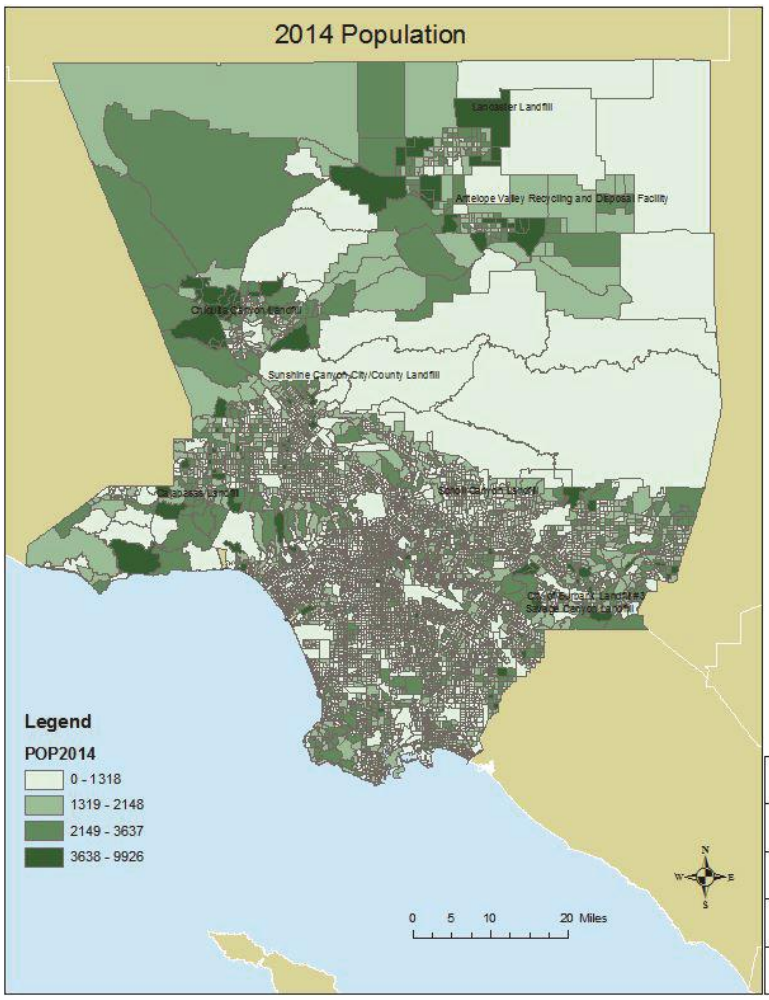
Current Landfill	Model Level	Score
>53,253.55	Suitable	3
53,253.55 - 24,140.21	Good	2
24,140.21 - 16,093.47	Fair	1
<16,093.47	Not Suitable	0

Figure 2: Current landfill site (8) in Los Angeles County with suitability model scores for proximity thresholds.

3.1.2 Proximity to Urban Center

Population density information, from the U. S Census Bureau point data for the years 2010 – 2014 was used to model major urban areas. Whenever the materials in landfill sites decompose, they release gases, which pose health hazards (e.g. nausea, headaches, eye irritation, sore throat and nose) and pollute the environment. The airborne pollution caused by the migration of gases, particles and chemicals during periods of active operation in the landfill site are inhaled by human causing illness and destroying the environment (Vrijheid, 2000; Berry & Bove, 1997). Therefore, siting a new landfill as far away as

possible from current urban centers was an important criterion. As with landfills, distances progressively further from urban areas were given increasing suitability scores (Figure 3)



Urban Center	Model Level	Score
>1318	Suitable	3
1318- 2148	Good	2
2148- 3637	Fair	1
<9926	Not Suitable	0

Figure 3: Urban centers in Los Angeles County with Suitability model scores for proximity thresholds.

3.1.3 Slope Data

A 30m resolution digital elevation model (DEM) was retrieved from the National Map Viewer (USGS) website. Degree slopes were then calculated from the DEM. In Sener et al (2006), slopes over 20% were considered problematic for landfill siting therefore this analysis will consider slopes less than this threshold as acceptable. The steeper the slope, the higher the risk of run-off, polluting local areas. Slopes less than 20% (Kontos et al,

2005; Akbari, 2008) were considered most suitable (Figure 4). Areas with no slope of nearly flat ground (<5% grade) were considered most suitable (<5%) while the high slopes were not suitable (>20%).

