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UNIVERSITI TEKNOLOGI PETRONAS

ENVIRONMENTAL IMPACT ASSESSMENT BASED GEOGRAPHICAL INFORMATION SYSTEM FOR LAND SUITABILITY OF PETROL FILLING STATIONS

by

SHABIR HUSSAIN KHAHRO

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ENVIRONMENTAL IMPACT ASSESSMENT BASED GEOGRAPHICAL INFORMATION SYSTEM FOR LAND SUITABILITY OF PETROL FILLING STATIONS

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SHABIR HUSSAIN KHAHRO

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DECLARATION OF THESIS

Title of thesis	ENVIRONMENTAL IMPACT ASSESSMENT BASED GEOGRAPHICAL INFORMATION SYSTEM FOR LAND SUITABILITY OF PETROL FILLING STATIONS

I, SHABIR HUSSAIN KHAHRO

hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTP or other institutions.

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Date:	Date:

DEDICATION

This work is dedicated to my "***MURSHIDS***" my father and mother, all family members, honorable teachers, beloved friends and my wife.

Without their support, I would not be where I am today

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ABSTRACT

A sustainable approach for protection of the natural environment remains the topic of interest for the developers in the developing countries. There has been a growing concern that development activities have the potential to cause severe damage to the environment. The rapid growth in urbanization offered an ample demand of vehicles, resulting more fuel consumption. A Petrol Filling Station (PFS) is the place catering this fuel need. A PFS is no doubt a very important facility but it is evinced that it has high potential of hazards, resulting the degradation and contamination of the natural resources and cause hazards like environmental, hydrological, geological and socioeconomic. Thus, Environmental Impact Assessment (EIA) was introduced as an effective planning and management tool, assisting the environmental and socioeconomic viability of the proposed development projects. It has been observed that the selected sites for such development projects may not pass the assessment tests. Hence, the site should be relocated or precautionary measures have to be followed, which are suggested by competent authority, resulting in project time and cost overrun. Thus, this study provides an integrated EIA-based GIS land suitability approach using Analytic Hierarchy Process (AHP) as a Multi Criteria Decision Making (MCDM) technique for viable site selection of the new petrol filling stations. A case study is conducted to develop and validate the theoretical approach into the practical end. The results of the case study show that there are 74% of the existing PFS located in the suitable zone, whereas there are still 26% of the total existing PFS, which are not located in the satisfactory zone. The result of the comparative study of codes indicates a closer significance in the codes of City Planning Department, Ipoh and Municipal Code for California City, USA. This EIA-based GIS approach for land suitability analysis using AHP is an effective tool for the decision makers to analyze such spatial problems. This model will proved to be a contribution in the developed Malaysia, 2020.

ABSTRAK

Pendekatan mampan untuk melindungi alam sekitar semulajadi masih kekal menjadi topik menarik kepada pemaju-pemaju di negara-negara membangun. Ini kerana terdapat kebimbangan bahawa aktiviti-aktiviti pembangunan mempunyai potensi menyebabkan pencemaran terhadap alam sekitar. Pertumbuhan pesat dalam pembangunan mengujudkan permintaan yang tinggi terhadap kemudahan pengangkutan, ini mengakibatkan kadar penggunaan bahanapi juga meningkat. Stesen Minyak adalah tempat di mana kenderaan boleh mendapatkan bahanapi mereka. Oleh itu ia menjadi satu kemudahan yang amat penting, tetapi ia juga mempunyai risiko yang tinggi dan merbahaya, yang mana ia boleh mengakibatkan kemusnahan dan pencemaran kepada sumber alam semulajadi dan alam sekitar umum nya. Oleh itu, Penilaian Kesan Alam Sekitar (*Environmental Impact Analysis*) telah di perkenalkan sebagai kaedah pengurusan dan pemantauan yang berkesan untuk membantu menilai daya maju sesuatu projek yang di rancang dari segi sosioekonomi dan kesan terhadap alam sekitar. Untuk tapak projek-projek yang gagal memenuhi penilaian ini, maka ia nya akan di pindahkan ke tapak yang lain, atau pun untuk meneruskan di tapak yang sama beberapa syarat tambahan kelulusan yang ketat perlu di penuhi yang menyebabkan kerugian masa dan kos. Oleh itu kajian ini menyediakan satu pendekatan bersepadu *GIS* berasaskan *EIA* menggunakan *Analytic Hierarchy Process* (*AHP*) sebagai teknik *Multicriteria Decision Making* untuk menentukan kesesuaian tapak baru bagi pembinaan stesen minyak. Satu kajian kes telah di jalankan untuk membangunkan dan mengesahkan pendekatan teori kajian ini terhadap penggunaan praktik nya. Keputusan kajian kes ini menunjukkan bahawa terdapat 74% daripada stesen minyak yang sedia ada terletak di kawasan yang bersesuaian, manakala 26% tidak di kawasan yang bersesuaian. Perbandingan antara kod jabatan perancang Bandar untuk penempatan stesen minyak mendapati kod Jabatan Perancangan Ipoh adalah hampir sama dengan menyamai Kod Majlis Perbandaran California di

Amerika Syarikat. Pendekatan *GIS* berasaskan *EIA* ini adalah alat yang berkesan kepada pembuat keputusan untuk tujuan analisis spatial seperti dalam kajian ini.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
ANP	Analytic Network Process
APEA	Association for Petroleum and Explosives Administration
CAD	Computer Aided Drawing
CI	Consistency Index
CPD	City Planning Department
CR	Consistency Ratio
DoE	Department of Environment
DWG	Drawing
EC	Expert Choice
EIA	Environmental Impact Assessment
ERDAS	Earth Resources Data Analysis System
ESRI	Environmental Systems Research Institute
F-AHP	Fuzzy Analytical Hierarchy Process
GDP	Gross Domestic Production
GIS	Geographical Information System
GPS	Global Positioning System
LPG	Liquefied Petroleum Gas
MADMA	Multi Attribute Decision Making Analysis
MCC	Municipal Code California
MCDA	Multi Criteria Decision Analysis
MCDM	Multi Criteria Decision Making
MCE	Multi Criteria Evaluation
MCES	Multi Criteria Evaluation System
MYGDI	Malaysian Geospatial Data Infrastructure
NEPA	National Environmental Protection Agency
PFS	Petrol Filling Station
PSSA	Preliminary Site Suitability Analysis

RAS	Raster
RI	Random Index
RS	Remote Sensing
RSO	Rectified Skewed Orthomorphic
S-AHP	Spatial Analytical Hierarchy Process
SDM	Spatial Decision Making
SEA	Strategic Environmental Assessment
SMCA	Spatial Multi Criteria Analysis
SMCDA	Spatial Multi Criteria Decision Analysis
SMCDM	Spatial Multi Criteria Decision Making
TIN	Triangulated Irregular Network
TOPSIS	Technique for Order Preferences by Similarity to an Ideal Solution
USA	Underground Storage Tank

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The term environment means (a) all layers of the atmosphere (b) all organic, inorganic matter and living organisms (c) air, water and land, buildings, structures, roads, facilities and works (d) all social and economic conditions affecting the community life [1].

There has been growing concern that development activities have the potential to cause severe damage to the environment. Development activities such as industries, high speed railway projects [2], airports, petrol filling stations [3] have high potential to cause damage to the natural environment including soil contamination, environmental pollution, water pollution and etc. The major challenge faced by the developers today, is to institute a sustainable development approach to carry out the development activities and ensuring these activities as environmentally sound and sustainable [4].

Recently, the rapid growth in urbanization has offered an ample demand of vehicles, resulting in more fuel consumption [5]. The place catering this increasing fuel need is known as a Petrol Filling Station (PFS). It is evident by different research studies that a PFS has high potential of impacts to the site and the surrounding. The type of impacts includes the environmental degradation, hydrological contamination, geological disintegration and socioeconomic losses [3]. There are various factors, which lead to the hazards and damage to the petrol filling stations such as fire hazard evoked by open flame [3], static electricity [5], the leakage of pipe and underground storage tank, resulting the contamination of groundwater, air pollution evoked by aromatic compound concentrations [6] and the traffic jam [7].

There is no doubt that the petrol filling station is an important facility but meanwhile, it is a hazardous facility. Thus, it needs special attention during site selection. However, site selection is one of the most important aspect of success for any business project.

Environmental Impact Assessment (EIA) was introduced to have a systematic process, which provides a framework for gathering, documenting information and provide views regarding the environmental consequences of the activities of any new project [8,9]. EIA entails the examination, analysis and assessment of planned activities in order to ensure them environmentally sound and sustainable for the proposed new development projects. Therefore, EIA can be regarded as an effective planning and management tool, which assists the environmental and socioeconomic viability of the new proposed development projects and their proposed sites [2,4,8-10].

It has been observed that EIA studies for land suitability process is a time and cost consuming job. However, the previous site suitability approaches are not effective enough to meet the needs of land suitability analysis in decision making of selecting a site. It is due to the complex nature of the development projects. There are various factors, which are involved in the site selection process of PFS. The manual approach of dealing such factors is difficult, so a smart approach is required to deal such spatial problems. This issue forces decision makers to use an efficient and intelligent approach for land suitability analysis.

Geographical Information System (GIS) was introduced to solve certain type of spatial problems. It is a tool, which has been successfully used several times to assist the decision makers in the land suitability analysis process of the various development projects [5,11,12]. Finding a viable site for a petrol filling station is also influenced by many factors. Hence, this problem can be considered as a Spatial Multi Criteria Decision Analysis (SMCDA).

Thus, this study provides a framework of an integrated EIA-based GIS uses Analytic Hierarchy Process (AHP) as a Multi Criteria Decision Making (MCDM) approach for appropriate site selection of petrol filling stations. GIS provides an opportunity to identify suitable sites by encountering various factors. The combined GIS and AHP approach have been successfully used several times in various development projects such as the housing site suitability assessment [11] site suitability of water harvesting reservoir [13], nuclear waste disposal site selection [12], land suitability of landfill site selection [14] and waste disposal site selection [15]. In this research, an EIA-based GIS land suitability model has been designed and developed for the proposed petrol filling stations using an integrated SMCDA approach. This study would be an effective approach for the petrol filling companies, investors (governmental/private) and the local governing bodies to select the suitable land parcels for petrol filling stations incorporating the environmental influencing factors.

1.2 Problem Statement

A petrol filling station is an important but meanwhile it is a hazardous facility, hence it needs special attention during its site selection. Furthermore, site selection is one of the most important aspect of success for any business project. EIA was introduced as an effective planning and management tool, which assists the environmental and socioeconomic viability of the new proposed development projects and their proposed sites. EIA is evident as a robust approach towards a sustainable environment.

In Malaysia, EIA became the legislation for the approval of any new development project prescribed by the Department of Environment (DoE) in 1987. However, Preliminary Site Suitability Analysis (PSSA) study became the approval document for non-prescribed projects. PSSA is the initial stage of EIA itself. PSSA study is carried out to assess the site for petrol filling stations. It has been observed that selected site may not pass the PSSA study. Hence, the owner has to relocate the site and revise the process of PSSA for the new site or the owner is suggested to follow the list of precautionary measures, which must be taken into consideration during the life cycle of the project. This problem results into project delay and cost overrun.

It is observed, what is lacking is a structured mechanism to assist in the selection of site for PFS and then it fulfills EIA requirement. Therefore, it is suggested that a comprehensive approach of GIS and SMCDA to be utilized for PFS site selection that would comply with EIA requirement.

1.3 Research Objectives

The aim of this research work is to design and develop an EIA-based GIS land suitability model, which can select and assess the viable land parcels for new proposed petrol filling stations. To achieve the main objective, following are the specific tasks:

1. Identification of the factors considered in an EIA study for PFS
2. Investigation and determination of the priority weights of the factors
3. Development of an EIA-based GIS land suitability model for PFS
4. Application of the model: A case study of Ipoh, Perak, Malaysia
5. Validation of the model

This study is a new approach to the land suitability analysis of petrol filling stations in perspective of the EIA-based GIS. It highlights all the environmental factors influenced by petrol filling stations during the construction, operation and even in the decommissioning phase.

1.4 Significance of the Research

GIS has provided a new dimension to solve the land suitability (spatial) problems as it has been applied in numerous studies and its success is evident by various researchers. The land suitability analysis becomes a complex activity because it involves various factors, which are difficult to handle, manage and analyze. Hence, the different multi criteria decision making techniques have been used to analyze such problems in the various studies. It is observed that Environmental Assessment Studies (EIA/PSSA) are time and cost consuming activities. At the end, the site may not meet the selection criteria of such studies carried out for the land suitability analysis.

The significance of this research is to provide EIA-based GIS approach for land suitability analysis, which involves environmental assessment studies and multi criteria decision making techniques simultaneously. Thus, this new flavor would help the decision makers to choose the viable location for the development projects and business locations such as petrol filling stations, shopping centres, stadiums, hospitals, industries and others. This approach is a step towards the sustainable decisions of location analysis for future development projects.

1.5 Research Scope and Limitations

This research presents an EIA-based GIS model for land suitability analysis of petrol filling stations using AHP as a MCDM technique. This is an effort towards land suitability assessment problems for installing new petrol filling stations. This model will help the decision maker to make feasible decisions for land suitability analysis. It will also help the local governmental authorities of Ipoh city to assists the sites for new proposed petrol filling stations in future.

This model is developed to assist the sites for new petrol filling stations but in the future, this model can be extended for other development projects requiring EIA. The criteria's and sub criteria's would be replaced, whereas the rest of the model and methodology will work for the other future research projects.

The research is conducted for Ipoh city and few segments of Batu Gajha due to the availability of the data, hence it is one of the limitation of this study. The tools used for data analysis were ArcGIS 9.3, MapInfo Professional 8.0 and Expert Choice 11.0 because the department offers free access to these tools, hence this is one of the limitation of this study.

1.6 Thesis Layout

This thesis focuses on land suitability analysis of petrol filling stations using EIA, GIS and MCDM approach. It is a new approach for Spatial Multi Criteria Decision Making (SMCDM) for solving land suitability problems. This thesis is structured into five chapters including;

Chapter 1 states the research background followed by research problem, research objectives, research significance and limitations.

Chapter 2 states the comprehensive up to date literature review carried out for this research work. The literature reviewed is summarized in a table to give a clear picture of the previous work carried out by the different researchers in the area of land suitability analysis using GIS and MCDM, in general and specifically for PFS. In this chapter, the role of GIS and MCDM is discussed in detail. The standards of different countries are also discussed in detail, which are normally used by the decision makers for site selection of PFS.

Chapter 3 states the research flow. This chapter is designed in a question and answer format. The research methodology is discussed extensively according to the research question. The pictorial presentation made the research methodology more convenient and easy to understand. Finally the complete methodology is printed in the shape of a flow diagram attached in the Appendix A.

Chapter 4 presents the complete results of this research work. All the results are presented in the map format, so as to give a clear picture of that particular feature followed by the results and discussions. A detailed discussion is made on the cumulative results. At the end, a comparative study of proposed new model and the map of existing petrol filling stations have also been carried out to validate this research work. A comparative study of the three codes used in this study is also done, which shows the performance & effectiveness of the codes.

Chapter 5 concludes with the research achievements. The effectiveness of this new EIA based GIS model for the land suitability analysis of proposed petrol filling stations is discussed in this chapter. The benefits of the research are highlighted with its limitations. Finally, the future guidelines are also suggested to enhance this research work in future.

CHAPTER 2

LITERATURE REVIEW

2.1 Land Suitability and Its Importance

Each land parcel on the earth is a sum of natural processes and these processes constitute social values. Site selection is one of the most important aspects for a successful business [5]. Survival and profitability of any business greatly related to the optimal site selection. In general, the site of any business is defined as the place where business operations are carried out. A poorly selected site of the business leads to inefficient use of resources, resulting in the business failure. Site selection for any business project involves various qualitative and quantitative factors [5].

The land suitability is of utmost importance for getting environmental approval of any new proposed project including petrol filling stations. The land suitability is carried out on the basis of project compatibility with the local plans, gazette structure, land use of the surroundings, provision of safe buffers and waste disposal requirements [16].

Land suitability analysis is carried out to determine the most appropriate spatial land for any particular activity and it is often used for planning purposes [17].

Land - Ground or soil of a specified situation, quality and nature

Suitability - Adapted to be used or purposed

Analysis - Depression of the whole into components

Based on the definition of the term, a land suitability analysis is basically the classification of nature and quality of land into different components, based on the land's ability to serve a particular use or purpose. Highly suitable land means that particular land parcel has relatively high numbers of the components it is going to serve or a particular purpose. While least suitable land means that the particular land parcel has relatively low numbers of the component it is going to serve or a particular purpose [18].

It is important to note that a land suitability analysis ultimately results in a map that suggest a pattern of future land use, but a proposed land-use map is not a plan. A proposed land-use map is an expression of physical, social, and economic goals [18].

Building a new capital improvement facility is a major, long-term investment for owners and investors. Site selection of a project is a critical decision made by owners/investors that significantly affect their profit and loss.

2.2 Role of GIS and Remote Sensing in the Land Suitability Analysis

Geographical Information System (GIS) is a tool used to input, store, retrieve, manipulate, analyze and output of spatial data [19]. The functionality of GIS plays a major role in the Spatial Decision Making (SDM). It has the ability to perform several tasks utilizing both spatial and attribute data stored in it. It has the ability to integrate a variety of geographic technologies including Remote Sensing (RS) and Global Positioning System (GPS) [17]. The ultimate goal of GIS is to support the spatial decision making process [20]. Many data layers are handled in Multi Criteria Evaluation (MCE) process in order to attain the suitability, which can be conveniently achieved using GIS.

Remote Sensing (RS) provides the information such as land use features, drainage density and topographical features. In combination with GIS, It is a powerful tool to integrate and interpret real world situations in more realistic and transparent way. Integrated GIS and RS technology saves time and provides good data quality to locate potential new sites for the development projects [21].

Land suitability analysis is a GIS-based process, which can be applied to determine the suitability of a specific area for any considerable use. It reveals the suitability of an area regarding its fundamental characteristics. A wide range of criteria's like environmental, social and economical can be incorporated using such GIS-based method [22].

GIS is an information tool helps in the acquisition of recent land use information studies required to solve environmental problems. The information of various features can be derived using this technique. The features may include; land use, roads, utility services, slope, elevation and etc. [23].

Technically, GIS is a set of software tools that is used to input, store, manipulate, analyze and display geographical information. Strategically, GIS may be a philosophy, a way of making decisions within an organization, where all information is held centrally and is related by its location. Technological development in computer science has introduced GIS as an innovative tool in the land suitability process. A GIS combines spatial data (maps, aerial photographs, satellite images) with the other quantitative, qualitative and descriptive information databases [14].

Geo-informatics technology, which at present embodies Geographical Information System (GIS), Remote Sensing (RS) and Global Positioning System (GPS) has been further developed to provide greater efficiency. In particular, GIS has been used extensively for spatial problems. GIS functions could be employed in several forms for the information including point, line and area. The system therefore possesses greater storage capacity for spatial information processed with identical standard. GIS also provides greater reliability and efficiency in lesser time and cost, when compared with manual operation.

2.3 Role of Multi Criteria Decision Making in the Land Suitability Analysis

A Multi Criteria Decision Making (MCDM) approach enables the decision makers to investigate a number of different alternatives. Despite the development of a large number of defined Multi Criteria Decision Aid (MCDA) methods, none can be considered as the ‘super method’ appropriate to all decision making situations. However, the Analytic Hierarchy Process (AHP) and its variants have long been used in numerous scientific MCDM applications. In 1980, Saaty has successfully introduced the AHP. It is a decision support tool used to solve complex decision problems. It uses a multi-level hierarchical structure including objectives, criteria’s, sub criteria’s and alternatives [5,19,20,24].

AHP offers some advantages over the classical site suitability analysis techniques. The advantages include;

I. It provides a structured approach to measure the suitability. It decomposes the suitability analysis problem into hierarchical units and levels. This approach allows a systematic and more in-depth analysis of the factors which may be better understood.

II. Relies less on the completeness of the data set but rely more on expert opinions or observations about the different factors and their perceived effects on site suitability.

III. This approach is more transparent, hence more likely to be accepted especially when the suitability analysis will ultimately serve as a basis for land allocation.

IV. It allows the participation of both the experts and the stakeholders in providing the suitability of a site relative to a proposed land use. Such framework allows the incorporation and accommodation of both qualitative and quantitative criteria’s for assessing site suitability.

AHP is very well documented in a significant number of published literatures, the list is given below. In this research work, a comprehensive literature review is carried out. Numerous research studies are carried out by the different researchers on land suitability analysis round the world. All of the researchers placed different trends to achieve their targets. Table 2.1 shows the detailed list of the different researchers carried out the research on such land suitability issues in different years. It also shows the methodology, tools and multi criteria decision making techniques which have been used.

Table 2.1: Summary of Literature Review

S.No.	Name of the Researcher	Year of Study	Objective	Methodology	Reference
1	E. S. Choudhury	2012	Landfill site selection	GIS, RS, MCA	[14]
2	Anifowose Y. B	2012	Waste disposal site selection	GIS, RS, MCDA	[15]
3	K. Deepa	2012	Site selection of decentralized treatment plants	AHP, GIS	[19]
4	Issa. M. S	2012	GIS-based MCES for site selection of landfill	GIS, MCES	[25]
5	Paul	2012	Urban waste disposal site location and allocation	GIS, MCA	[26]
6	Srdjevic Z	2012	Location selection of pumping stations	AHP	[27]
7	Semih Tuzmen	2011	Factor evaluation for gas station site selection	AHP	[5]
8	Chandio I. A	2011	Land suitability analysis for hillside development	AHP, GIS	[20]
9	Mohammad Aslani	2011	Site selection of small gas stations	AHP, FUZZY AHP, GIS	[24]
10	Afzali. A	2011	Municipal landfill site selection	GIS, AHP, Fuzzy Logics	[28]
11	Chandio I. A	2011	Land suitability of public parks	AHP, GIS	[29]

12	Babalola	2011	Selection of landfill sites for solid waste	GIS, ANP	[30]
13	Soltani	2011	Hospital site selection using a two-stage fuzzy MCDM process	GIS, MCDM, Fuzzy Logics	[31]
14	Lotfi	2011	Pixel-based site selection of local park using integrated methods	GIS, TOPSIS, AHP	[32]
15	Sudabe Jafari	2010	Land suitability analysis using MADMA	S-AHP, GIS	[22]
16	Yahaya	2010	Landfill site selection for municipal solid waste	GIS, AHP	[33]
17	Ahmed Wahid	2009	Land suitability scenarios for arid coastal plains using GIS modeling	GIS, ERDAS	[34]
18	Lotfi S	2009	Cemetery site selection	AHP, GIS	[35]
19	Prasanta K.D	2008	Site selection for limestone quarry expansion	AHP	[36]
20	Liu L.B	2008	Offshore outsourcing location selection	AHP	[37]
21	Carrion J.A.	2008	Site selection for grid-connected photovoltaic power plants	AHP, GIS	[38]
22	M. M Rahman	2008	Suitable sites for urban solid waste disposal using GIS	GIS, MCE	[23]

23	Ni-Bin Chang	2008	Combining GIS with fuzzy MCDM for landfill siting	FUZZY AHP, GIS	[39]
24	Kauko T	2007	Evaluating residential location quality profile	AHP	[40]
25	Lee K.L	2007	Evaluating the competitive position of location for the global logistics hub	AHP	[41]
26	J Baynes	2007	A GIS-based assessment of land suitable for growing hoop pine	GIS	[42]
27	Banar M	2006	Choosing a municipal landfill site	AHP, ANP	[43]

2.4 Relationship of Environmental Impact Assessment (EIA) and Geographical Information System (GIS)

The Environmental Impact Assessment (EIA) is noticed as one of the most effective and advanced way of improving environmental management. The EIA process supports the principle objectives of the project for minimizing the negative impacts on the environment and human health.

EIA is a complex investigation process used to determine the possible negative effects, their possible impacts and predict the occurrence in relation to proposed human activities.

Table 2.2: EIA Phases and Possible GIS Applications [44]

EIA Phase	Possible GIS Usage
Screening and Scoping	Data gathering, Spatial modeling, Calculation of impact magnitude
Description of the project	Geographical context

Description of baseline conditions	Biophysical inventories, hydrology, soils, historic resources, land ownership, topography, roads and utilities
Impact identification	Overlay analysis, modeling, habitat, suitability analysis
Predication of impact magnitude	Percentage change, impact magnitude maps, risk maps, modeling results
Assessment of impact significance	Maps impact significance by alternative
Impact mitigation and control	Identify mitigation measures or effectiveness of mitigation, spatially and/or temporally
Public consultation and participation	Preparing presentation material, to explain the project to the public, responses to comments
Monitoring and auditing	Design monitoring programs, processing and storage of monitoring data, comparison of actual outcomes to predicted outcomes, impacts over time.

2.5 Petrol Filling Station

A Petrol Filling Station (PFS) is a place where fuel is provided for all type of vehicles. In general, vehicular fuel means petrol, diesel and liquefied petroleum gas (LPG). In addition to fuelling facilities and services such as lubricating, cleansing, retail sales, mosque and toilet are also provided which are compatible with the operation of the PFS [45].

Petrol filling stations fall into two definable categories; One catering the needs of traffic and the other is providing their services to the local sources such as residential, commercial and industrial areas. In the former category, the fringe of built-up areas would be a more suitable place to install PFS. For the second category consideration should be given to install PFS at suitable locations not causing nuisance, pollution or unacceptable risk to adjacent users [45].

2.5.1 Hazards due to Petrol Filling Stations

In the oil industry, it became central to think the awareness of the importance of environmental issues in the last decades. In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and can't be isolated. It is also important that the government plays a vital role in setting and enforcing regulations to minimize the potential environmental impacts. Oil spills, accidents, damaged land, fires, air pollution and water pollution is inevitable in the oil and gas industry [46].

A PFS can be a major source of pollutants that can contaminate the air, soil, and water in the surrounding areas [47]. Petrol contains a complex mixture of hydrocarbon that has varying degrees of toxicity towards living organism [48]. It could be released into the environment by incidents that have occurred as a result of damage or carelessness. The release of toxic materials at PFS due to spillage or leakage from underground storage tanks and pipes will result in a serious degree of soil and groundwater contamination [46]. In some cases, the pollutants can also contaminate surface water when the petrol soaks directly into the ground or flows through drains and culverts [48]. It is because petrol floats on the surface of water and it can be dispersed along the underlying water table. This will transport the hazardous material to quite far away areas from the source of the leak or spill. Those subsequent dispersions and movements are difficult to predict as petrol can migrate through soil, sewers, and water courses. These dispersions then can accumulate in the cellar or basement of a property posing a potential hazard to the occupants of the property [45]. A number of environmental crises can occur as a result of human carelessness due to the following circumstances:

- Petrol adsorbed onto soil particles or held in the soil pores
- Petrol floats on the groundwater
- Petrol constituents dissolved in the groundwater
- Petrol floats on surface water (i.e. Rivers and Lakes)

- Petrol at impervious ground layers such as clay
- Petrol in drains or underground voids
- Petrol vapors released from the above sources into the atmosphere or underground voids, etc.

Additional to it, there are a number of on-site hazards, which can cause serious damage to the resources. The possible occurrence of such hazards is limited to the boundary of the PFS. The nature of such on-site hazards includes;

- Leaking of pipes
- Leaking of underground storage tank
- Leakage of underground pipes
- Broken or leaking fuel dispenser
- Overfilling by staff when refilling USTs
- Overfilling due to customers refilling their vehicles
- Dispensing pavement area may not oil-proof
- Absence of drainage and oil separator at dispensing area
- Fire hazards

Whereas, there are a number of surrounding hazards, which can cause serious damage to the resources. The possible occurrence of such hazards is not limited to the boundary of the PFS but such hazards normally occur in the surrounding area of the PFS. The nature of such surrounding hazards includes;

- Contamination of groundwater
- Contamination of surface water
- Degradation of soil
- Fire hazard evoked by open flame
- Air pollution
- Traffic jam due to vehicle queue to access petrol filling station

2.6 Methods and Gap in the Existing Land Suitability Analysis Techniques for Petrol Filling Stations

Land suitability is defined as the appropriateness of the land for a defined use. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses. Land suitability analysis is an essential starting point for the development of any project. There are limited studies carried out specifically on the land suitability of petrol filling stations, which are mentioned earlier in the literature review. The nature and the gap in the previous research work done for PFS is discussed in detail below.

The mapping of existing petrol filling stations in Kaduna Petropolis has been done by Sule in 2011 [49]. The hand held Global Positioning System (GPS) receiver named Garmin76S has been used to collect the coordinates only to verify the locations of the existing petrol filling stations. Finally, ArcView 3.2 is used to make a digitize map. The factors, which are considered and suggested by the guidelines of different countries for installing a new PFS, are not incorporated in this study.

A multi criteria factors evaluation has been done for sighting the petrol filling stations by Semih in 2011 [5]. Analytical Hierarchy Process (AHP) has been used for selecting the different quantitative and qualitative factors considered in the site selection of PFS. At the end, the priority table of the different quantitative and qualitative factors is generated. This is a theory based approach to deal with the land suitability problems of PFS Whereas, the graphical approach to deal with certain land suitability problems is lacked, which is getting importance after successful use of Geographical Information System (GIS).

Suitability analysis of the PFS site using GIS has been carried out by B. U Aulia in 2010 [50]. A GIS-based approach to analyze the suitable site for PFS has been used but all of the factors considered in a practical approach of site selection for PFS are not incorporated. EIA/PSSA is a mandatory assessment, which has to be carried out to get the approval from the city planning departments & environmental agency of the country. This GIS-based approach may not satisfy the current practices for land suitability of petrol filling stations as for as EIA is concerned.

A site selection study for small gas stations using GIS has been carried out by Mohammad Aslani in 2011 [24]. A GIS-based approach is proposed to select the sites for small gas stations in Tehran. Analytical Hierarchy Process (AHP) and Fuzzy AHP have been used to calculate the priority of the selection factors but less number of selection factors is incorporated. While, in the practical approach various other factors are also taken into consideration during the land suitability of the petrol filling stations.

It is indeed that land suitability analysis for petrol filling stations is very important and remains the focus of the researchers in recent years but still there is a gap in the available methods. EIA-based GIS approach using AHP for land suitability analysis of petrol filling stations will fulfill the needs of EIA. Hence, it is significant to move on with EIA-based GIS approach using AHP as a MCDM technique for selecting the viable land parcels for the future petrol filling stations.

2.7 Identification of Selection Factors

The identification of the selection factors is carried out after a long brain storming with the different environmental experts. As the study is EIA based modeling for land suitability, so all of the factors are included, which are normally taken into account for an EIA study of a PFS. The detailed analysis is done using various EIA reports, which are already done for existing petrol filling stations in different countries. The list of those reports is shown in the Table 2.3 describing the theme of the reports.

Table 2.3: List of EIA Reports Carried Out for the Site Selection of PFS

EIA Report	Year	Project Proponent	Consultant	Reference
EIA study for the proposed fuel station	2010	Mr. George Boro Njoroge	Environment Cost Management Centre	[51]
EIA project study report for proposed new desnol petrol station	2010	Desnol Investement Ltd	Eco-Stweards	[52]
EIA report for proposed Toona Investments Ltd service station	2010	Toona Investments Limited	Douglas Mwagwi	[53]
EIA study report for proposed Jupiter service station,	2010	Jupiter Service Station	Dr. Stanley O. Omuterema	[54]
EIA study report for proposed petrol station	2010	Timothy Wang'ombe Wambui	Mr. Gitau Muiruri Mr. Angela W. Warui	[55]
Impact Assessment of proposed petrol filling station in Durban	2010	Airports Company South Africa Pty Ltd	SRK Consulting	[56]

All of these EIA reports are studied and analyzed. There is a particular trend of such EIA reports. The EIA has been carried throughout the life cycle of the proposed petrol filling stations. The environmental factors are different at each level of the study and the factors are considered in three phases including;

- Construction Phase
- Operation Phase
- Decommissioning Phase

The factors considered in these three phases have got some positive and negative impacts as shown in the Table 2.4.

Table 2.4: Impacts of the Factors in the Life Cycle of the PFS [51]-[56]

Construction Phase	
Positive Impacts	**Negative Impacts**
Employment opportunities	Landscape and ecosystem change
Increase in GDP	Soil erosion
Boosting of the informal sector	Solid waste generation
Boosting of security	Liquid waste, leakages and oil spills
Opportunity for learning new constructional skills	Dust generation and aerosol emission
	Noise pollution
	Generation of exhaust emissions (Air Pollution)
	Workers safety and health
	Disturbance to existing vegetation etc.
Operation Phase	
Positive Impacts	**Negative Impacts**
Source of employment	Vector breeding grounds
Beneficial use of land	Pollution of surface and groundwater
Improved access to water and electricity	Oil and fuel spill in the forecourt during fueling and off-loading of petroleum products
Efficiency in service delivery	Oil and fuel spill at the dispensers and under dispenser trays
Improved revenue for central and local governments	Oil and fuel spill along the pipe works
Boosting of security	Oil leakages at the underground tanks
Improves the aesthetical value of the area	Soil contamination
	Emissions to air
	Solid waste generation

	Generation of exhaust emissions (Air Pollution)
	Workers safety and health Fire hazards
Decommissioning Phase	
Positive Impacts	**Negative Impacts**
Almost same as that of construction phase	Noise and vibration
Productive land use	Solid waste generation
Materials	Dust emissions
	Loss of employment opportunities

The complete list of the criteria's and sub criteria's normally considered during the EIA studies of petrol filling stations are given in the Table 2.5.

Table 2.5: Factors Considered in an EIA Study for PFS [51]-[56]

EIA for Petrol Filling Station	Land Use	*Residential Zone* *Educational Zone* *Health Care Zone* *Commercial Zone* *Industrial Zone* *Religious Zone* *Historical Buildings* *Parks and Playgrounds*
	Accessibility	*Highway* *Primary Road* *Secondary Road* *Railway Line* *Airport* *Jetty*
	Hydrological Conditions	*Sea Water* *River* *Lake* *Public/Private Well*
	Natural Environment	*Vacant Land* *Forest*
	Topography	*Slope* *Elevation*
	Utility Services	*Transmission Line* *Gas/Oil Line* *Fresh Water Line*

2.8 Standards used in Some Countries for the Site Requirements of the Petrol Filling Stations

To select the site for such facilities, some standards are designed by the respective governmental agency of the different countries. The standards contain different types of data including the safe recommended distance of different land uses from the new development, precautionary measures during the project life cycle, limitations of the slope and elevation. The distance behaves like the buffer to that land use. The purpose of such standards is to ensure the compatibility of such facilities with surrounding land uses and properties. Proper application of these standards avoids any impact associated with such land uses. For this case study, different standards are used as discussed below.

2.8.1 City Planning Department, Ipoh, Perak, Malaysia

The City Planning Department (CPD) is the competent authority of all the land use activities in Ipoh [69]. The owner of any development project has to follow the rules & regulations of this office. For installing a new petrol filling station, this office suggests some standards, which are to be followed to select the site.

- No limitation would be imposed on the number of petrol filling stations to be constructed on certain road and all applications would be treated on merit basis.
- Petrol filling station boundary shall be located not closer than 20 feet from any boundary of the property line.
- Petrol filling station should be sited on a road with minimum 120 feet frontage.
- Petrol filling station should be sited on a road with width more than 30 feet.
- Every petrol filling station shall have at least two connections to the public road.

- The maximum gradient along any section shall be 1 in 20.

2.8.2 Municipal Code, California, USA

The Municipal Code California (MCC), USA also provides such guidelines, which are considered during the site selection of a petrol filling station [57]. The purpose of guidelines for petrol filling stations is to ensure the compatibility of such uses with the surrounding uses and properties to avoid any impacts associated with such uses.

- The petrol filling station will not substantially increase vehicular traffic on the streets in a residential zone, and that the PFS will not substantially lessen the usability and suitability of adjacent or nearby residentially zoned property for residential use.

- The petrol filling station will not substantially lessen the usability of adjacent or nearby commercially zoned property for commercial use by interfering with pedestrian traffic.

- The petrol filling station will not create increased traffic hazards to pedestrians when located near a school.

- The petrol filling station site is served by streets and highways adequate in width and pavement type to carry the quantity and the kind of traffic generated by such service station use.

- The petrol filling station site is adequate in size and shape to accommodate said use and it also accommodate all yards, walls, parking, landscaping and other required improvements.

- The gross land area shall be not less than one acre, with a minimum street frontage of 100 feet.

- Petrol filling station buildings shall be located not closer than 30 feet from any property line.

- Ancillary buildings, including car wash buildings, shall be located no closer than 30 feet to any street right-of-way.

- Gasoline pumps or dispensers and canopies shall be located no closer than 20 feet from any property line.

2.8.3 National Environmental Protection Agency, Jamaica

The National Environmental Protection Agency (NEPA) of Jamaica also provides such guidelines, which are considered during the site selection of a petrol filling station [58].

- Petrol filling stations should be located within a growth center or an urban area except in circumstances where it can be shown through appropriate studies that the need exists.

- Land should be zoned for commercial/industrial use or be designated specifically for the purpose in a subdivision.

- Petrol filling stations should be located at a minimum of 500 feet from any public institution such as schools, churches, public libraries, auditoriums, hospitals, public playgrounds, etc.

- Petrol filling stations will not be allowed in any area where the traffic situation is such that it will cause obstructions in entering or leaving a station or on tight curves where visibility is not adequate.

- Vehicular access/egress/crossover should be reasonably safe with adequate approach distances especially where main roads and intersections are involved.

- Wherever possible, petrol filling stations should be erected on the level rather than sloping site to prevent rolling or discarded materials such as cans, drums, etc.

- When sited in shopping centres, stations should be located in an isolated area of the development as long as planning criteria are met, example, set back.

- Environmental impact on streams, lakes, ponds, aquifer, etc., will be taken into consideration. An Environmental Impact Assessment may be required from the applicant for installing a petrol filling station.