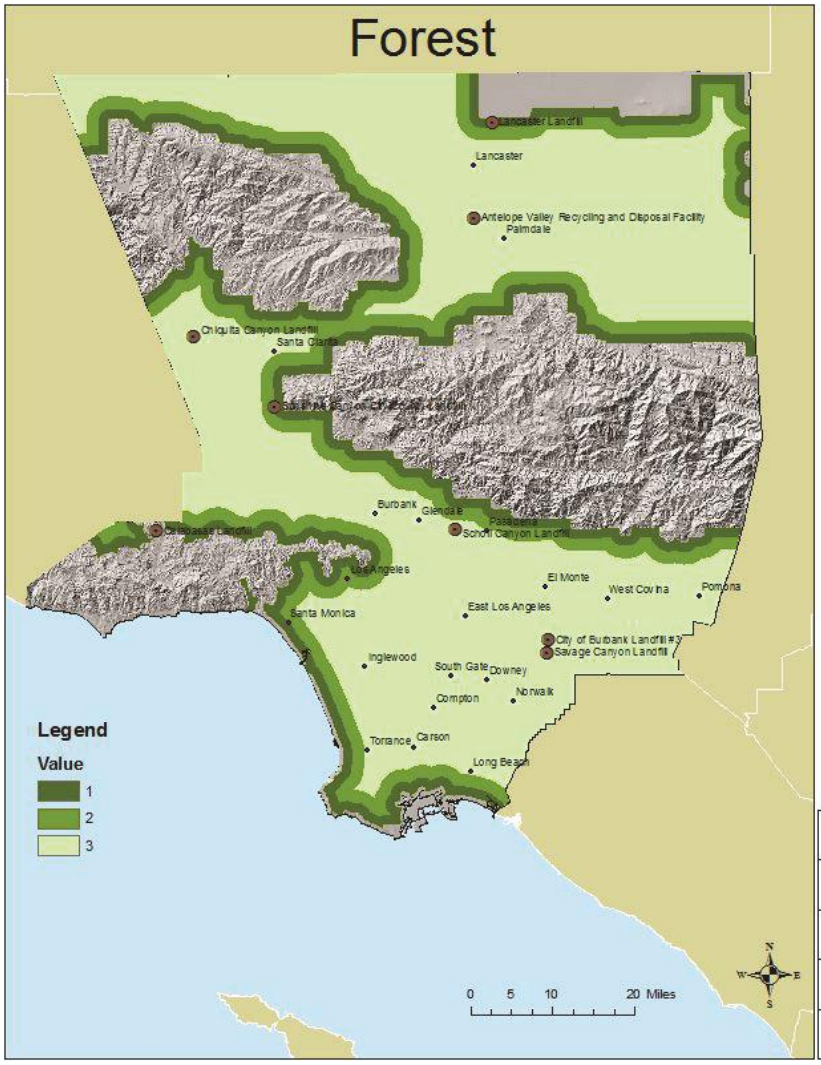
Slope	Model Level	Score
<5%	Suitable	3
5% - 10%	Good	2
10% - 15%	Fair	1
>70.32%	Not Suitable	0

Figure 4: Slopes in Los Angeles County with suitability model scores.

3.1.4 Proximity to Forests

The National Forest in Los Angeles County is an important environmental and recreational area and was therefore given weight in this analysis. The Angeles national forest is a protected public land, therefore areas within less than 500 meters of this forest

were scored as not suitable in this analysis (World Bank, 2004; Demesouka et al., 2013). Anything greater than 500 was given an increasing suitability score (Figure 5). Los Angeles National Forest data retrieved from ESRI Data for 2013 and reclassified to fit this model (Figure 5).



Forest	Model Level	Score
<500	NoData	0
500 - 2000	Fair	1
2000 - 4000	Good	2
>24930.1	Suitable	3

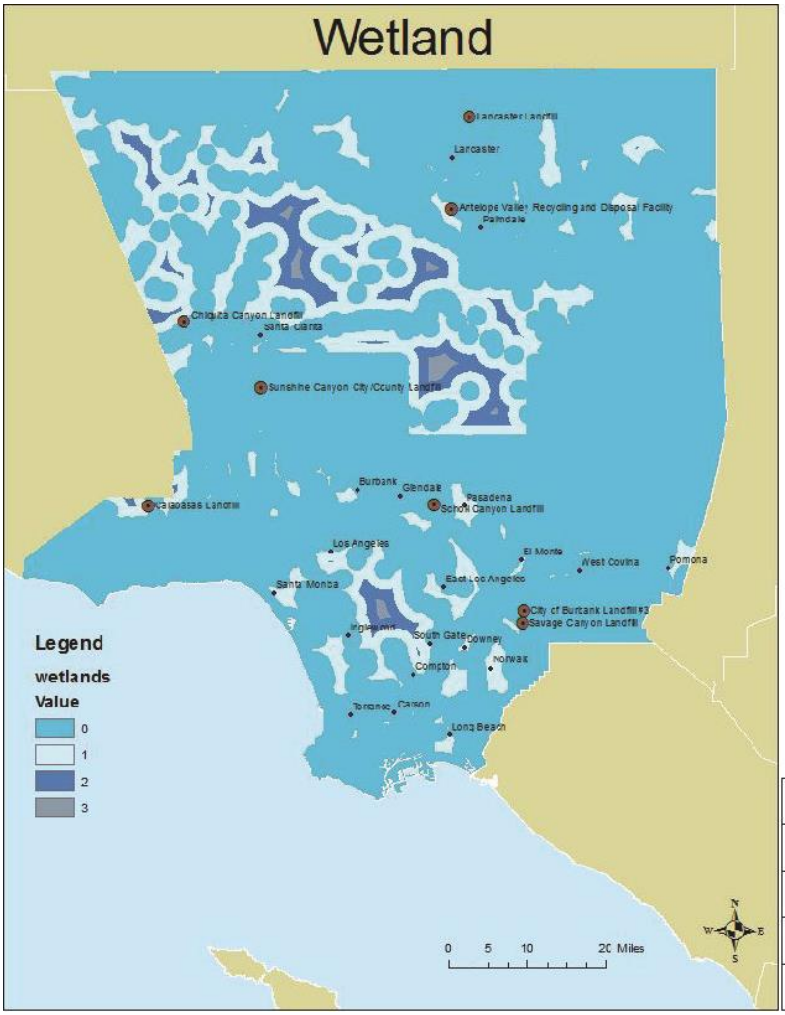
Figure 5: The Angeles National Forest with suitability model scores for proximity thresholds.