- Buildings are to be located a minimum of 40 feet from road property boundaries to provide adequate area for maneuvering of vehicles in the service area.

- Petrol filling stations shall be located a minimum of 100 feet from any residential building.

- Fuel should be stored in a double walled container to minimize leakage and prevent contamination of ground water.

- Normally no access to nor egress from a petrol filling station shall be closer than 150 feet to any road intersection or 250 feet from the intersection of two main roads.

2.9 Criteria Combined List of the Spatial Data Buffering

The complete list of the criteria's, sub criteria's and their recommended buffer values to be used in the generation of the final land suitability map of petrol filling stations for this case study are shown in the Table 2.6.

Table 2.6: Criteria Combined List of the Spatial Data Buffering with Values

S.No	Criteria	Sub Criteria	Ipoh (2003) [69]	USA (2007) [57]	Jamaica (1999) [58]
1	Land Use Protection	Residential Zone	20 feet	30 feet	100 feet
2		Educational Zone			500 feet
3		Health Care Zone			500 feet
4		Commercial Zone			100 feet
5		Industrial one			100 feet
6		Religious Zone			500 feet
7		Historic Zone			500 feet
8		Parks & Play Grounds			500 feet
9	Accessibility	Dual Highway	20 feet	30 feet	100 feet
10		Primary Roads			40 feet
11		Secondary Roads			40 feet
12		Railway Line			820 feet
13		Airport			4920 feet
14	Hydrological Conditions	Rivers	20 feet	30 feet	500 feet
15		Lakes			300 feet
16	Natural Environment	Vacant Land	Preferable Land		
17		Forest	20 feet	30 feet	3280 feet
18	Topography	Slope	< 30 %	< 30 %	< 35 %
19	Utility Services	High Voltage Transmission Line	20 feet	30 feet	150 feet
20		Water Pipes			100 feet

2.10 Summary of the Literature Review

Land suitability is an important subject and remains the topic of interest of the researchers. It plays a vital role in the success of any business and development project. Apparently, Petrol Filling Station (PFS) is also an important facility but it has the potential to cause serious damage to the natural environment and resources. Hence, the land suitability of such facilities is given attention. A number of attempts have been made to assist the land suitability of PFS including a multi criteria factor evaluation model for PFS [5], site selection for small gas stations using GIS [24], distribution of PFS using GIS [49], site suitability analysis for petrol stations using GIS [50] but still there is a lacking in the existing land suitability analysis techniques for PFS. The existing land suitability approaches do not consider the Environmental Impact Assessment (EIA) and Preliminary Site Suitability Analysis (PSSA) studies in the land suitability analysis process for PFS. There are various factors considered in these studies and the existing land suitability approaches do not fulfill the requirements of such environmental assessments studies. These assessment tests are the compulsory segment before commencement of any new development project.

Thus, it is essential to fill this gap in the existing land suitability techniques. This EIA based GIS approach for land suitability analysis will fulfill this gap and assists the suitable land parcels for PFS fulfilling the requirements of EIA/PSSA. This approach will help the decision makers and the town planners to take such spatial decisions accordingly.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Identification and Priority Weights Calculation of the Factors

The comprehensive research flow has been given in appendix A. The detailed literature review has been carried out including various EIA studies, which have been already conducted successfully for installing new petrol filling stations [51-56] and legal legislation documentations of the Department of Environment (DoE) [16]. Later on, the interviews have been conducted with the EIA professionals to verify the factors. Finally, the list of the verified factors was prepared, which are normally considered in an EIA study of petrol filling stations shown in the Table 3.1.

Table 3.1: Factors Considered in EIA Studies for PFS [51-56]

S. No	Factor	S. No	Factor
1	Residential Zone	14	Jetty
2	Educational Zone	15	Sea Water
3	Health Care Zone	16	River
4	Commercial Zone	17	Lake
5	Industrial Zone	18	Public/Private Well
6	Religious Zone	19	Vacant Land
7	Historical Buildings	20	Forest
8	Parks and Playgrounds	21	Slope
9	Highway	22	Elevation
10	Primary Road	23	Transmission Line

11	Secondary Road	24	Gas/Oil Line
12	Railway Line	25	Fresh Water Line
13	Airport		

For the investigation of priority weights of the selection factors, Analytical Hierarchy Process (AHP) has been used as a decision making technique for this study because it has been successful used in various studies specifically for decision problems in land suitability analysis [5,19,20,24,27,61]. It is a powerful tool for decision making in land suitability problems [22]. The AHP data has been analyzed in the Expert Choice 11.0 software package. It has been successfully used in several studies for the analysis of pairwise matrices [35,36,62].

The integration of GIS and MCDM has been found as an effective tool to solve the problems of land suitability selection [20]. GIS provides the opportunity for well-organized manipulation and presentation of the data, whereas MCDM delivers consistent ranking of the potential land parcels based on a variety of criteria's [61].

In general, MCDM problems involve six components.

- A goal or a set of goals to attain
- Decision makers involved in the decision making process with their preferences and respect to the evaluation criteria
- A set of evaluation criteria (objectives and/or physical attributes)
- Set of decision alternatives
- Set of uncontrollable (independent) variables or states of nature (decision environment)
- Set of outcomes or consequences associated with each alternative attribute pair

The AHP developed by Saaty (1980) [63] analyses and supports decisions in which multiple & competing objectives are involved and multiple alternatives are available. It is based on three principles; Decomposition, Comparative judgment and Synthesis of priorities.

In general, AHP problems involve five steps as below:

1. Defining the unstructured problem and identification of input/output parameters
2. Hierarchical structure of the problem (Tree)
3. Pairwise matrix at each level of the problem and criterion weights calculation
4. Sensitivity test
5. Overall priority ranking represented by weights

3.1.1 Defining the Unstructured Problem and Identification of Input / Output Parameters

Spatial Multi Criteria Decision Making (SMCDM) requires an articulation of the decision makers' objectives and an identification of the attributes useful for indicating the degree to which these objectives were achieved. An attribute was used to measure performance in relation to an objective. Criteria were kept comprehensive and measurable. A set of criteria was complete, operational, decomposable, non-redundant and minimal. Each criterion has been represented as a map layer in the GIS database. A number of different attributes were necessary to provide a complete assessment of the degree to which the objective were achieved [61].

The main objective of this study was to develop an EIA-based GIS model for land suitability of petrol filling stations. The factors usually considered in an

EIA study of the PFS have already been identified. These identified factors were further classified into criteria and sub criteria in the hierarchical structure.

3.1.2 Hierarchical Structure of the Problem (Tree)

The relationship between objectives and attributes has a hierarchical structure. At the highest level, the most general objectives has been placed, which may be defined in terms of more specific objectives, hence themselves can be further defined at still lower levels. At the lower level of the hierarchy, attributes has been placed, which were quantifiable indicators of the extent to which associated objectives has been realized [17].

The hierarchy of the complete factors has been shown in the Figure 3.1. These factors were normally considered in an EIA study to evaluate the site for the petrol filling station. The factor has been further classified in criteria and sub criteria to be analyzed in analytical hierarchy process.

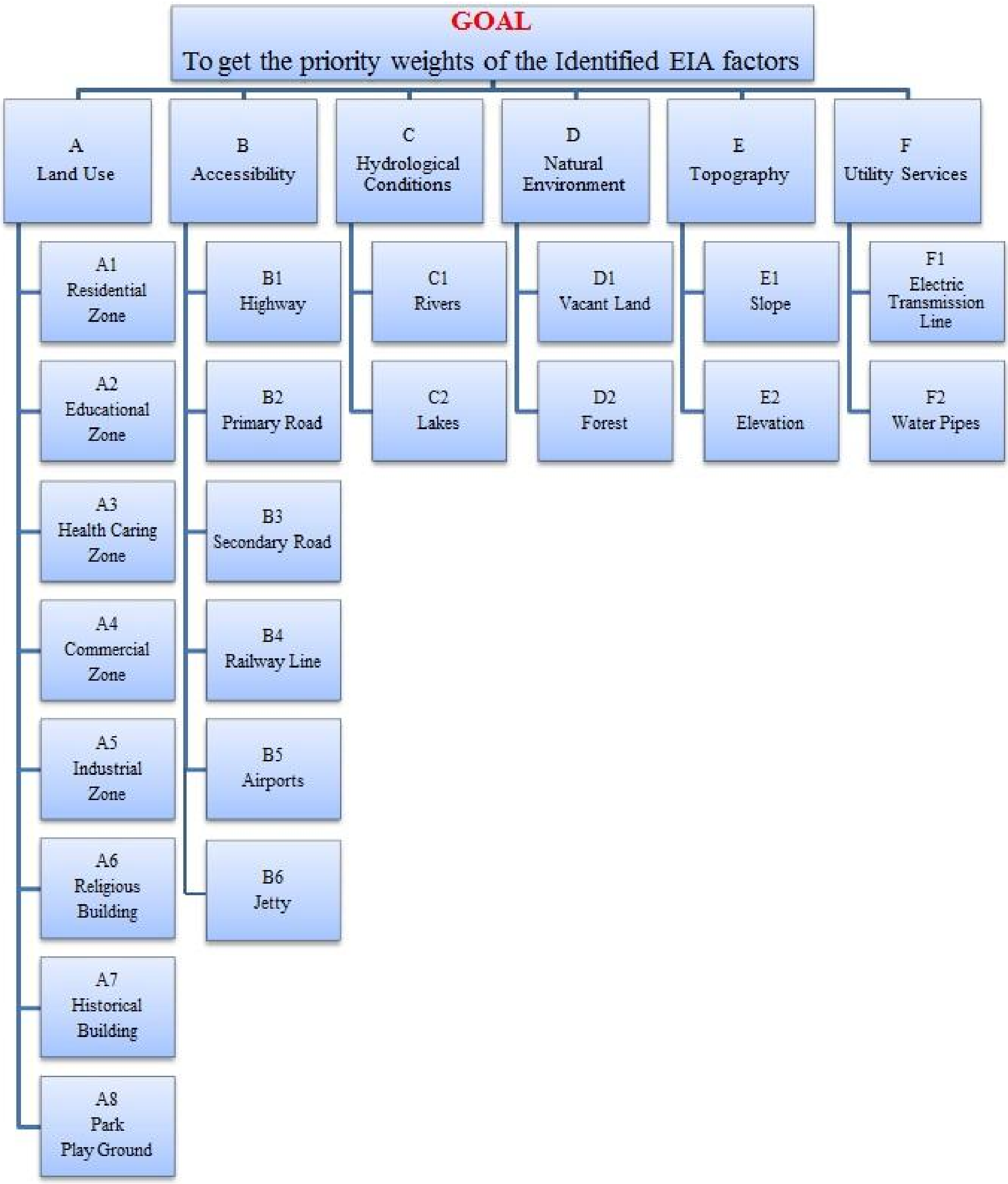

Figure 3.1: Hierarchical Organization of the Factors

3.1.3 Pairwise Matrix at Each Level of the Problem and Criterion Weights Calculation

Criterion weights can be calculated by different methods including;

I. Ranking Method

II. Rating Method

III. Pairwise Comparison Method

IV. Trade-off Analysis Method

In this study, pairwise comparison method has been used due to its number of benefits over all other methods as shown in the Table 3.2.

Table 3.2: Criterion Weights Calculation Methods [61]

Methods/ Features	Ranking	Rating	Pairwise Comparison	Trade-off Analysis
# of judgements	n	n	n(n-1)/2	<n
Response scale	Ordinal	Interval	Ratio	Interval
Hierarchical	Possible	Possible	Yes	Yes
Underlying theory	None	None	Statistical/ heuristic	Axiomatic/ deductive
Ease of use	Very easy	Very easy	Easy	Difficult
Trustworthiness	Low	High	High	Medium
Precision	Approximations	Not precise	Quite precise	Quite precise
Software availability	Spreadsheets	Spreadsheets	Expert Choice	Logical Decision
Use in a GIS environment	Weights can be imported from a spreadsheet	Weights can be imported from a spreadsheet	Component of IDRISI	Weights can be imported from LD

Due to its comparison approach, high precision and compatibility in expert choice and arcgis, pairwise comparison method is used. The ratio matrix has been built up through pairwise comparison of each decision factor under the top most goal. It considered the pairwise matrix as an input and generates the relative weights as output. The comparison results are presented in a square matrix as below:

$$A = (aij)nn = \begin{bmatrix} a11 & a12 & \dots & a1n \\ a21 & a22 & \dots & a2n \\ \dots & \dots & \dots & \dots \\ an1 & an2 & \dots & ann \end{bmatrix} \quad [61]$$

Where aij denotes the ratio of the ith factor weight to the jth factor weight and n is the number of factors. To collect the expert opinions on the pairwise importance of criteria/sub criteria following scale has been used as shown in the Table 3.3, developed by Saaty in 1980 [61].

Table 3.3: Scale for Pairwise Comparison [61]

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between adjacent scale values

To calculate the criterion weights following operations were involved.

- Sum of the values in each column
- Divide each element of the matrix by its column total (referred to be a normalized matrix)
- Compute the average value of the elements in each row of the normalized matrix

I. Consistency test:

This test has been performed to determine consistent of our comparisons. Following stages were used to perform this test.

- Determination of the weighted sum vector
- Determination of the consistency vector
- Determination of the Lambda (λ) [its average of consistency vector]
- Determination of Consistency Index (CI)

$$CI= (\lambda-n) /(n-1) \quad [61]$$

Where n is the number of criteria under consideration

- Determination of Consistency Ratio (CR)

$$CR= CI/RI \quad [61]$$

Where, RI is termed as random index, the consistency index of a randomly generated pairwise comparison matrix. It depends on the number of elements being compared as shown in the Table 3.4.

Table 3.4: Random Inconsistency Indices [61]

n	RI	n	RI	n	RI
1	0.00	6	1.24	11	1.51
2	0.00	7	1.32	12	1.48
3	0.58	8	1.41	13	1.56
4	0.90	9	1.45	14	1.57
5	1.12	10	1.49	15	1.59

The determination of CR value is critical. In this study, we adopted a standard CR threshold value of 0.10. This value has been widely used as a measure of the consistency in a set of judgments of AHP applications in literature [5]. The

CR value should be <0.10, this ratio indicates a reasonable level of consistency in the pairwise comparisons. If, CR value is ≥ 0.10, this ratio indicates an inconsistence judgment. In such cases, we have to rethink and review the original values in the pairwise comparison matrix [20].

One of the main advantages of the pairwise comparison method is to consider two criteria at a time but when many criteria's were being compared, the method may get very large and complicated if solved manually. Whereas, Expert Choice 11.0 is one of the most popular and successfully software package used to analyze such comparisons [29]. For this study Expert Choice 11.0 has been used to analyze the pairwise comparison matrix.

3.1.4 Questionnaire Distribution and Collection

Due to the nature of the case study, a questionnaire was designed to get the stake holders opinion regarding the choice of land suitability for PFS. The questionnaire is presented in appendix B. The questionnaires were sent to the different mind sets including the environmental experts, representatives of different governmental and non-governmental agencies, researchers, owners of the petrol filling stations and local people via email and hard copy. A total number of 60 questionnaires were sent and at the end 27 were collected successfully. After analyzing the questionnaires, two were discarded because of insufficient and inappropriate data. Finally 25 were analyzed in the expert choice 11.0 software package. The Table 3.5 shows the complete statistics of the questionnaires.

Table 3.5: Questionnaire Responses

Stake Holders	**No. of Questionnaires**
Owner of the Petrol Filling Stations	6
Environmental Specialists	7
Town Planners (Government Officers)	4
Researchers	3
Local Public	5
Total Number of Responses	**25**

Whereas Figure 3.2 is a pie chart, depicts the clear picture of the scenario of the stake holders.

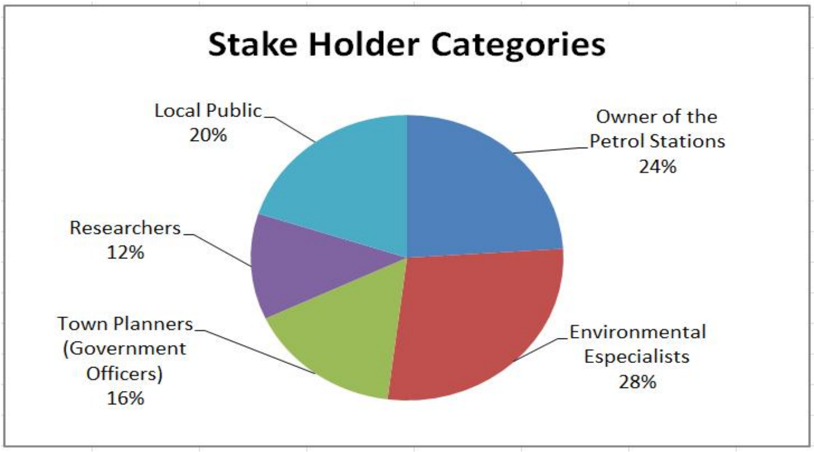

Figure 3.2: Stake Holder Categories

After collecting the stake holder's opinion, it was analyzed using AHP techniques in the expert choice 11.0 statistical package. The results of the stake holder's opinion are discussed in details in the next chapter.

3.1.5 Analysis of AHP in Expert Choice

Expert Choice (EC) is a statistical package normally used for the analysis, synthesis and justification of complex decisions and evaluations. It has been used for a wide variety of applications including allocating resources, selecting alternatives, asset allocation, and cost benefit analysis [50]. It takes the guesswork out of decision making. Based on the analytic hierarchy process, a hierarchy was used in expert choice to organize thought and intuition in a logical fashion. This hierarchical approach allows the decision maker to analyze all options for efficient decision making.

The decision makers are often faced with the problem of choice, to choose an option from a set of available options so as to satisfy best the decision maker's goals. In complex real life decision processes, the problem of choice can be extremely difficult, mainly because of complex, interrelated or even conflicting objectives. To support the decision makers, a decision model is designed to evaluate the options. Also, it can be used for the analysis, simulation and explanation of decisions. In practice, this approach has been most often used for technical or economical decision problems such as project or investment evaluation, portfolio management, strategic planning and knowledge management [66].

Decision modeling using expert choice typically consists of five steps;

I. Structuring the decision model

II. Entering sub criteria

III. Establishing priorities

IV. Synthesize results

V. Sensitivity Analysis

A complex decision problem is divided into a hierarchical structure. The decision problem should be formed in the shape of overall goal, criteria, sub criteria, scenarios and alternatives.

An expert choice model consists of a minimum of three levels;

I. At top level, overall goal of the decision

II. At second, sub criteria

III. And at third, alternatives

The model with many levels should place further general factors of the decision in the upper levels of the hierarchy and more specific criteria in the lower levels.

3.1.6 Hierarchical Structure of the Problem

As mentioned earlier, the criteria's and sub criteria's were structured in a hierarchical manner in the expert choice 11.0. The Figure 3.3 shows the hierarchy in the expert choice interface.