3.1.5 Proximity to Wetlands

Groundwater is easily polluted by leachate from waste disposal sites, therefore wetland data must be included in this study. The National Wetlands Inventory (U.S. Fish

& Wildlife Service) used in this work was acquired from the National Wetland Inventory (NWI). This dataset includes such waterbody classifications as estuarine and marine deep water, riverine, lake, freshwater pond, estuarine and marine wetlands, freshwater emergent wetland, freshwater forested/shrub wetland and other (Figure 6). It is important to minimize the impact of such landfills on groundwater quality and the environment in general (Ramke, 2009; Berry & Bove, 1997). For instance, areas close to sea level are considered inappropriate for landfill siting, as the risk of flooding becomes increasingly high.

Proximity to nearest wetland value were calculated for all areas in Los Angeles County. Areas a two miles of a wetland were considered not suitable (Winter et al., 1998; Gainesville, 2004; World Bank, 2004). Distance progressively further from wetlands were given increasing better suitability scores (Figure 6).

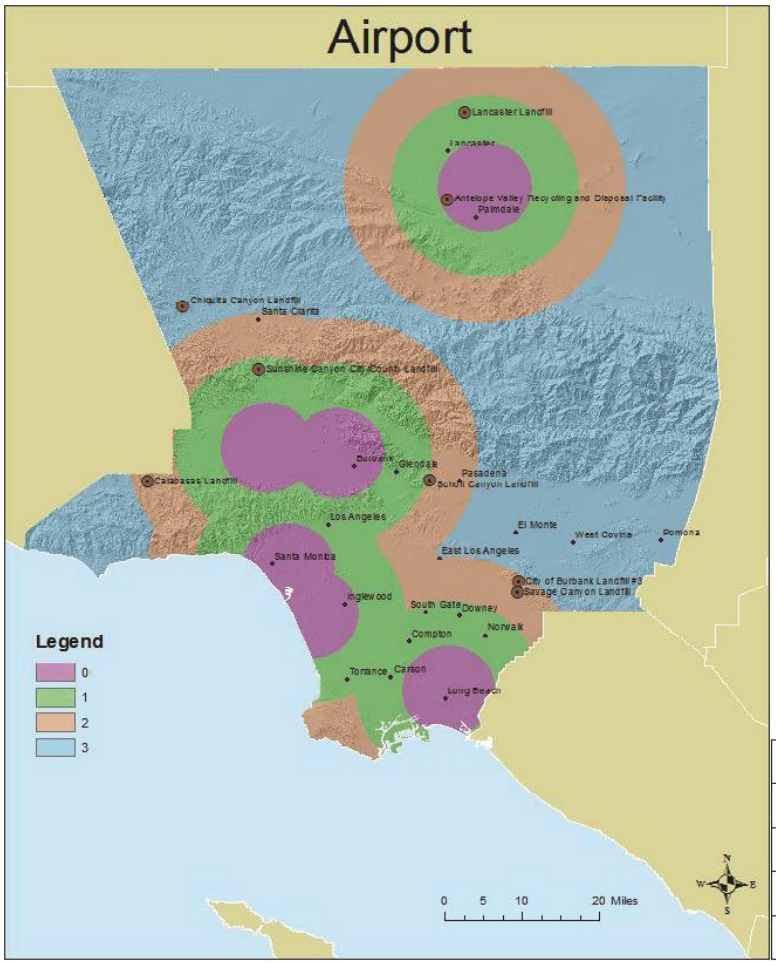


Wetland	Model Level	Score
< 1,679.21	Not Suitable	0
1,679.21 - 3,358.42	Fair	1
3,358.42 - 5,037.63	Good	2
>6,716.85	Suitable	3

Figure 6: The wetland in Los Angeles County with suitability model scores for proximity thresholds.