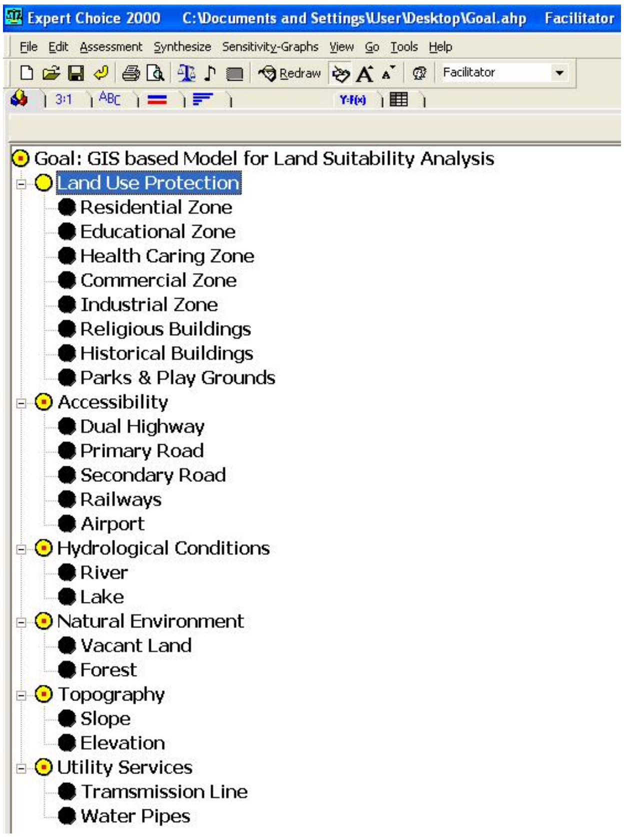

Figure 3.3: Hierarchy of the Selection Factors in the EC interface

3.1.7 Pairwise Comparison Matrix at each Level of the Problem

At each node of the hierarchy, a matrix has collected the pairwise comparisons of the decision maker using the AHP ratio scale valued from 1 to 9. The scale required no units due to comparison in nature. The judgment was a relative value or a quotient x/y of two quantities x and y having the same units (intensity, meters, utility and etc.). The decision maker needed to provide a numerical judgment or a verbal judgment which was familiar in our daily life. The Figure 3.4 shows the pairwise comparison matrix of criteria's in the expert choice interface.

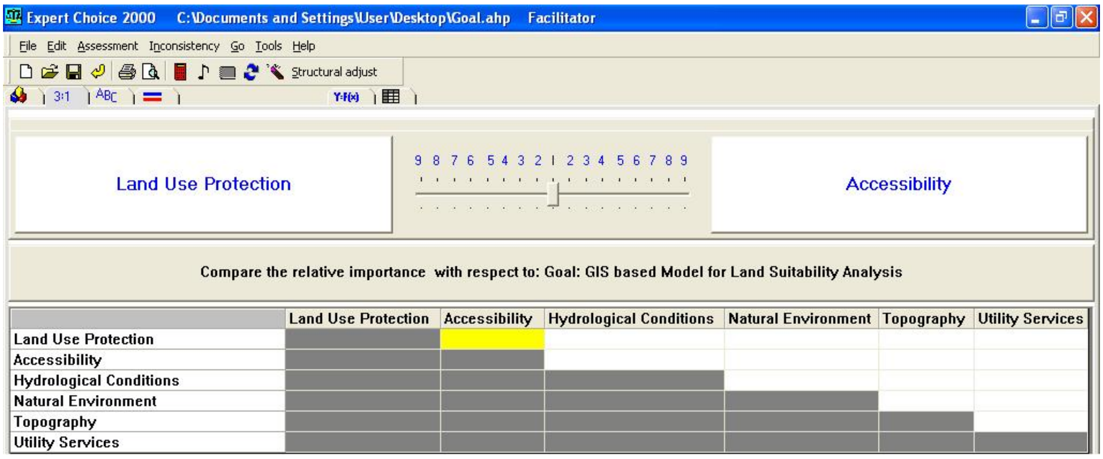

Figure 3.4: Pairwise Comparison Matrix of the Criteria's in the EC Interface

Whereas, Figure 3.5 shows the pairwise comparison matrix of the sub criteria's in the expert choice interface. The figure shows the sub criteria's of the single criteria "Land Use". All other sub criteria's were also analyzed accordingly in the expert choice.

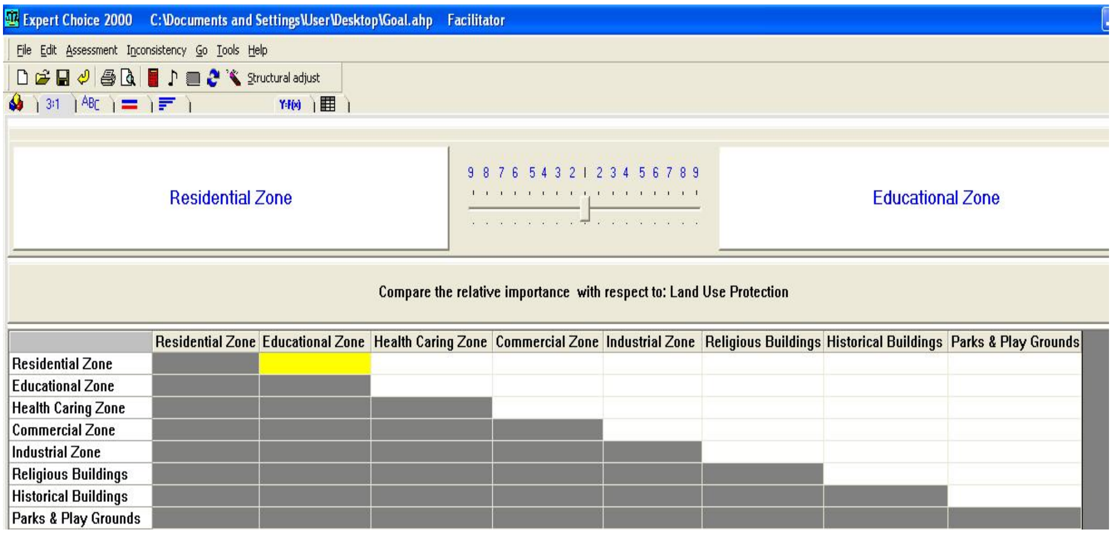

Figure 3.5: Pairwise Comparison Matrix of the Sub Criteria's in the EC Interface

Psychologists argue that it is easier and more accurate to express one's opinion on only two alternatives than simultaneously on all the alternatives. It also allows consistency and cross checking between the different pairwise comparisons.

3.1.8 Overall Priority Ranking

The final stage was to aggregate the relative weights of the levels to produce the composite weights. This has been done by a sequence of multiplications of the matrices of relative weights at each level of the hierarchy except the top one because the top level does not have any matrix. The sequence is one in which the relative weights matrix for the second level is multiplied by the relative weights matrix for the third level, and then this resulting matrix is multiplied by the relative weights matrix for the next lower level. This process were continued until all levels from the second level to the bottom level have been multiplied together, forming a vector of composite weights. The vector of composite weights has a dimension of 1 by m where m is the number of decision alternatives at the bottom level of the hierarchy. The composite weights also referred to as decision alternatives scores were the basis from which decisions could be made. These serve as ratings of the effectiveness of each alternative in achieving the goal. The overall score Ri of the ith alternative is the total sum of its ratings at each of the level and is thus computed as:

$$R_i = \sum_k W_k R_{ik} \qquad [61]$$

Where W_k is the vector of priorities associated with the k^{th} element of the criterion hierarchical structure, $\sum W_k = 1$ and R_{ik} is the vector of priorities derived from comparing alternatives for each criterion. The most preferred alternative was selected by identifying the maximum value of R_i (i = 1, 2, 3,…m).

3.2 Sensitivity Test

Many of the approaches assumed implicitly that complete information is available, so that the decision maker knows precisely the criterion outcomes associated with each alternative. However, this is a real-world situation and the information available may be often uncertain and imprecise because of measurement and conceptual errors. Such uncertainties in multi criteria decision making should be analyzed and avoided. Hence, sensitivity test is a method to incorporate uncertainties in the decision-making process [64]. This test is concerned about the way in which errors in the set of input data affect the error in the final output. If the changes do not significantly affect the outcome, the ranking is considered to be robust. If the current results have been found unsatisfactory, we may use information about the outcome to return to the problem formulation step.

This test considers criterion weight and criterion value (attribute value) as the most important elements but attribute weight is more important for this test. The method to perform this test is to impose some perturbation on the weights of criteria. We attempt to determine the degree to which the output of the added weighting procedure will change. Accordingly, a ± 0.1 perturbation to the weights were imposed by added weighting procedure. If there is a significant change of priority ranking to the alternative criteria results then it means that the resultants indicate the sensitivity of some areas of the weighting scheme. Whereas, if the ranking remains unaffected as the weights are varied, errors in the estimation of attribute weights can be considered insignificant. If the ranking of alternatives proves to be sensitive to one or more weights, the accuracy in estimating weights has to be examined carefully. This test is usually conducted via a series of test in which the modeler uses different input values that vary around a central value within certain bounds to see how a change in input causes changes in the output data set. For this study dynamic sensitivity test has been carried out using expert choice 11.0.

3.3 Development of an EIA-based GIS Model for the Land Suitability Analysis of PFS: Case Study of Ipoh

A case study was conducted to analyze the performance of the EIA-based GIS model for the land suitability of petrol filling stations. Ipoh city of Perak state was selected for the case study because this is the nearest large city and it was adequate enough to collect the data. Ipoh is one of the largest and capital city of Perak state, Malaysia. This city is a commercial center in the tin mining area. It is located in the middle of the Kinta valley on the bank of Kinta river and meeting point of Sungai Pinji & Sungai Pari rivers. The total land covered for this case study is

44950 hectares. The population of the city is 1,143,778 including 702464 of urban population in 2009. Taiping and Lang Mountain lakes are situated in the city. This city has a tropical rainforest climate, with an average temperature of 27 degree celsius with little variation throughout the year. The city gets high precipitation throughout the year with an average 2340mm of rain per year. Wettest month is November with an average 320 mm of rain and driest month is February with an average 70 mm of rain. This city have bus stations, airport, playgrounds including Sultan Azlan Shah, railway station, roads, highway and others as shown in the Figure 3.6.

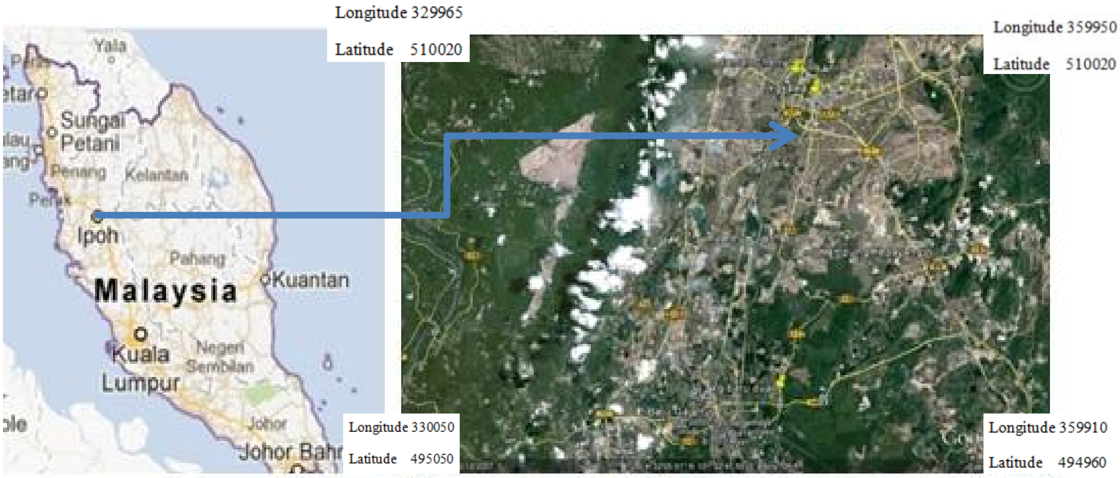

Figure 3.6: Study Area (Ipoh, Perak, Malaysia)

It was one the largest city nearby and it was bit convenient & comfortable to collect the data and conduct the interviews from different environmental experts of department of environment and planners of city development authority that was the core reason to choose this area for the case study.

3.3.1 Data Collection and Preparation

The data for this research work was collected from Mapping and Surveying Department of Malaysia. The format of the data collected was in drawing (.dwg) format. The data comprised of a number of data layer including land use maps, topographical details, hydrological details and natural resources. The scale of the data was 1: 25,000 and covered the area of 450 square kilometers. The complete raw data collected for the above mentioned office is shown in appendix C. As mentioned earlier, the data collected was in the format of .dwg, which was supportive to Computer Aided Drawing (CAD) software package. The data was converted into the shape files, which was the acceptable format of ArcGIS software package. The data was processed through different phases to convert it in to shape file acceptable in ArcGIS as shown in the Figure 3.7

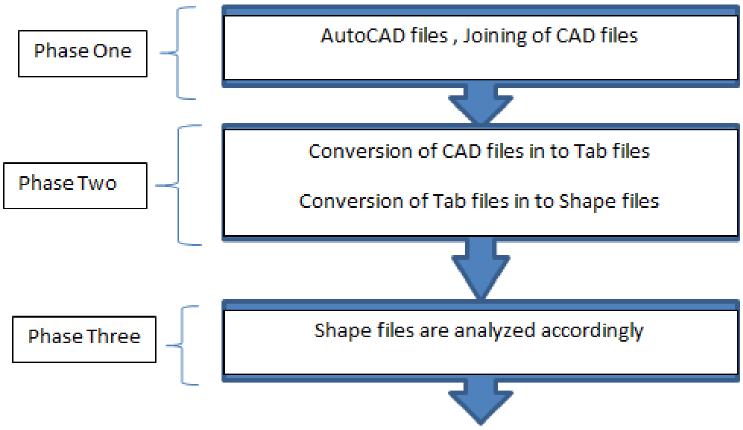

Figure 3.7: Data Preparation Phases

Different software packages were used to process the data. For phase-I, AutoCAD 2000 software package was used to join the data, which was collected from the Mapping and Surveying Department, Malaysia. AutoCAD 2000 software package is best supportive to .dwg format data [67].

For phase-II, MapInfo Professional 8.0 software package was used to convert the AutoCAD files into Tab files, meaning that conversion of .dwg format files into mapinfo tab file and later on mapinfo tab files were converted into ESRI shape file. The conversion process is shown in the Figure 3.8

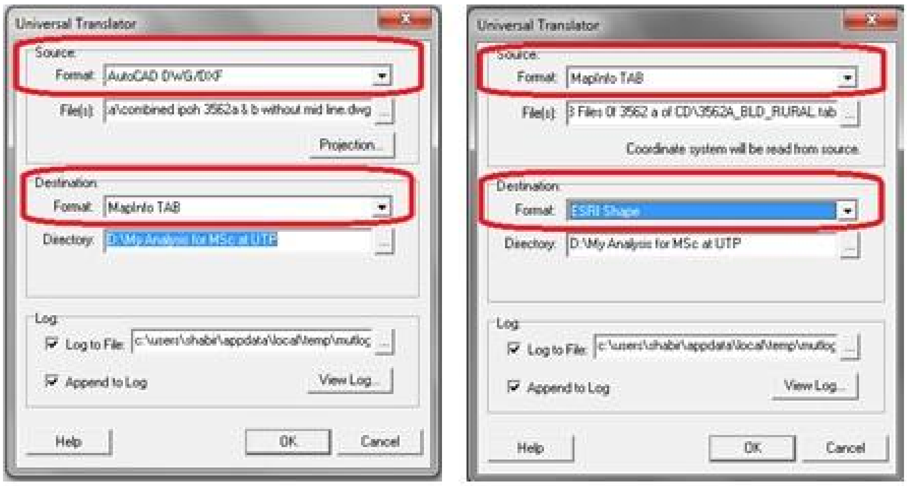

Figure 3.8: Conversion Procedure of the Data in MapInfo Professional 8.0

In the last phase, ArcGIS 9.3 software package was used to analyze the final data layers in the format of the vector shape file. Following stages were used to prepare the final data layers to be used in the model.

- Vector shape file
- Placement of the buffers
- Union of the boundary layer
- Defining the projections
- Conversion of the layer from vector format to raster (grid) format
- Reclassification of the layer

To provide a better understanding of the above layer preparation stages, one of the layers is discussed in detail. The vector shape file of the airport data layer is shown in the Figure 3.9.

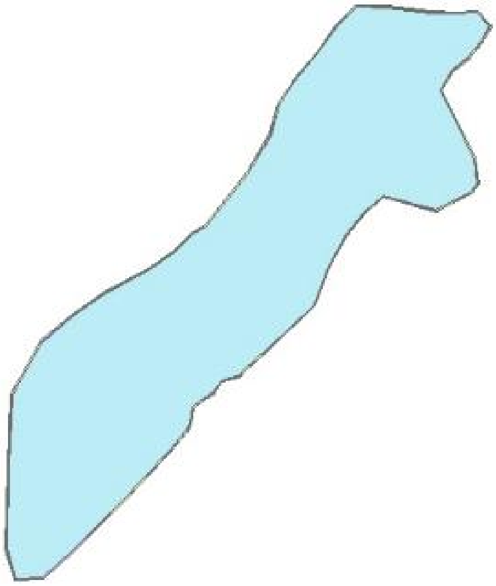

Figure 3.9: Vector Shape File of Airport Data Layer

Buffer was provided to outline and protect the zones around any specified feature. It provided the clear picture of the areas of influence. It constructed the area feature by extending outward from point, line or polygon features at certain specified distance. The Figure 3.10 shows the airport layer with 1500 meters buffer.

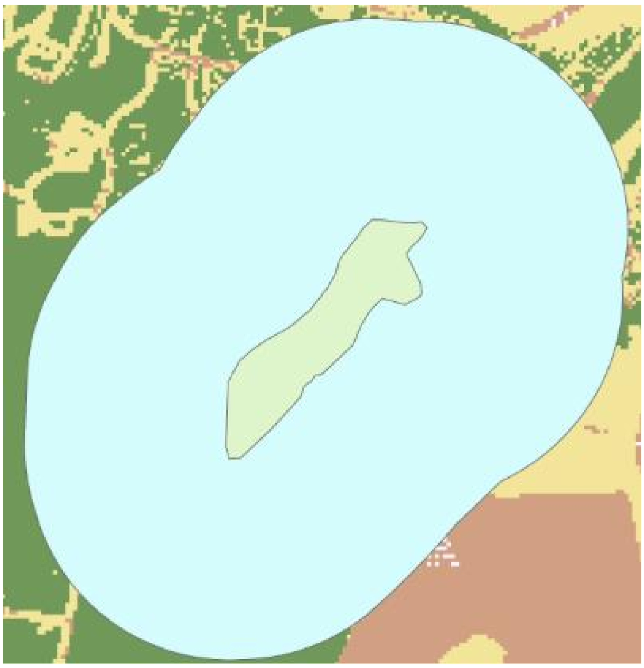

Figure 3.10: Vector Shape File of the Buffered Airport Data Layer

The shaded area represents the airport boundaries with the placement of buffer value. This characterizes that the shaded area is not suitable for the installation of the new petrol filling station. Whereas, the reset area represents the boundary, which characterizes that this area is suitable for installation of the new petrol filling station in contrasts to this particular layer. The next stage was the addition of the airport data layer with the boundary layer. Boundary layer is representing the complete study area. This task has been achieved by using the union command. Before the union, there were two layers, one was the airport data layer and other was the boundary (reset of the study area). After union, the data layer will behave as a single data layer and it was easy and robust to convert this vector data layer into raster (Grid-based) layer. This stage was important because it provided a uniform and homogenous platform to overlay the different data layers.

It was important to display the data layers correctly and thus data layers were provided with a projection. Every data layer has a coordinate system, which is used to integrate it with other data layers. Projections enabled the data layers to perform various integrated analytical operations like overlay of the data layers. Although, it was possible to work with the data layers having undefined projection. It was not possible to properly overlay the data layers from different projections without defining a projection first. For this case study, Rectified Skewed Orthomorphic (RSO) Malaya Grid (meter) was used because it is normally used in Malaysia and West Malaysia. The procedure to define the projection in the ArcGIS 9.3 software package is shown in the Figure 3.11.

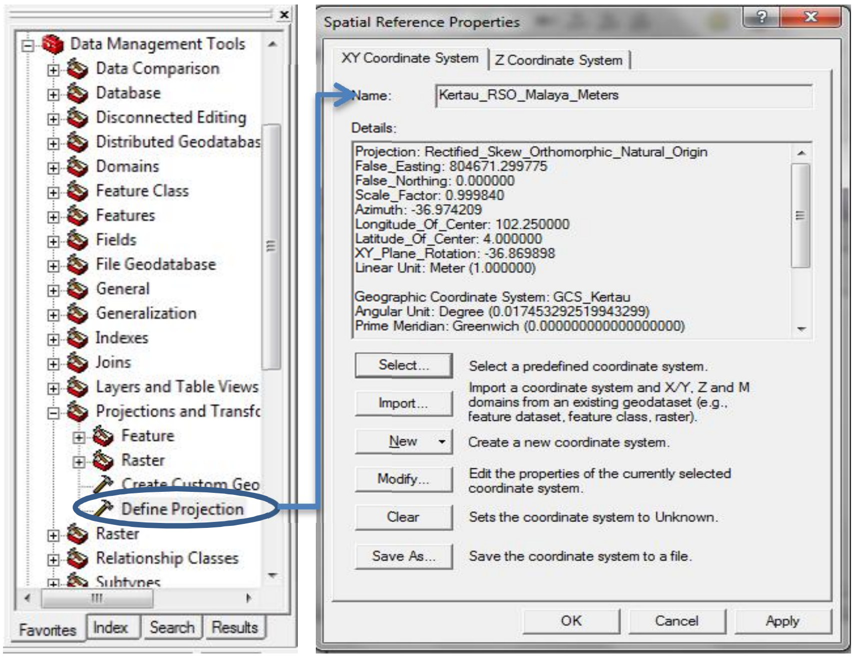

Figure 3.11: Defining Projections of Data Layer

After defining the projections to the data layer, the next stage was to convert the vector data layer into a raster (Grid-based) data layer. This task has been achieved by using spatial analyst tool in ArcMap 9.3. The airport data layer in raster format is shown in the Figure 3.12

Figure 3.12: Raster Shape File of the Buffered Airport Data Layer

As discussed earlier, raster is a grid based approach. This raster data layer consists of different cells and the cell size is 30m x 30m. The calculation of the suitable and non-suitable land parcels was quite comfortable in this case because the whole area was divided into a grid of cells sized 30m x 30m each. The final stage of the data processing was the reclassification of the raster layer. The purpose of reclassify the data layer was to assign numeric values to classes with each map layer, so they will have equal importance in determining the most suitable locations [68]. This task has been achieved by using the reclassification command of spatial analyst tool.

Now the final airport data layer was ready to overlay with the other different data layers. Details of suitable land parcels with reference to the airport data layer can be analyzed easily. All of the data layers were processed accordingly with the placement of suggested buffers by the different codes discussed in the chapter of literature review. Finally, all the data layers were overlaid to generate the final land suitability map as shown in the Figure 3.13.

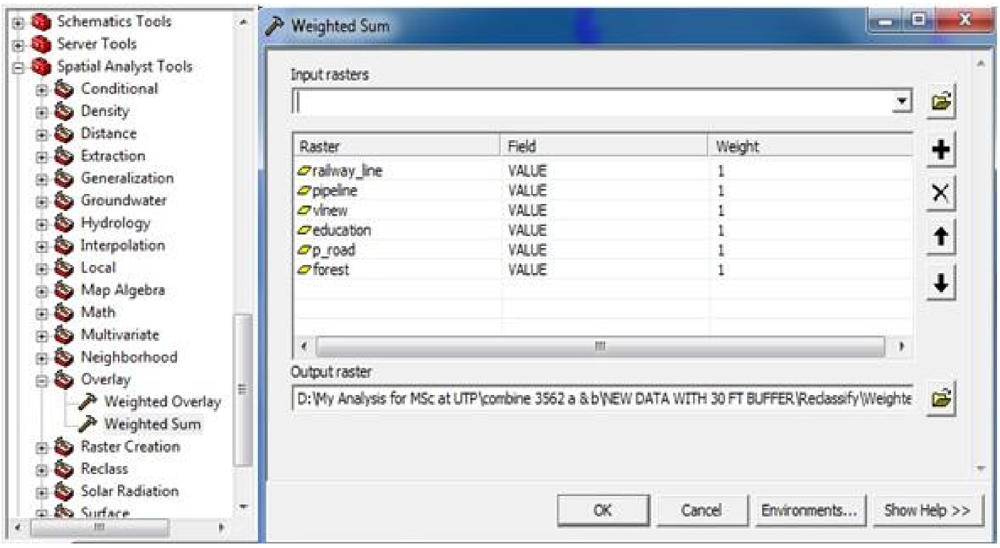

Figure 3.13: Overlay the Data Layers

All the data layers were overlaid using the overlay command of spatial analyst tool of ArcMap. The calculated weights of all the selection factors were incorporated to generate the final land suitability map for installing a new petrol filling station using this command. It was mandatory that the total sum of the weights calculated for the selection factors should be 1 in decimal valued weights or it should be 100 in ordinary weights.

3.4 Validation of the Model

The identified factors were validated by conducting the interviews with different EIA consultants and environmental experts from department of environment and city planning department. The suggestions of these experts were incorporated and finally a list of the selection factors was shaped into questionnaire. Later on, the questionnaire was sent to the various stakeholders involved in the process of land selection for the new petrol filling station to get their opinion. The input of the stakeholders was analyzed in the Expert Choice 11.0 statistical package and the inconsistencies in their decisions were investigated by consistency ratio index. The final weights of the land suitability selection criteria's were validated by using a dynamic sensitivity test. This test was performed at the different intervals and significant changes and decisions were taken accordingly.

Finally, the generated land suitability map for petrol filling stations was validated by overlaying the map of existing petrol filling stations in the study area. The existing petrol filling stations were officially approved by the city planning department and department of environment, Malaysia. The coordinates of existing petrol filling stations were collected manual by using Garmins hand global position system. The complete list of the coordinates is given in appendix D.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Calculation of Criterion Weights

The comparison matrices data has been incorporated in expert choice software package, it has been adequate now to calculate the priorities of the factors. Expert Choice 11.0 has provided the opportunity to analyze the response of numerous respondents at a single time and the cumulative result were calculated easily. Figure 4.1 shows the weights of the criteria's.

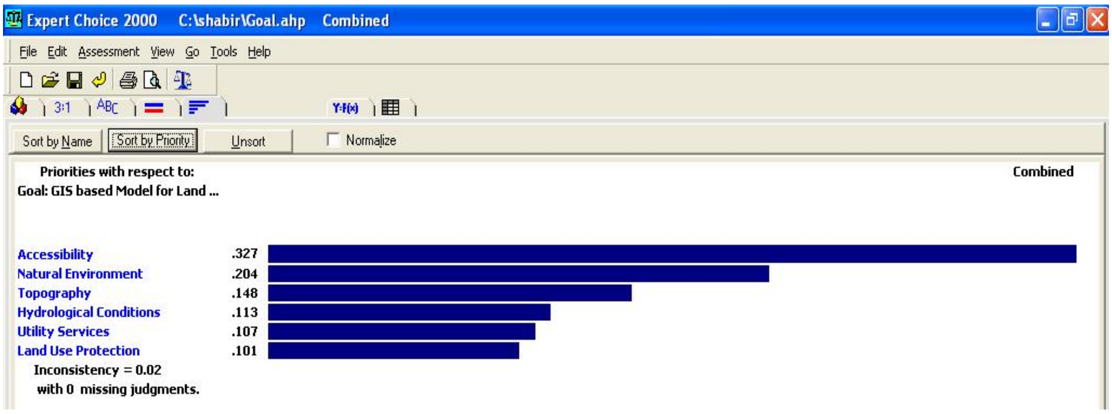

Figure 4.1: Final Synthesize Results of the Criteria's in the EC Interface

Consistency of the comparisons has been determined by the consistency ratio. The ratio indicated a reasonable level of consistency in the pairwise comparison matrix. The consistency ratio of the analyzed data for the criteria's was 0.02, which was less than 10%, representing the consistency of the pairwise comparison matrices [5]. The Figure 4.2 shows the weights of the sub criteria's.

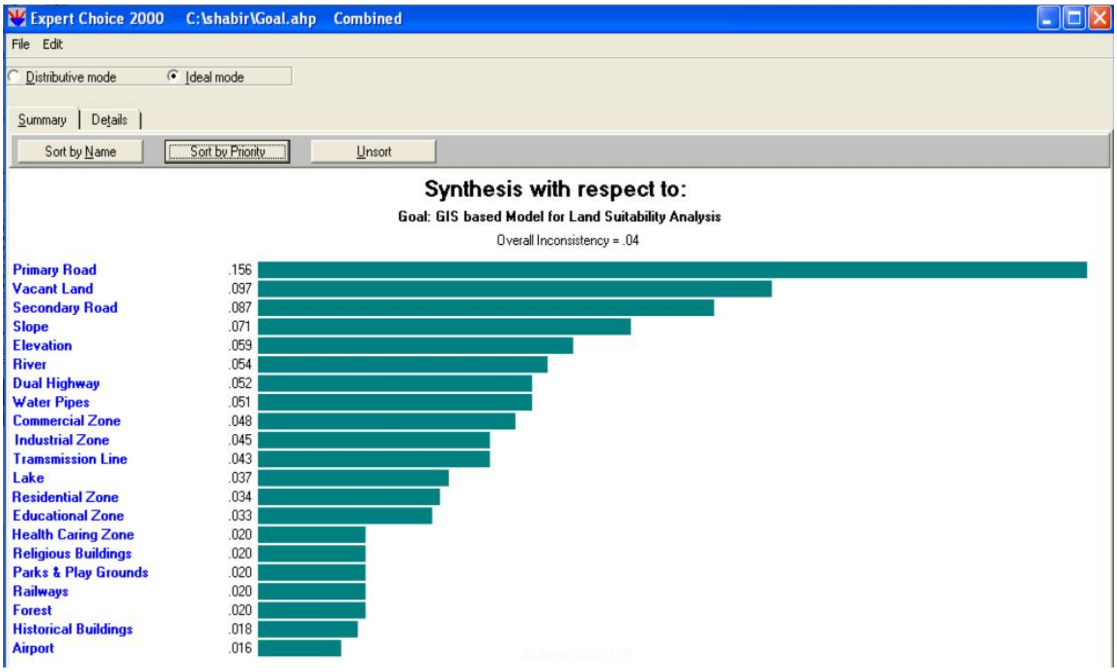

Figure 4.2: Final Synthesize Results of the Sub Criteria's in the EC Interface

The consistency ratio of the analyzed data of the sub criteria's was 0.04, which was less than 10% again, representing the consistency of the pairwise comparison matrices.

4.2 Sensitivity Test

The last step of the decision process was the sensitivity analysis test. It has been performed to investigate how sensitive the rankings of the alternatives were, to the changes in the importance of the criteria. Expert Choice 11.0 software package offered different modes of sensitivity analysis test, where the input data were slightly modified in order to observe the impact on the overall results. If the ranking does not change, the results are said to be robust. Figure 4.3 shows the results of the dynamic sensitivity analysis test of the selection factors.

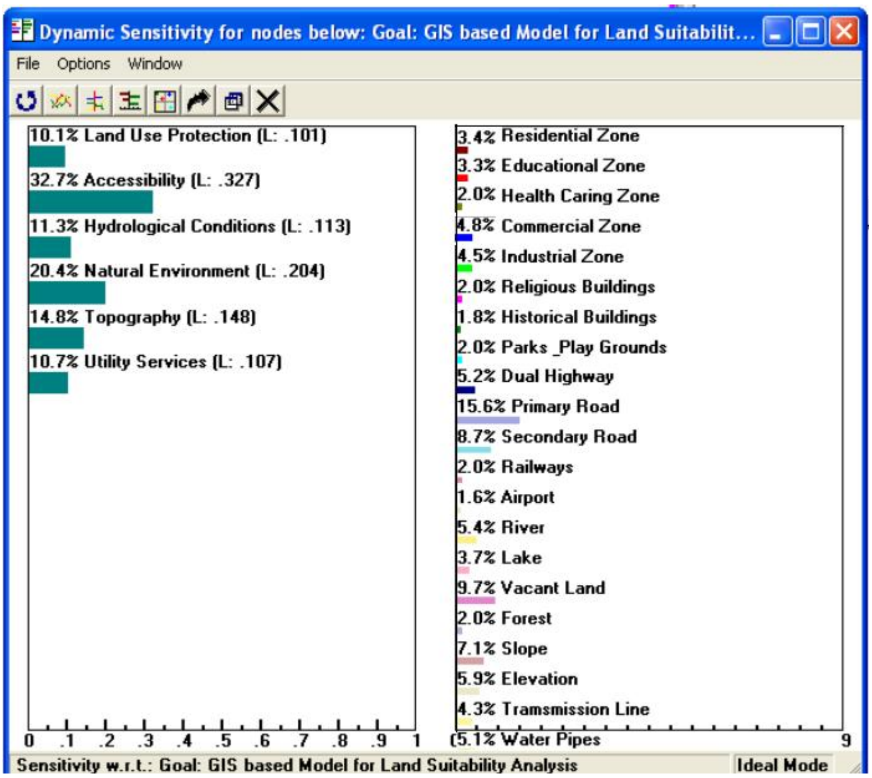

Figure 4.3: Sensitivity Analysis Test of the Selection Factors in the EC Interface

The sensitivity analysis test has been carried out at 10% increment and decrement in to the actual weights of the criteria's. Table 4.1 shows the results of the sensitivity analysis test of the selection factors.

Table 4.1: Final Sensitivity Test Results of the Factors with the Change of 10%

				Land Use		Accessibility		Hydrologic Conditions		Natural Environment		Topography		Utilities	
Factor list	Senthesize Results	Ranking	%	10% plus	10% Minus	10% plus	10% Minus	10% plus	10% Minus	10% plus	10% Minus	10% plus	10% Minus	10% plus	10% Minus
Primary Road	0.156	1	15.6	15.5	15.8	17.4	14.2	15.5	15.9	15.2	16	15.3	15.9	15.4	15.8
Vacant Land	0.097	2	9.7	9.6	9.8	9.8	10.3	9.6	9.9	11.6	8	9.5	9.9	9.6	9.8
Secondary Road	0.087	3	8.7	8.6	8.5	9.6	7.9	8.6	8.4	8.4	8.9	8.5	8.8	8.6	8.8
Slope	0.07	4	7	7	7.1	6.8	7.2	7	7.2	6.9	7.3	8	6.3	7.5	7.2
Elevation	0.059	5	5.9	5.9	6	5.7	6	5.9	6	5.8	6.1	6.8	5.3	6.2	6
River	0.054	6	5.4	5.3	5.5	5.2	5.7	6	4.6	5.3	5.6	5.3	5.5	5.6	5.5
Highway	0.052	7	5.2	5.1	5.2	5.6	5.4	5.1	5.2	5	5.3	5.1	5.2	5.4	5.2
Water Pipe Line	0.051	8	5.1	5.1	5.2	4.9	5.4	5.1	5.2	5	5.2	5	5.2	5	4.5
Commercial Zone	0.048	9	4.8	5	4.7	4.4	4.9	4.7	4.9	4.7	4.9	4.7	4.9	4.7	4.9
Industrial Zone	0.045	10	4.5	4.6	4.5	4.1	4.5	4.4	4.5	4.3	4.6	4.4	4.5	4.4	4.5
Transmission Line	0.043	11	4.3	4.3	4.4	4.1	4.6	4.3	4.4	4.2	4.4	4.2	4.4	4.3	3.8
Lake	0.037	12	3.7	3.6	3.7	3.5	3.9	4.1	3.5	3.6	3.8	3.6	3.7	3.6	3.7
Residential Zone	0.034	13	3.4	3.5	3.3	3.1	3.4	3.3	3.4	3.3	3.5	3.3	3.4	3.3	3.4
Educational Zone	0.033	14	3.3	3.4	3.2	3	3.3	3.2	3.3	3.2	3.3	3.2	3.3	3.2	3.3
Health Caring Zone	0.02	15	2	2	1.9	1.8	2	2	2	1.9	2	1.9	2	1.9	2
Religious Zone	0.02	15	2	2	1.9	1.8	2	2	2	1.9	2	1.9	2	1.9	2
Parks & Play Grounds	0.02	15	2	2	1.9	1.8	2	2	2	1.9	2	1.9	2	2	2
Rail line	0.02	15	2	2	1.9	2.2	1.8	2	2	1.9	2	1.9	2	2	2
Forest	0.02	15	2	2	2.1	2	2.2	2	2.1	2.4	1.6	2	2.1	2	2
Historical Buildings	0.018	16	1.8	1.9	1.8	1.7	1.9	1.8	1.9	1.8	1.6	1.8	1.9	1.8	1.9
Airport	0.016	17	1.6	1.6	1.7	1.6	1.5	1.6	1.7	1.6	1.7	1.6	1.7	1.6	1.7

A significant change has been found in one of the selection factor named forest in the sensitivity analysis test at 10% change. For the rest of the selection factors, there was no significant change found in the sensitivity analysis test. This change in forest layer has been notified and therefore, another trial of sensitivity analysis test has been carried out at the increment and decrement of 20% in the criteria's. Table 4.2 shows the results of the sensitivity analysis test of the selection factors.