3.1.6 Proximities to Transportation Systems

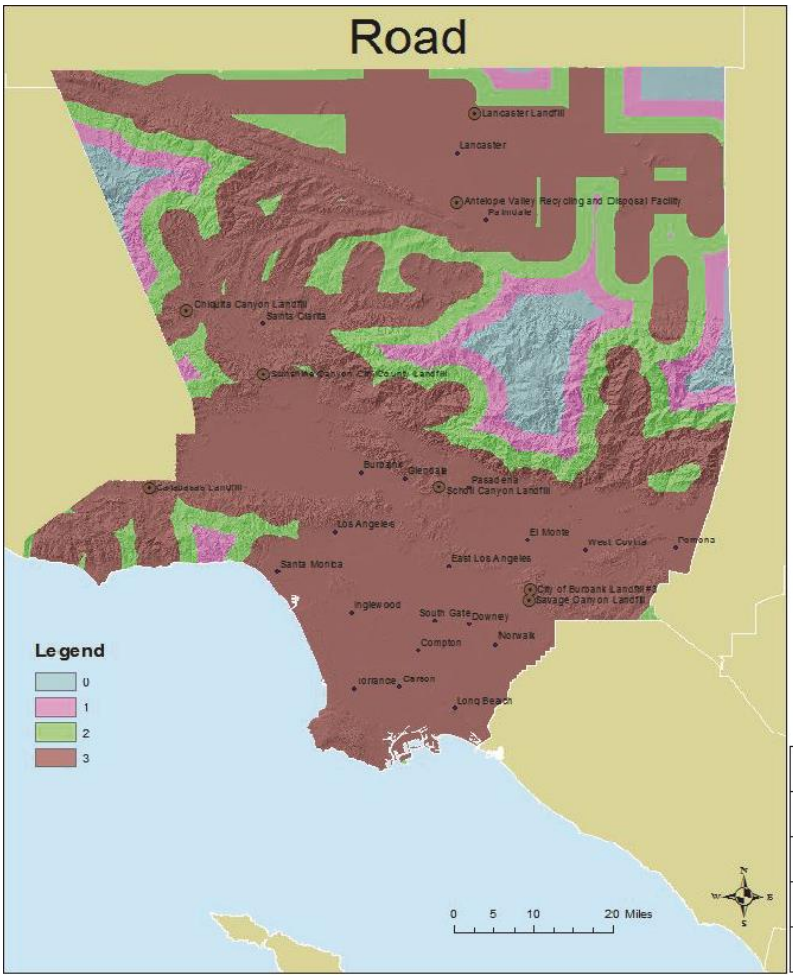
Proximity to various transportation systems relevant to landfill siting, including the road network, railways, and airports are also worthy of consideration. Proximity roads is good, but proximity to airports is bad. In section 503 of the Ford Act, landfill sites cannot be within six miles of an airport due to the risk of wildlife interfering with airplanes, predominately bird strikes, as birds will often flock to landfills to scavenge. In this research, the six miles (8,046.74 meter) proximity threshold will be used, in keeping with the Ford Act (Figure 7). Increasing distances from airports will be modeled as increasingly suitable.



Airport	Model Level	Score
<8,046.74	Not Suitable	0
8,046.74 -16,093.47	Fair	1
16,093.47 - 24,140.21	Good	2
>77,003.40	Suitable	3

Figure 7: The Los Angeles County, Airport with suitability model scores for proximity thresholds.

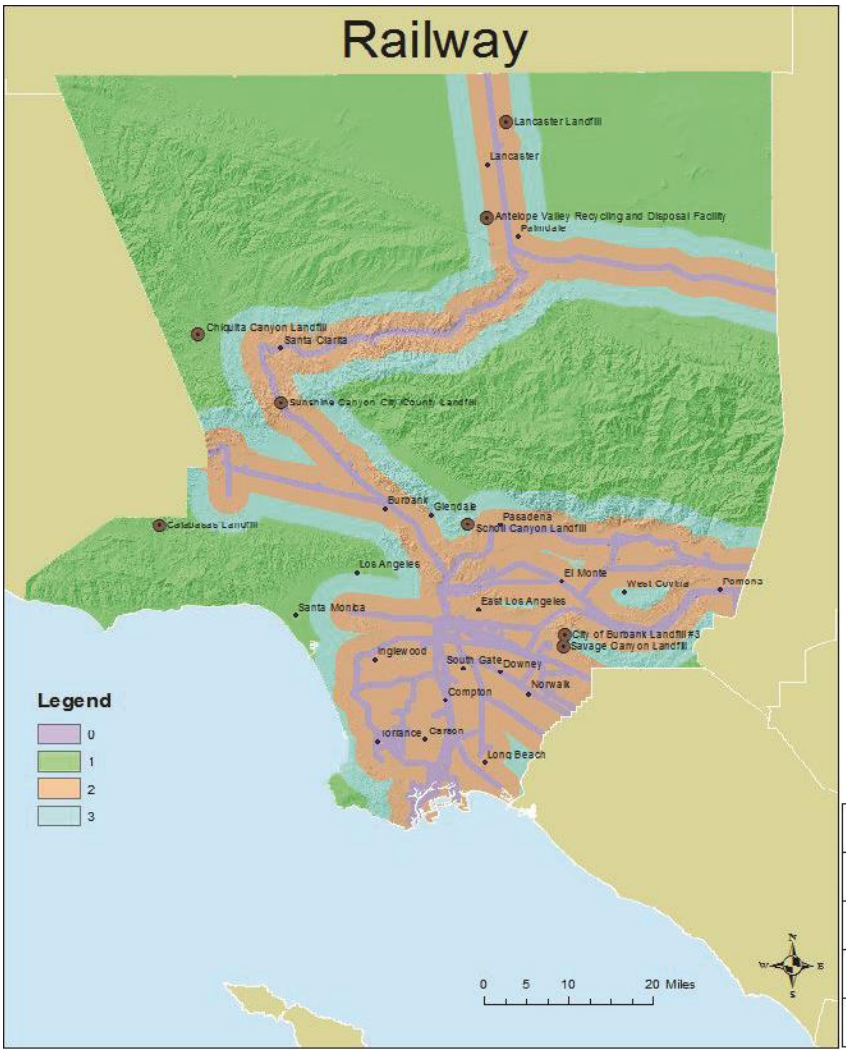
The road network is an important access point to enable garbage trucks to travel to and from the landfill sites. Therefore areas within 2,993.38 meters of a highway were considered suitable (Kumar, 2014) (Figure 8). Areas furthest from the road network were considered least suitable.



Road	Model Level	Score
<2,993.38	Suitable	3
2,993.38 - 5,986.76	Good	2
5,986.76 - 8,980.14	Fair	1
>15,892.46	Not Suitable	0

Figure 8: The Road network in Los Angeles County with suitability model scores for proximity thresholds.

Railways are an efficient mode of transportation for waste, therefore landfill sites should be located near to the rail lines. Therefore, a threshold of "good" was assigned to those locations within 2000 meters of a rail line (Figure 9). However, there is a disadvantage to siting landfills too close to the railway as well. Previous research suggested that landfills should not be sited within 500 meters of the railway (Sener et al., 2006; Alanbari, 2014) (Figure 9).



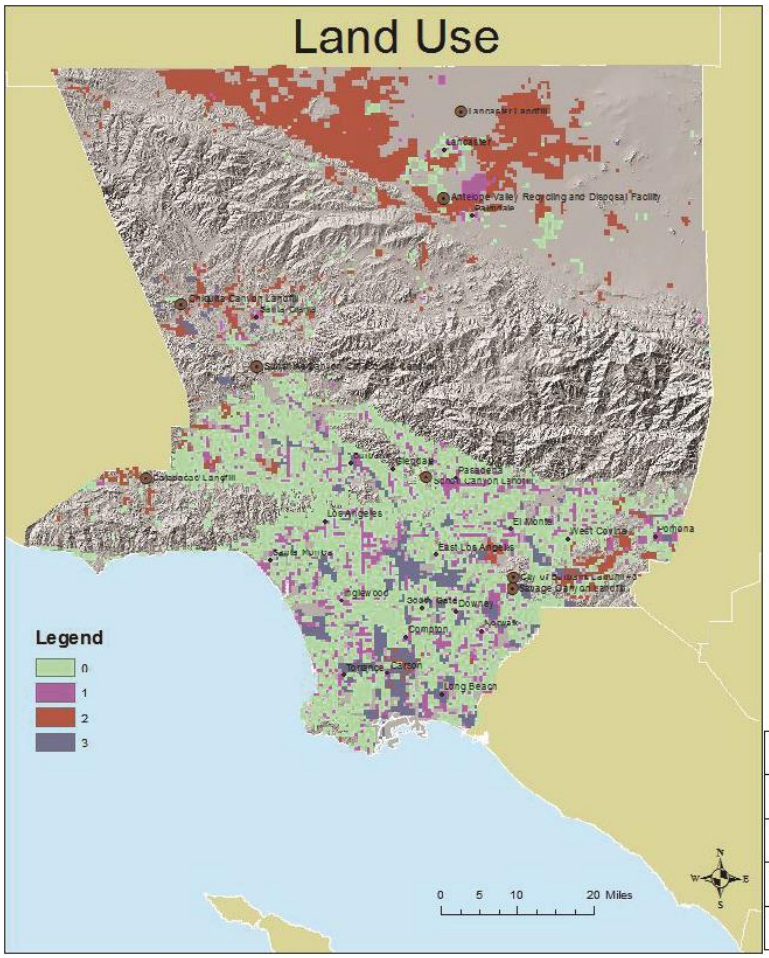
Railway	Model Level	Score
<500	Not suitable	0
500 - 2000	Good	2
2000 - 4000	Suitable	3
>54717.8	Fair	1