Table 4.2: Final Sensitivity Test Results of the Factors with the Change of 20%

				Land Use		Accessibility		Hydrologic Conditions		Natural Environment		Topography		Utilities	
Factor List	Senthesize Results	Ranking	%	20% plus	20% Minus	20% plus	20% Minus	20% plus	20% Minus	20% plus	20% Minus	20% plus	20% Minus	20% plus	20% Minus
Primary Road	0.156	1	15.6	15.2	16	18.7	12.6	15.3	16.1	14.9	16.1	15.1	16.2	15.3	16
Vacant Land	0.097	2	9.7	9.5	9.9	11.1	9.7	9.5	9.5	13.4	9.3	9.4	10.3	11.2	9.6
Secondary Road	0.087	3	8.7	8.5	8.9	9.8	8.1	8.5	8.3	8.2	8.3	8.4	9.1	8.5	8.3
Slope	0.07	4	7	6.9	7.2	6.4	7.8	6.9	7.3	6.7	7.1	8.8	5.6	7.6	7.2
Elevation	0.059	5	5.9	5.8	6.5	5.3	6.5	6.7	6.1	5.6	5.9	7.4	5.1	5.8	6.9
River	0.054	6	5.4	5.3	5.5	4.9	5.9	6.1	5.3	5.1	5.1	5.2	5.5	5.5	5.5
Highway	0.052	7	5.2	5.1	5.3	5	5.5	5	5.1	4.9	4.9	5	5	5	6.1
Water Pipe Line	0.051	8	5.1	5	5.2	4.6	5	5	4	4.9	4.7	4.9	4.9	5.3	5.1
Commercial Zone	0.048	9	4.8	5	4.5	4.3	4.9	4.7	4.9	4.6	5	4.6	4.7	4.7	4.9
Industrial Zone	0.045	10	4.5	4.8	4.1	4	4.6	4.3	4.6	4.2	4.7	4.3	4.6	4.4	3.9
Transmission Line	0.043	11	4.3	4.2	4	3.9	4.5	4.2	4.4	4.1	4.5	4.2	4.5	3.9	3.7
Lake	0.037	12	3.7	3.7	3.7	3.3	4	4.5	3.9	3.5	3.8	3.5	3.8	3.6	3.2
Residential Zone	0.034	13	3.4	3.6	3.3	3	3.7	3.3	3.5	3.2	3.5	3.3	3.5	3.3	3.1
Educational Zone	0.033	14	3.3	3.5	3	2.9	3.6	3.2	3.3	3.1	3.4	3.1	3.4	3.2	3
Health Caring Zone	0.02	15	2	2.1	2	1.8	2.2	1.9	2	1.9	2.1	1.9	2	1.9	2
Religious Zone	0.02	15	2	2.1	1.8	1.8	2.2	1.9	2	1.9	2.1	1.9	2	1.9	2
Parks & Play Grounds	0.02	15	2	2.1	1.8	1.8	2.2	1.9	2.1	1.9	2.1	1.9	2.1	1.8	1.9
Rail line	0.02	15	2	1.9	1.7	2.4	1.6	1.9	2	1.9	2	1.9	2	1.8	1.9
Forest	0.02	15	2	2.1	2	1.8	2.2	1.9	2	2.8	2	2	2	2	2.1
Historical Buildings	0.018	16	1.8	1.9	1.7	1.7	2	1.8	1.9	1.8	1.9	1.8	1.9	1.8	1.9
Airport	0.016	17	1.6	1.6	1.7	1.6	1.3	1.6	1.7	1.6	1.7	1.6	1.7	1.6	1.7

It has been analyzed that there was no significant change found in rest of the selection factors excluding forest, which was notified during the 10% change. Hence, it was concluded to revise the rank of forest data layer as shown in the Table 4.3.

Table 4.3: Final Results of the Selection Factors

Selection Factors	Senthesize Results	Ranking	Percentage
Primary Road	0.156	1	15.6
Vacant Land	0.097	2	9.7
Secondary Road	0.087	3	8.7
Slope	0.07	4	7
Elevation	0.059	5	5.9
River	0.054	6	5.4
Highway	0.052	7	5.2
Water Pipe Line	0.051	8	5.1
Commercial Zone	0.048	9	4.8
Industrial Zone	0.045	10	4.5
Transmission Line	0.043	11	4.3
Lake	0.037	12	3.7
Residential Zone	0.034	13	3.4
Educational Zone	0.033	14	3.3
Forest	0.021	15	2.1
Health Caring Zone	0.02	16	2
Religious Zone	0.02	16	2
Parks & Play Grounds	0.02	16	2
Rail line	0.02	16	2
Historical Buildings	0.017	17	1.7
Airport	0.016	18	1.6
	1		100

This is the final list of the selection factors with the respective weights. These weights have been incorporated to generate the final land suitability map for site selection of new petrol filling stations.

4.3 Development of Land Suitability Map for PFS using Code Suggested by National Environmental Protection Agency (NEPA), Jamaica

There has been six main criteria's considered important for installing a new petrol filling station. Apparently, these criteria's were further classified into sub criteria's as discussed in detail in the chapter of literature review. Each criteria and sub criteria has got its importance, few were important to an environmental expert whereas others were important to a businessman. Therefore, the aggregated weights have been calculated to incorporate to generate the final land suitability map for site selection of new petrol filling station. All these criteria's and sub criteria’s data layers are discussed in detail below referring to the code suggested by National Environmental Protection Agency (NEPA), Jamaica.

4.3.1 Land Use

This criterion contains different type of land uses including residential zones, educational institutions, health caring centers, commercial zones, industrial zones, religious places, historical places, park and playgrounds. All these land uses are very important for installing a new petrol filling station. A petrol filling station should be sited at certain distance from these land uses. All these land uses are discussed in detail below.

4.3.1.1 Residential Zone

Residential zone consists detail of the residential aspects including housing schemes, colonies, sky scrapers etc in the study area. This land use data layer is very important. The site for the new petrol filling station should be located at certain safe distance usually called as a buffer from the residential buildings. The buffer suggested by the National Environment Protection Agency (NEPA) is 100 feet. Figure 4.4 shows the residential details in the study area provided with the suggested buffer distance.

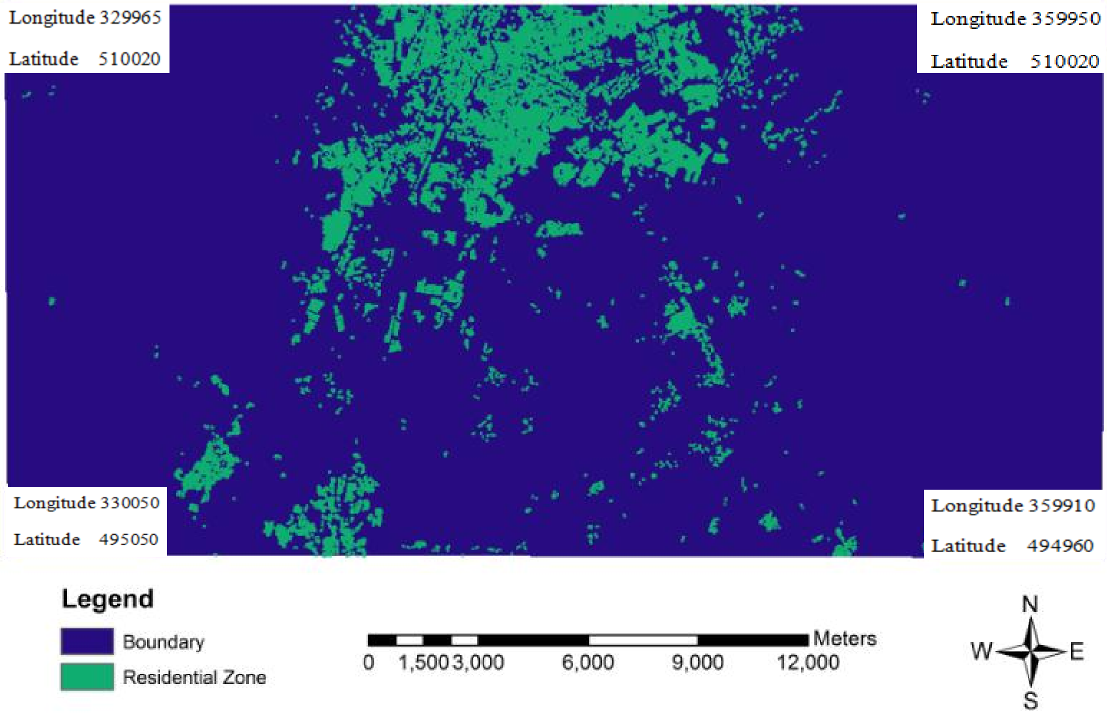

Figure 4.4: Residential Zone with Buffer using NEPA Code

Zoom in technique has been used to give a clear picture and understanding of the suggested buffer values from the existing land use feature. Figure 4.5 shows a simple example of the buffering scenario in this land use feature.

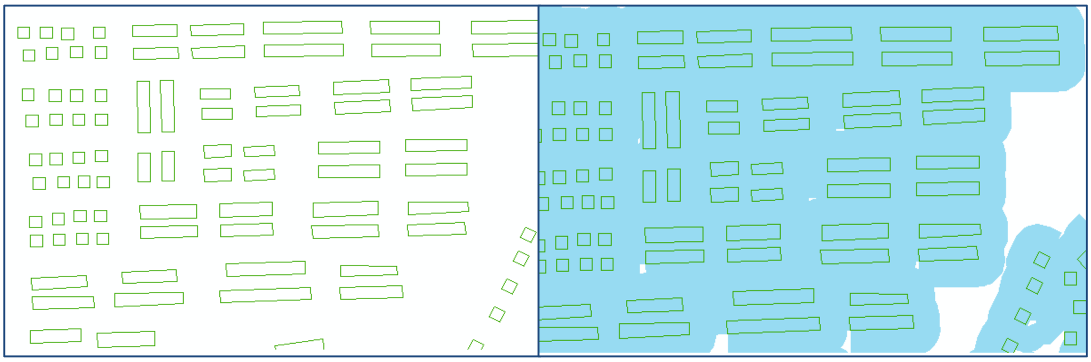

Figure 4.5: Residential Zone Before and After Buffer Placement

The calculation of suitable land parcels rendering to residential zone has been done by using the following expressions.

Area of the feature in square meters = Number of cells Covered X-axis of the Cell * Y-axis of the cell*

Area of the feature in hectares = Area of the feature in square meters / Ten thousands

The final map is a raster based image and it was divided into number of cells. Each cell consists of X and Y axis value like length and width of the cell. The suitability has been calculated by counting these cells favoring that particular feature. In this figure, the numbers of cells representing suitable land parcels with reference to the residential zone are 446411 and the numbers of cells representing the occupancy of the existing residential zone with the safe buffer are 52896.

To calculate the net area in hectares the above two expressions has been used and the results are as follows;

*Area of the non-suitable zone in square meters = 52896 *30*30 = 47606400 m*^{2}

Area of the feature non-suitable zone in hectares = 47606400/10000 = 4760.64 hectares

*Area of the suitable zone in square meters = 446411*30*30 = 401769900 m*^{2}

Area of the suitable zone in hectares = 401769900/10000 = 40176.99 hectares

The cell size used to raster all of the data layers is 30m x 30m, which is a normal value and takes less time for the analysis. Hence, the suitable area for the development of the new petrol filling station in accordance to residential zone only is 40176.99 hectares whereas 4760.64 hectares are the non-suitable land parcels in the study area.

4.3.1.2 Educational Zone

An educational zone consists detail of the educational features including all types of primary and secondary schools, public and private colleges and universities. This land use data layer is important. The buffer suggested by the National Environment Protection Agency (NEPA) is 500 feet. Figure 4.6 shows the educational institutional details in the study area provided with the suggested buffer distance.

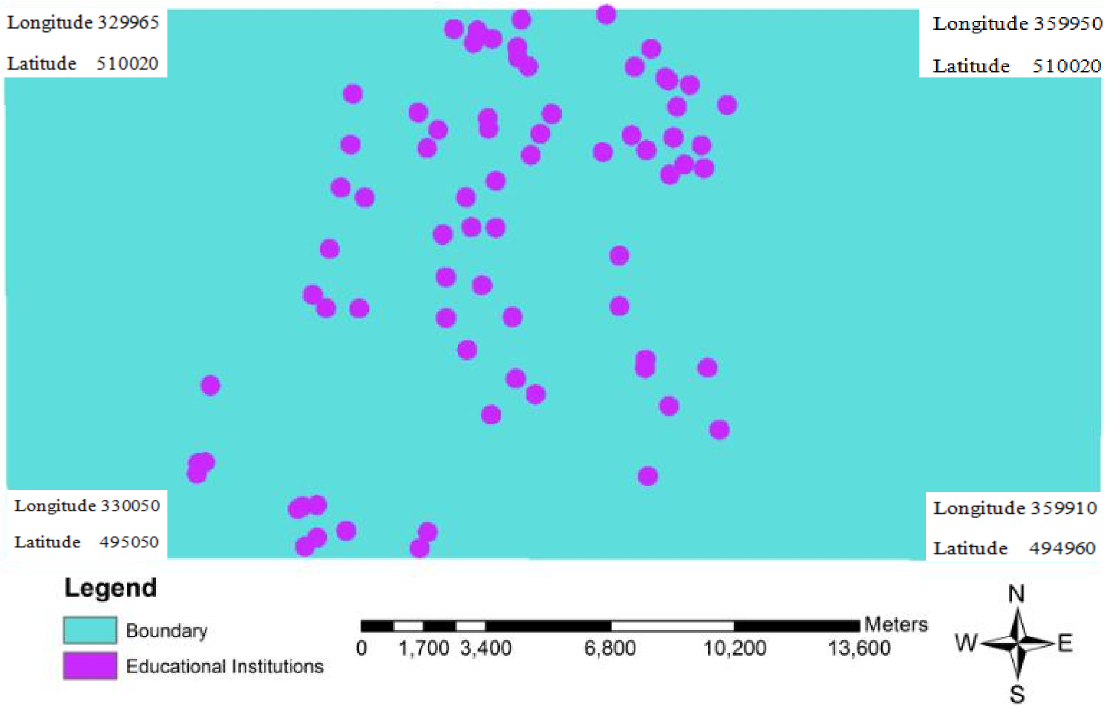

Figure 4.6: Educational Zone with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.7

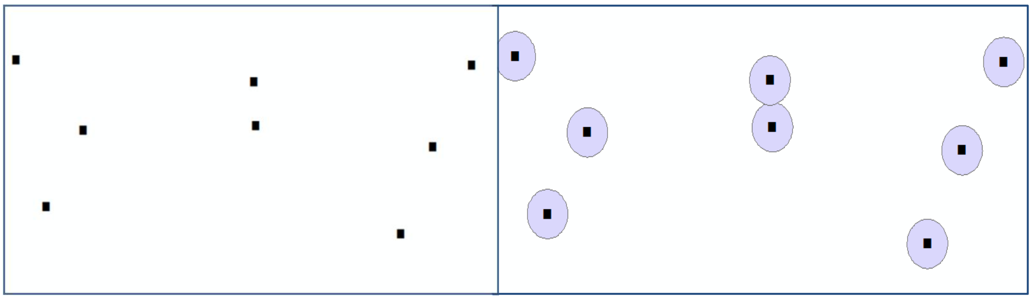

Figure 4.7: Educational Zone Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the educational institutions are 481471 and the number of cells representing the occupancy of the existing educational institutions with the safe buffers are 17855. Hence, the suitable area for the development of the new petrol filling stations in accordance to educational zone only is 43332 hectares whereas 1607 hectares are the non-suitable land parcels in the study area.

4.3.1.3 Health Care Zone

Health care zone consists detail of the health care facilities including public & private hospitals and clinics. This land use data layer is also very important. The buffer suggested by the National Environment Protection Agency (NEPA) is 500 feet. Figure 4.8 shows the health care zone details in the study area provided with the suggested buffer distance.

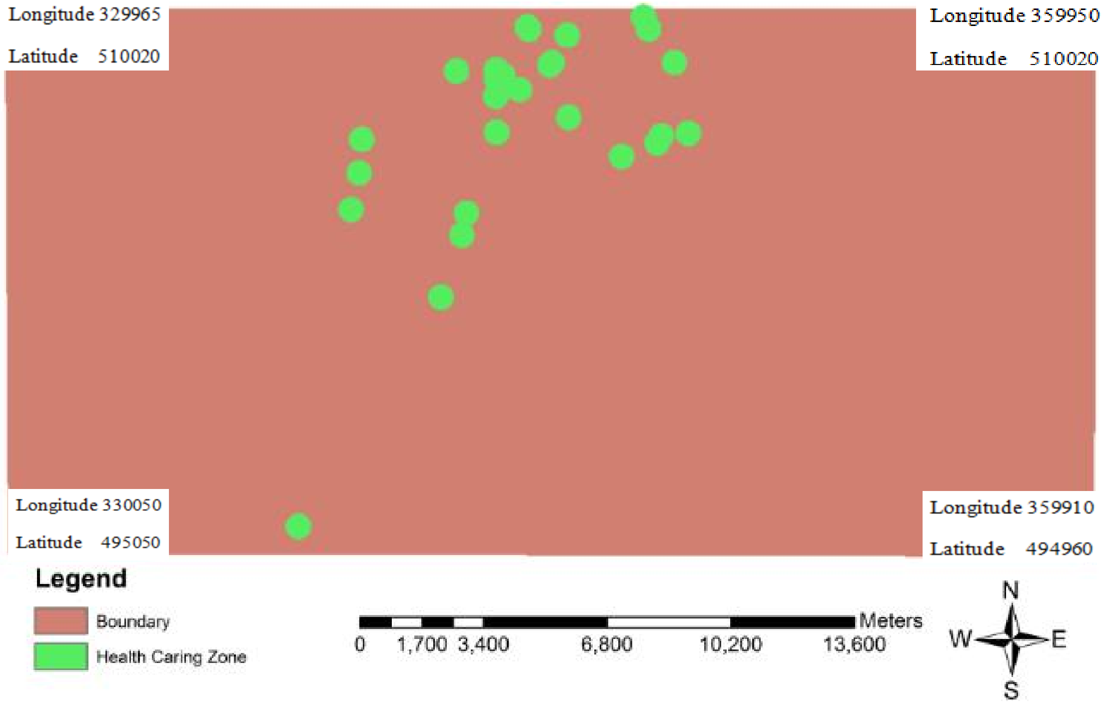

Figure 4.8: Health Care Zone with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.9

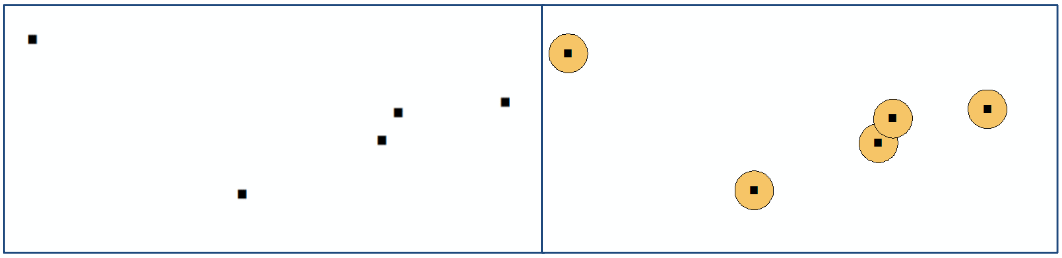

Figure 4.9: Health Care Zone Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the health caring centers are 489489 and the number of cells representing the occupancy of the existing health caring centers with the safe buffers are 9829. Hence, the suitable area for the development of the new petrol filling stations in accordance to health care zone only is 44054 hectares whereas 885 hectares are the non-suitable land parcels in the study area.