Figure 9: The Los Angeles County, Railway network with suitability model scores for proximity thresholds.

3.1.7 Land Use Data

Landfills should not be placed on a site close to a residential or an urban area to avoid deterioration of the land value and effects on development. The zoning data for Los Angeles County was retrieved via the LA County GIS Data Portal, EGIS website. This data represents agriculture, urban residential, open space, transportation, communication, utilities, industrial, and urban commercial land use types (Figure 10). Land use was simplified into four general types: residential, commercial and services, industrial, and

cropland and pasture. Landfills must be sited outside of residential areas. Industrial areas were considered most suitable as they are already zoned for heavy industry (Figure 10).



Land use	Model Level	Score
Residential	Not Suitable	0
Commercial and Services	Fair	1
Industrial	Suitable	3
Cropland and Pasture	Good	2

Figure 10: The Los Angeles County, Land use with suitability model scores for proximity thresholds.

3.2 Weighted Overlay

In order to determine a suitable area for a new landfill site in Los Angeles County, suitability was calculated using a multi-criteria suitability analysis which included environmental characteristics important to this location, including land use, transportation, and terrain (slope). Areas were modeled on a scale of 0 to 3, from not suitable to most suitable. The resulting layers were then weighted based upon their overall importance in

the final site location decision. Nine input raster layers were weighted with a different percentage of influence based on the priority of each criteria (Table 4).

CRITERIA	INFLUENCE
Landfill	11%
Slope	9%
Land Use	15%
Forest	11%
Wetland	15%
Highway	11%
Road	5%
Airport	11%
Railway	12%

Table 4: Percentage Influence of the multiple criteria used in the landfill suitability analysis for Los Angeles County.

The total influence for all factors equal 100 percent (see table 4 above). Wetlands and land use were assigned with the highest percentage weight (15%) because they were most important. Wetland have a very high risk of contamination and they exert an important environmental influence on drinking water. Land use was rated important because its represents existing human uses of the land, many of which are incompatible with landfills.

The percentage influence of the railway was rated 12% due to its importance or the role a railway play in terms of advantage aspect. Railway transporting of waste to landfill

sites saves cost of truck traveling by road to isolated site of over 200 miles. Landfill, Forest, Highway and Airport was rated the same influence percentage of 11%.

Slope was assigned 9% of the weighted influence based on the cost of drilling the ground and runoff of waste due to steepness while the road network was rated 5% because a landfill site cannot be operated if there is no access to the site.

In order to complete the analysis, each criterion was calculated after being reclassified with a value of 0 for “Not Suitable”, 1 for “Fair”, 2 for “Good”, and 3 for “Suitable” (Fig 6 - Fig 14). A final composite map was produced by using a technique in GIS known as overlay analysis or weighted overlay, which combines all the criteria maps into a single composite map using the weights discussed above (see Table 4).

Chapter 4

Result

4.1 Descriptive of Result

The result of this analysis revealed the most suitable areas for a new landfill site in Los Angeles County. These suitable locations were then reviewed using satellite imagery to confirm their appropriateness. The total number of pixels for suitable areas found in Los Angeles County is 194,739,300. The result showed in figure 11, shows multiple different areas are deemed fit to have a new landfill site. Among the areas are Calabasas, Lancaster, Santa Monica, West Hollywood, La Canada Flintridge, La Crescenta-Montrose, San Fernando, and Agoura Hills.

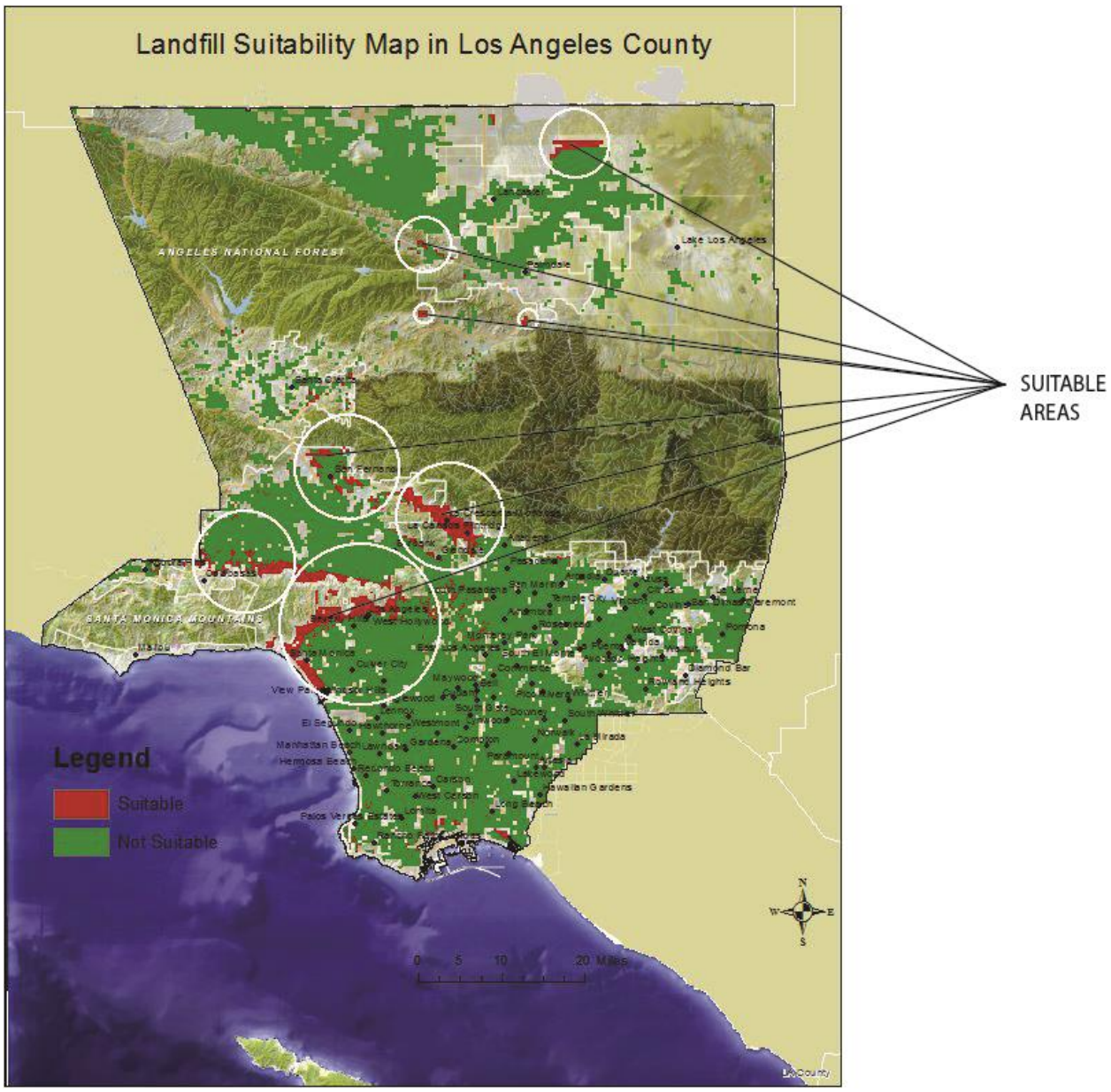


Figure 11: Shows the Suitable areas for a new landfill site.

During the review, satellite imagery was used to confirm the results. The area north of the City of Lancaster was deemed the best because of its vast supply of open space of 3954.63 acres near both Roosevelt and North Lancaster.