4.3.1.4 Commercial Zone

Commercial zone consists detail of the business features including all types of shops, restaurants, hotels and banks. This land use data layer is also important. The buffer suggested by the National Environment Protection Agency (NEPA) is 100 feet. Figure 4.10 shows the commercial details in the study area provided with the suggested buffer distance.

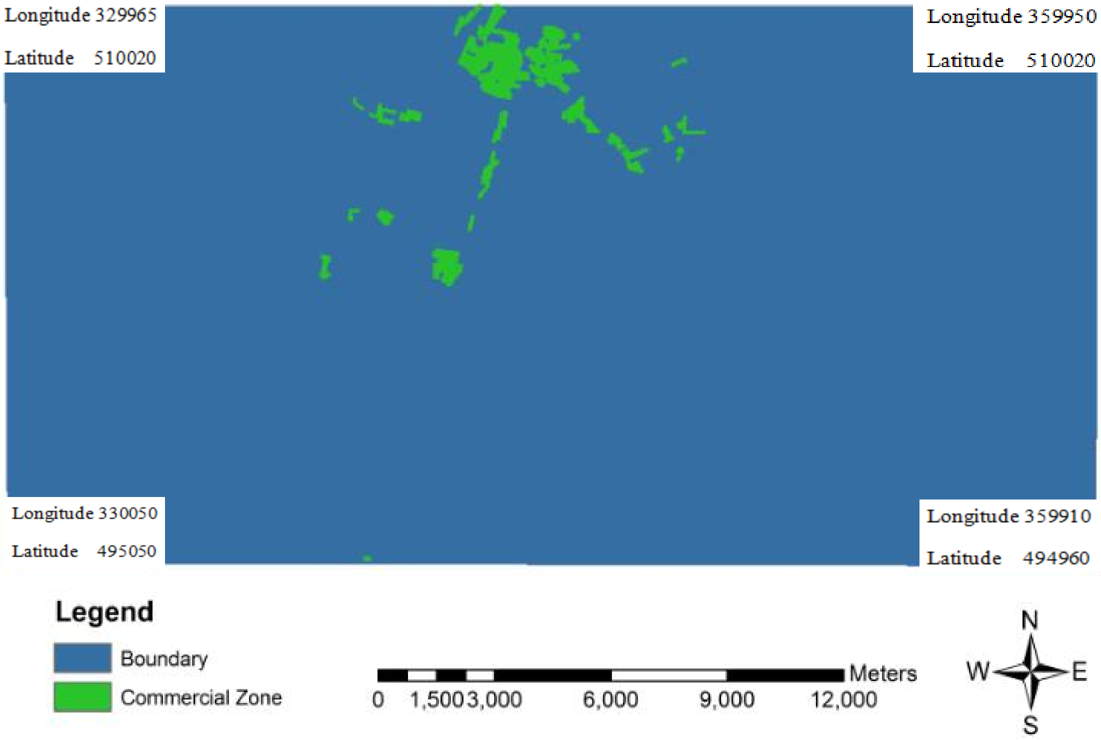

Figure 4.10: Commercial Zone with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.11

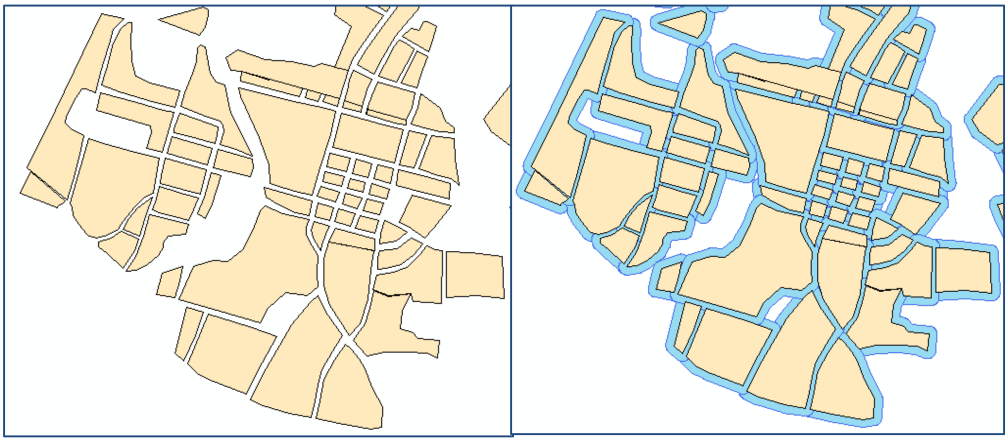

Figure 4.11: Health Care Zone Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the commercial zones are 491704 and the number of cells representing the occupancy of the existing commercial zones with the safe buffers are 7581. Hence, the suitable area for the development of the new petrol filling stations in accordance to commercial zone only is 44253 hectares whereas 682 hectares are the non-suitable land parcels in the study area.

4.3.1.5 Industrial Zone

Industrial zone consists detail of the industrial features including all types of small and large industries in the area. This land use data layer is also important. The buffer suggested by the National Environment Protection Agency (NEPA) is 100 feet. Figure 4.12 shows the industrial details in the study area provided with the suggested buffer distance.

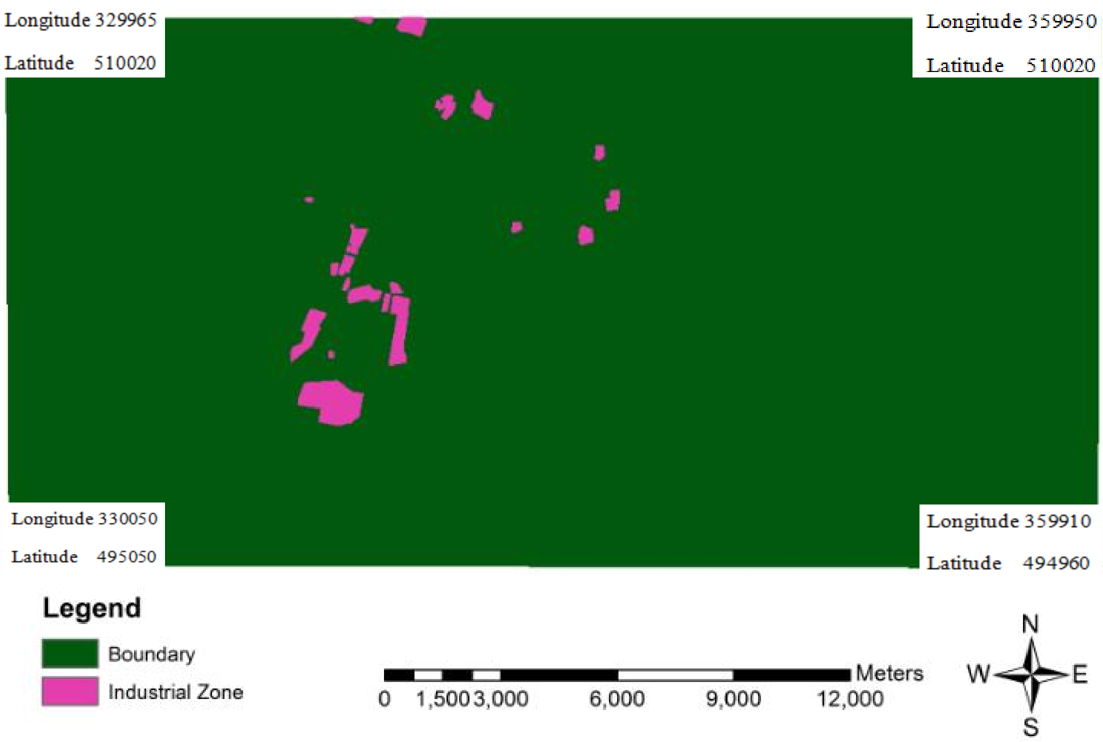

Figure 4.12: Industrial Zone with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.13

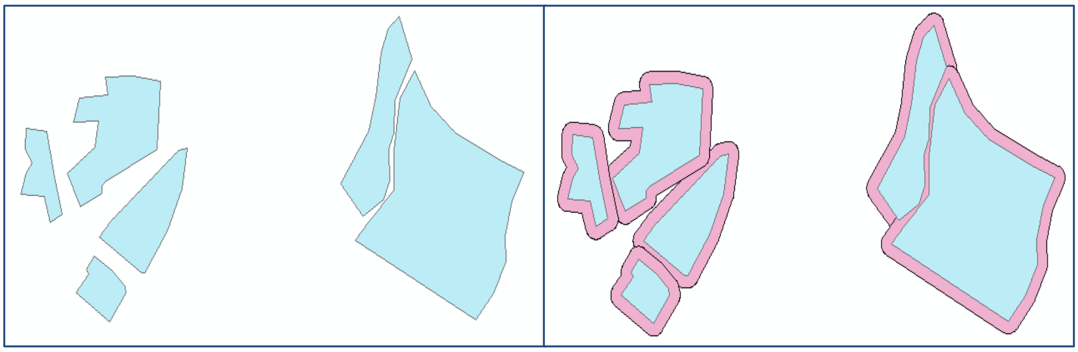

Figure 4.13: Industrial Zone Before and After Buffer Placement

The number of cells representing the suitable land in reference parcels with the industrial zones are 493303 and the number of cells representing the occupancy of the existing industrial zones with the safe buffers are 6008. Hence, the suitable area for the development of the new petrol filling station in accordance to industrial zone only is 44397 hectares whereas 541 hectares are the non-suitable land parcels in the study area.

4.3.1.6 Religious Zone

Religious zone consists detail of the religious features including mosques, hindu temples, chinese temples, churches, cemeteries. This land use data layer is also very important. The buffer suggested by the National Environment Protection Agency (NEPA) is 500 feet. Figure 4.14 shows the religious places details in the study area provided with the suggested buffer distance.

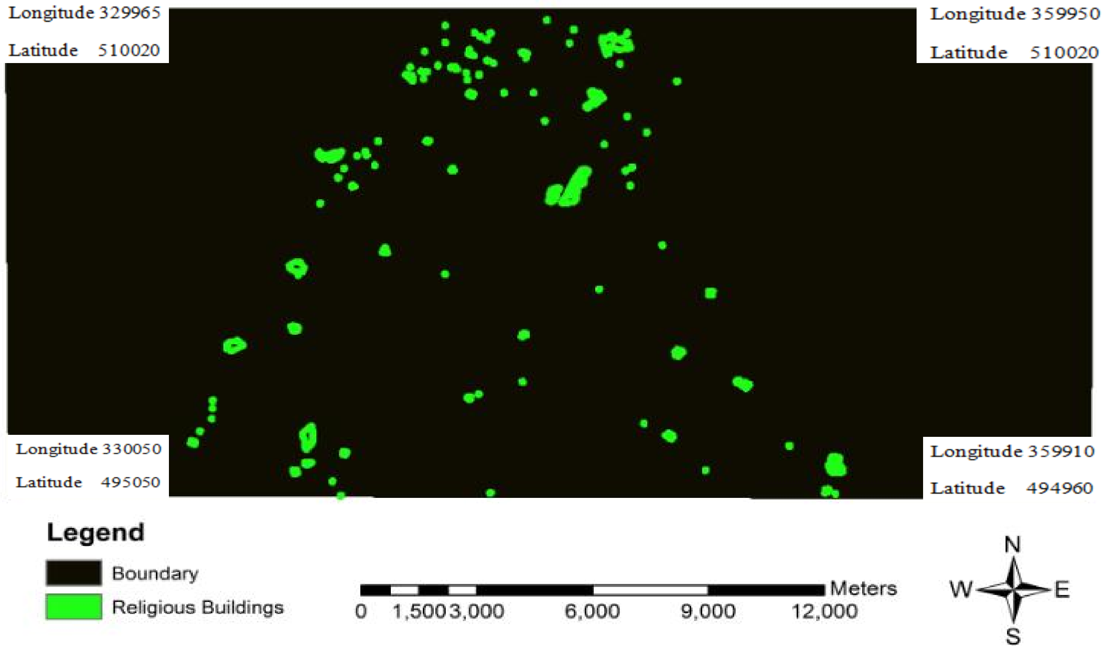

Figure 4.14: Religious Zone with Buffer using NEPA Code

The number of cells representing the suitable land parcels with reference to the religious zone are 491077 and the number of cells representing the occupancy of the existing religious zones with the safe buffers are 8624. Hence, the suitable area for the development of the new petrol filling stations in accordance to religious zone only is 44112.6 hectares whereas 839.79 hectares are the non-suitable land parcels in the study area.

4.3.1.7 Historic Zone

Historic zone consists detail of the historic features including museums, buildings and town halls. This land use data layer is also important. The buffer suggested by the National Environment Protection Agency (NEPA) is 500 feet. Figure 4.15 shows the historic details in the study area provided with the suggested buffer distance.

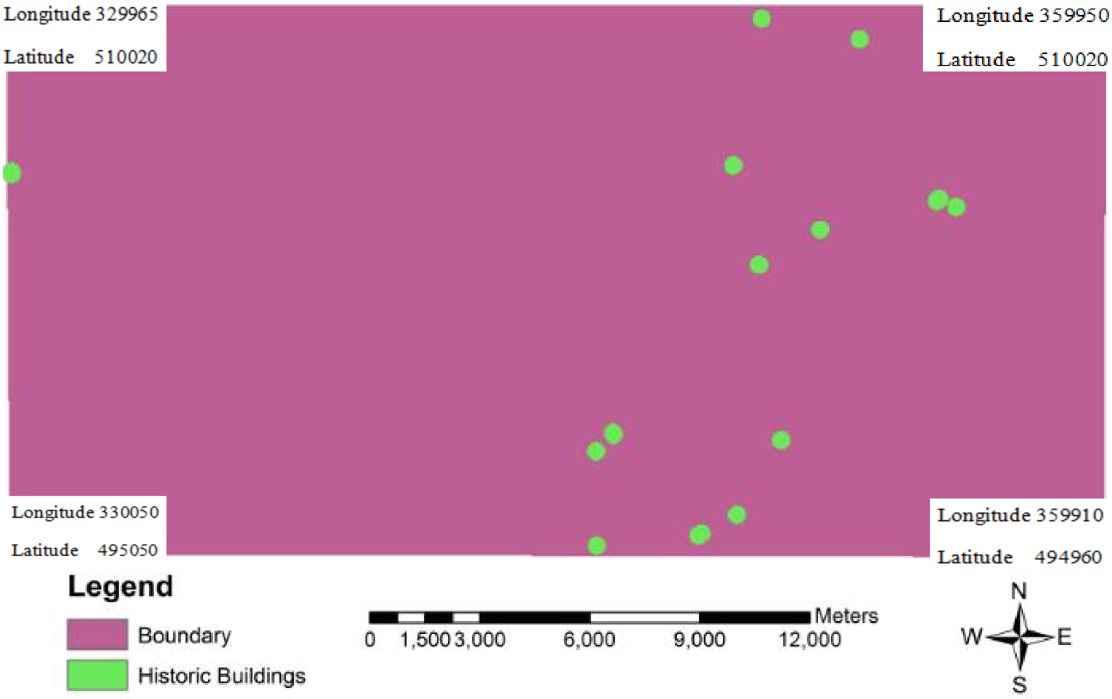

Figure 4.15: Historic Zone with Buffer using NEPA Code

The number of cells representing the suitable land parcels with reference to the historic zone are 496099 and the number of cells representing the occupancy of the existing historical places with the safe buffers are 3261, this will behave like the constraint towards the land suitability of the petrol filling stations. Hence, the suitable area for the development of the new petrol filling stations in accordance to historic zone only is 44649 hectares whereas 294 hectares are the non-suitable land parcels in the study area.

4.3.1.8 Parks and Playgrounds

Parks and playgrounds zone consist detail of the open space recreational features including different parks and playing grounds. This land use data layer is also important. The buffer suggested by the National Environment Protection Agency (NEPA) is 500 feet. Figure 4.16 shows the parks and playgrounds details in the study area provided with the suggested buffer distance.

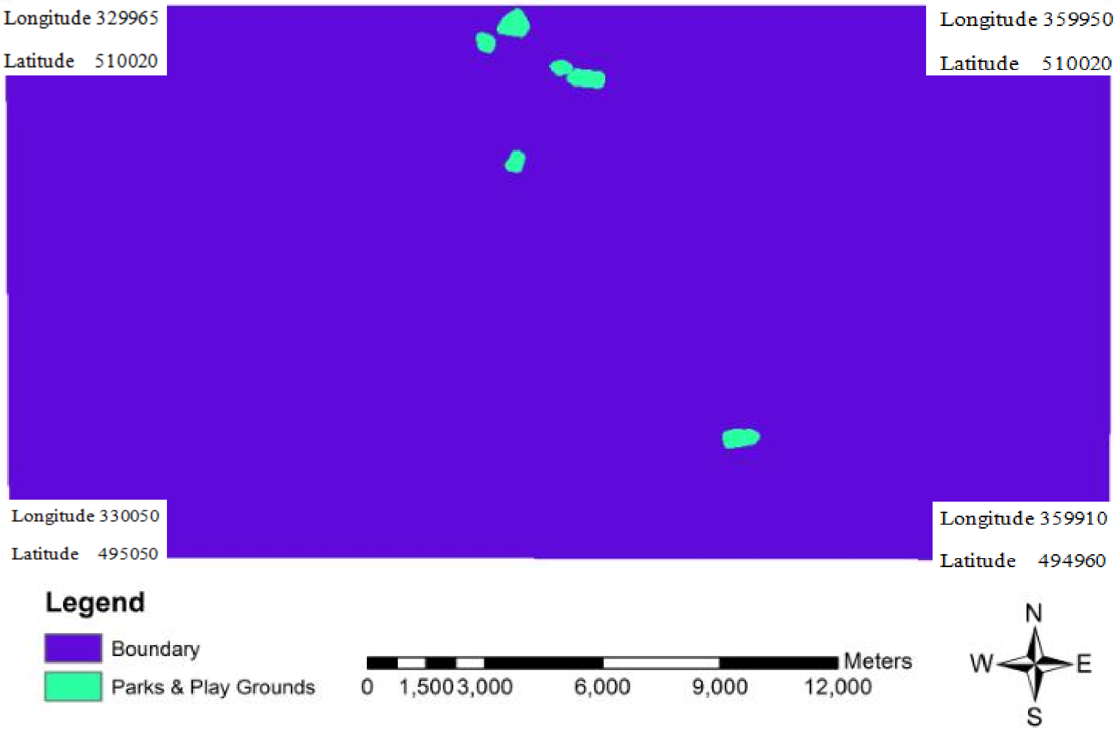

Figure 4.16: Parks and Playgrounds Zone with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.17

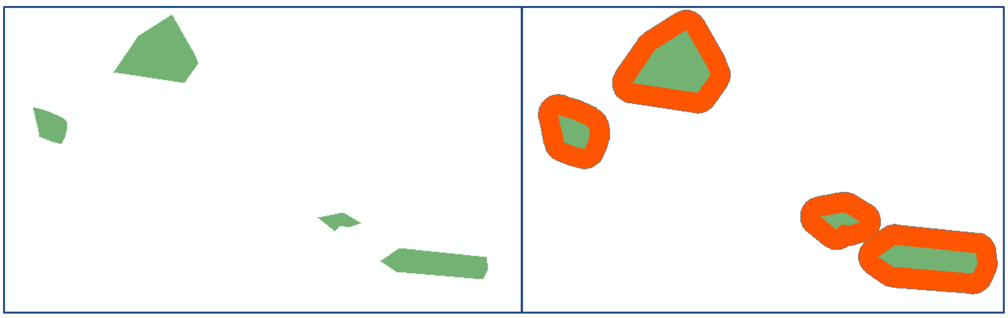

Figure 4.17: Parks & Playgrounds Zone Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the parks and playgrounds zone are 496973 and the number of cells representing the occupancy of the existing parks and playgrounds with the safe buffers are 2301. Hence, the suitable area for the development of the new petrol filling stations in accordance to parks and playgrounds zone only is 44728 hectares whereas 207 hectares are the non-suitable land parcels in the study area.