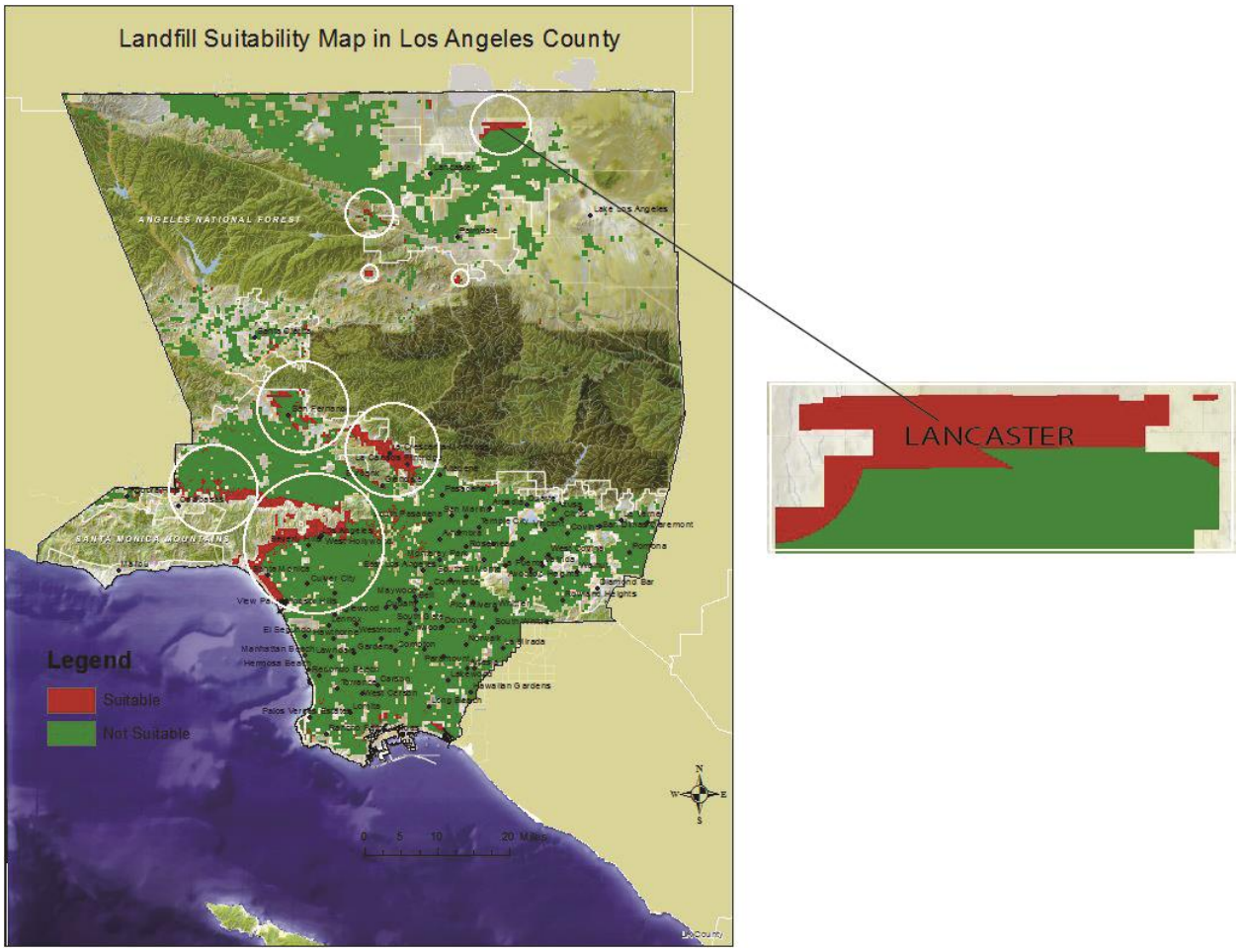


Figure 12: Landfill suitability.

Chapter 5

Discussion

5.1 Summary of Results

This thesis demonstrated a technique for finding ideal sites for a landfill in Los Angeles County using a multi-criteria approach employed in combination with GIS-based overlay analysis.

After studying the identified area for landfill suitability, only one suitable site for landfill construction was selected (Figure 16). The other selected areas were not considered based on proximity to residence, availability of sufficient land space, or steepness concerns.

5.2 Limitations

The research study was established upon a set of basic criteria, which were carefully chosen with the previously accessible information from previous research on Los Angeles County's landfill suitability conditions. The successful screening of the first level of overlay analysis produced a set of potential sites identified as suitable (Figure 15). However, after analyzing the potential sites with base map, some sites were later excluded in western part of Los Angeles County because they contained areas in excess of 15% slope (see Figure 7) which will normally lead to higher excavation budgets; so it is unsuitable.

This research was only limited to published research on landfill suitability analysis with the help of GIS and multi criteria analysis, but I believe it could have been excellent if field work was applied. Urban center were not used in the final result because land use data was among the criteria and accounted for concerns about urban core locations. Apart

from urban centers, there are other criteria (infrastructure, soil types, power lines, oil pipe lines, etc.) that were also omitted due to lack of time or accessible data.

Although a landfill site was chosen, it remains difficult to claim that it is a proper solution to the waste management system. Given that urban populations continue to increase annually, unoccupied lands now may become occupied in the near future. So future research is needed to find other methods of waste disposal in addition to continue research on health effects of landfill sites.

5.3 Conclusions

Based on the results of this analysis, Los Angeles County will be running out of land for landfill sites in the near future. So consideration of waste management issues needs to include modifications in citizen behavior and a commitment to reduce, reuse and recycle. That gives people the idea of reducing what we discard every day because we wouldn't want landfills taking over the space left in the County.

This landfill site suitability analysis has shown the feasibility of combining GIS with Multi Criteria Analysis to make complex decisions. In order to find appropriate sites for landfills, multiple criteria can be considered simultaneously as determining factors. The Lancaster regions appeared to be the best selection because it was far from water sources but was desirable based on other variables put into analysis. However, if the population of Lancaster continues to grow, the suitability of the site may be in question without stricter regulations on waste management.

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