4.3.2 Accessibility

This criterion contains different modes of transportation including dual highways, primary roads, secondary roads, railway lines and airport in the study area. All these modes of transportation are very important and petrol filling stations should be sited at a certain distance from these features. All these modes of transportation are discussed in detail below.

4.3.2.1 Highways

This data layer consists detail of the highway pass through the study area. The buffer suggested by the National Environment Protection Agency (NEPA) is 40 feet. Figure 4.18 shows the highway details in the study area provided with the suggested buffer distance.

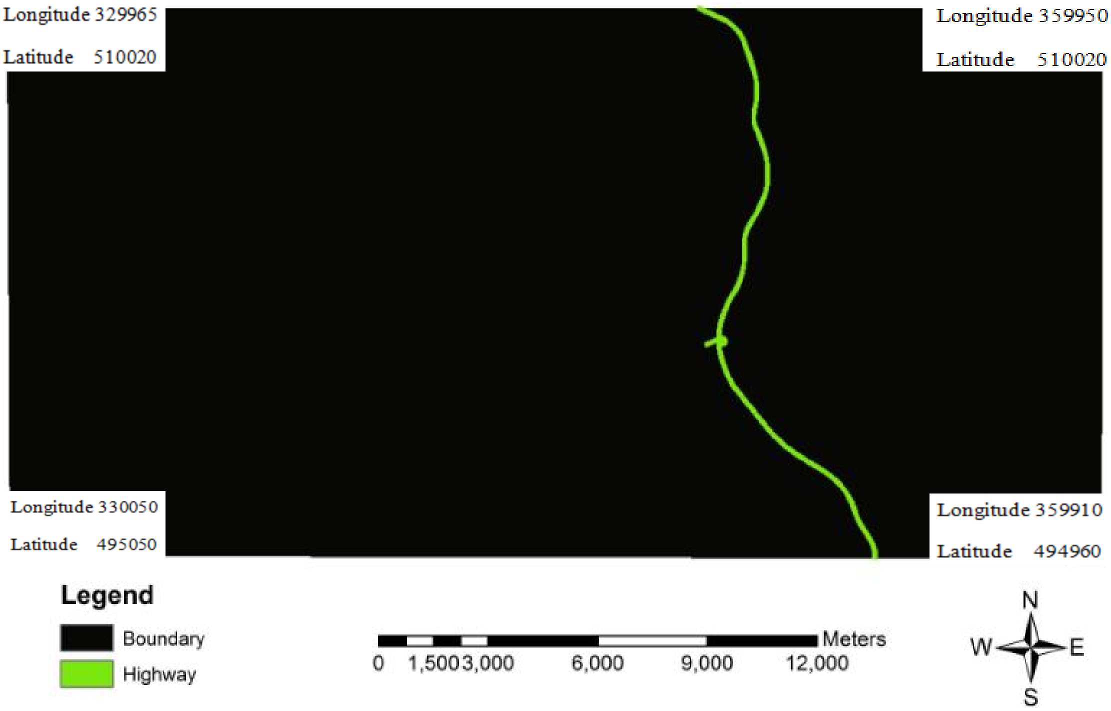

Figure 4.18: Highway with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.19

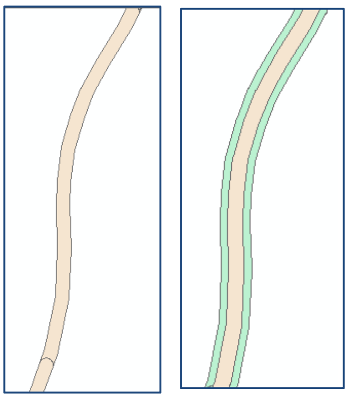

Figure 4.19: Highway Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the dual highway are 495897 and the number of cells representing the occupancy of the existing highway with the safe buffers are 2951. Hence, the suitable area for the development of the new petrol filling stations in accordance to the highway only is 44631 hectares whereas 266 hectares are the non-suitable land parcels in the study area.

4.3.2.2 Primary Roads

This data layer consists detail of the primary roads in the study area. The buffer suggested by the National Environment Protection Agency (NEPA) is 40 feet. Figure 4.20 shows the primary roads details in the study area provided with the suggested buffer distance.

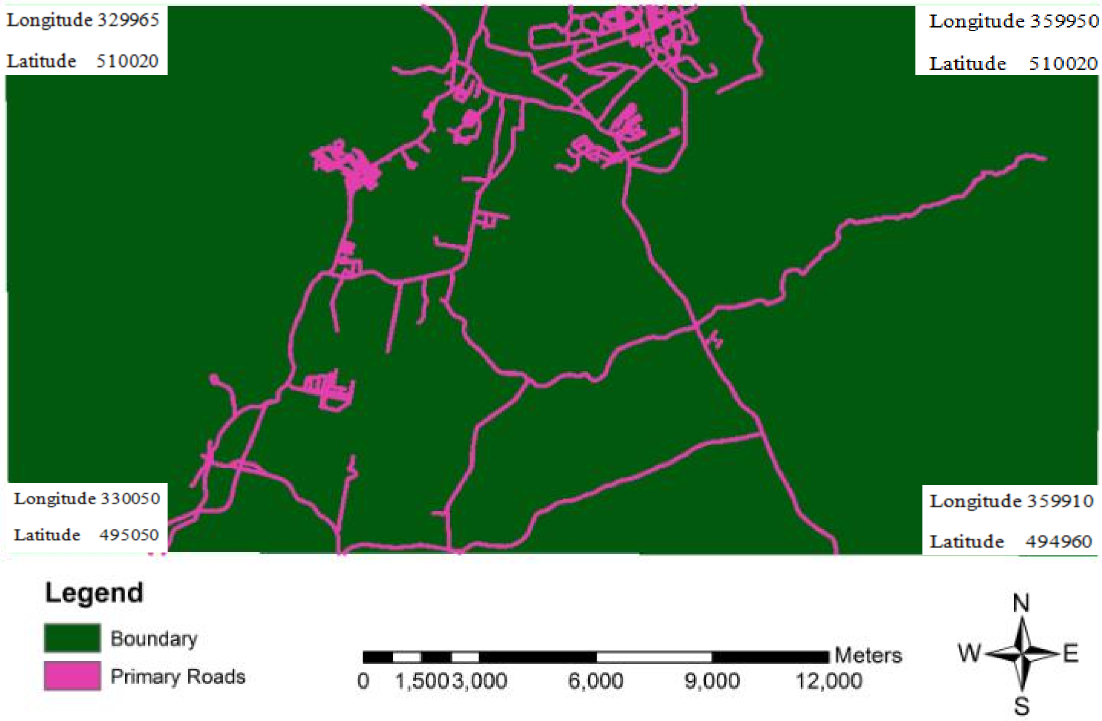

Figure 4.20: Primary Roads with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.21.

Figure 4.21: Primary Roads Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the primary roads are 469836 and the number of cells representing the occupancy of the existing primary roads with the safe buffers are 29211. Hence, the suitable area for the development of the new petrol filling stations in accordance to primary roads only is 42285 hectares whereas 2629 hectares are the non-suitable land parcels in the study area.

4.3.2.3 Secondary Roads

This data layer consists detail of the secondary roads in the study area. The buffer suggested by the National Environment Protection Agency (NEPA) is 40 feet. Figure 4.22 shows the secondary roads details in the study area provided with the suggested buffer distance.

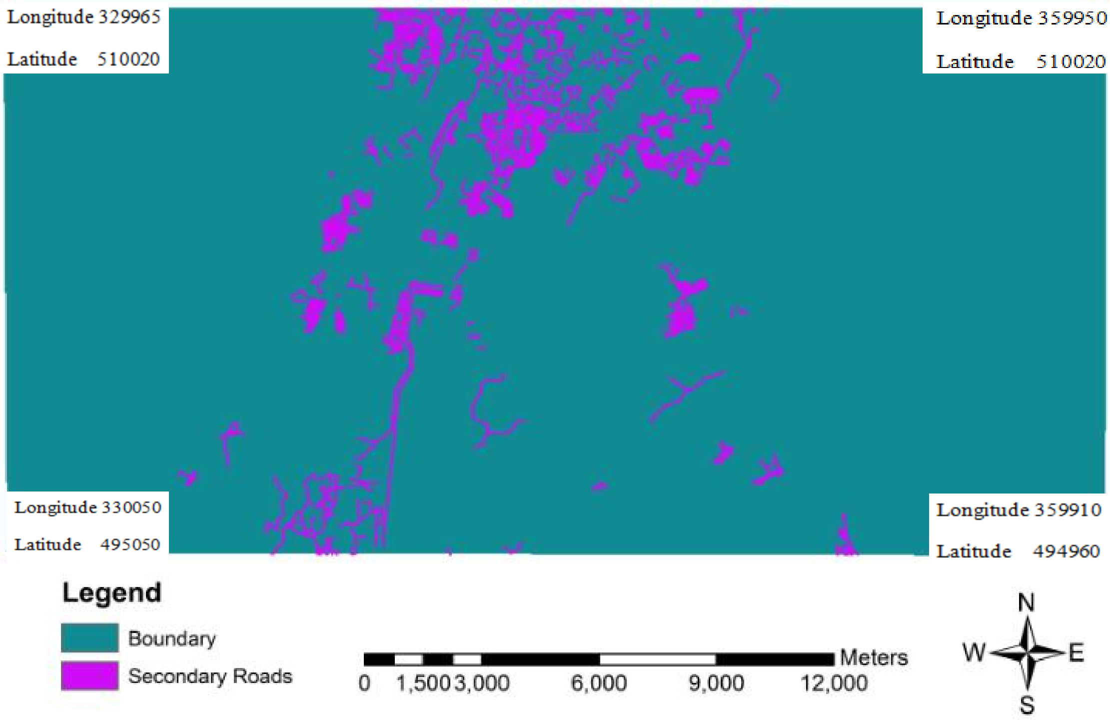

Figure 4.22: Secondary Roads with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.23.

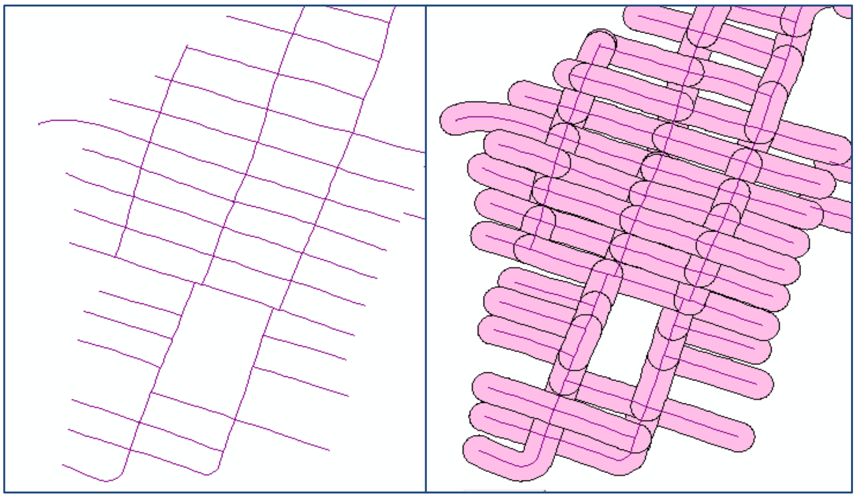

Figure 4.23: Secondary Roads Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the secondary roads are 474915 and the number of cells representing the occupancy of the existing secondary roads with the safe buffers are 24411. Hence, the suitable area for the development of the new petrol filling stations in accordance to secondary roads only is 42742 hectares whereas 2197 hectares are the non-suitable land parcels in the study area.

4.3.2.4 Railway Lines

This data layer consists detail of the railway lines passing through the study area. The buffer suggested by the National Environment Protection Agency (NEPA) is 750 feet. Figure 4.24 shows the railway lines details in the study area provided with the suggested buffer distance.

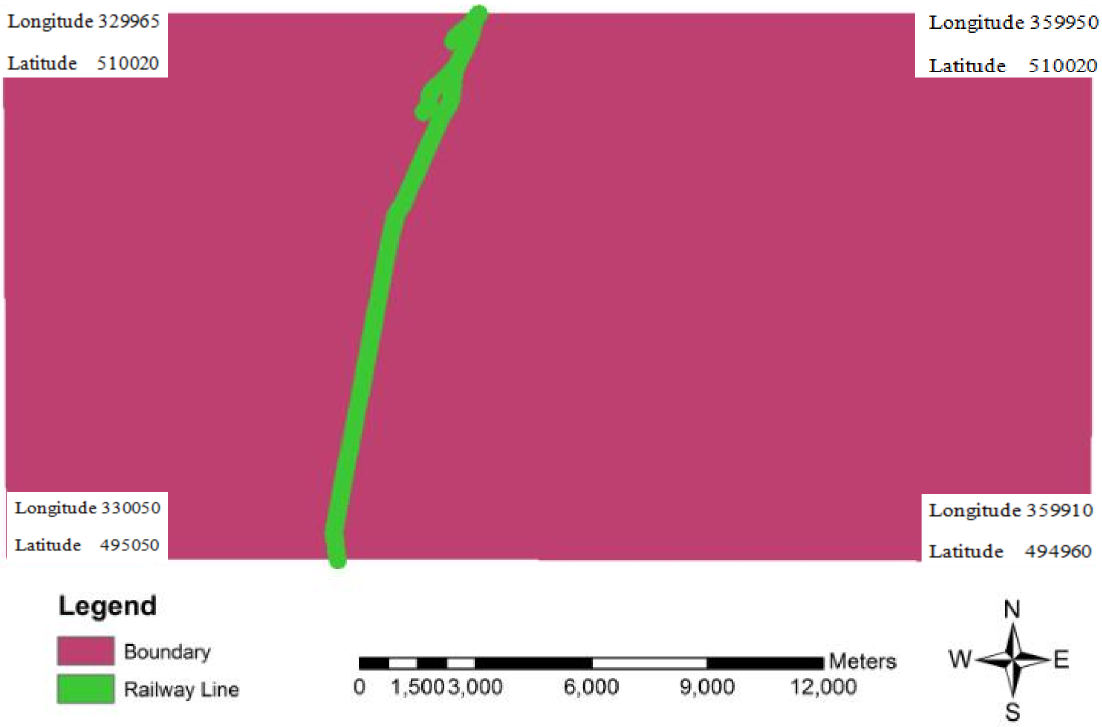

Figure 4.24: Railway Line with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.25

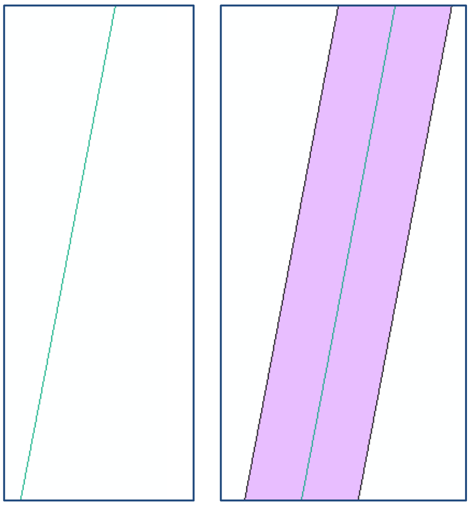

Figure 4.25: Railway Line Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the railway lines are 489518 and the number of cells representing the occupancy of the existing railway lines with the safe buffers are 9939. Hence, the suitable area for the development of the new petrol filling stations in accordance to railway lines only is 44057 hectares whereas 895 hectares are the non-suitable land parcels in the study area.

4.3.2.5 Airports

This data layer consists detail of the airport in the study area. The buffer suggested by the National Environment Protection Agency (NEPA) is 1500 feet. Figure 4.26 shows the airport details in the study area provided with the suggested buffer distance.

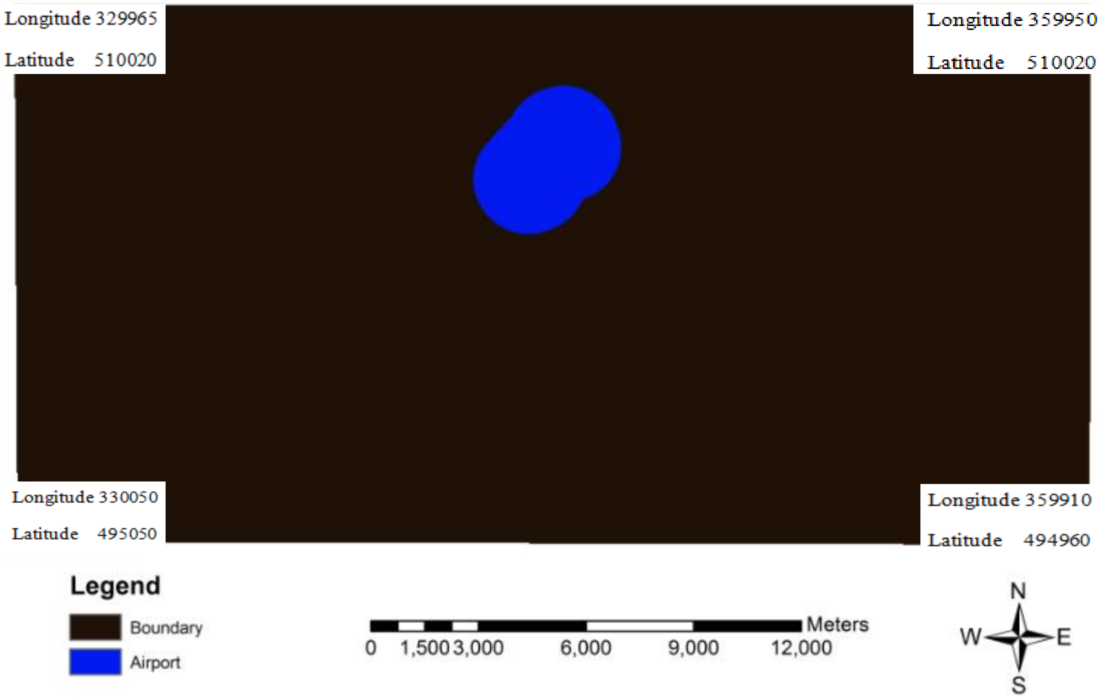

Figure 4.26: Airport with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.27.

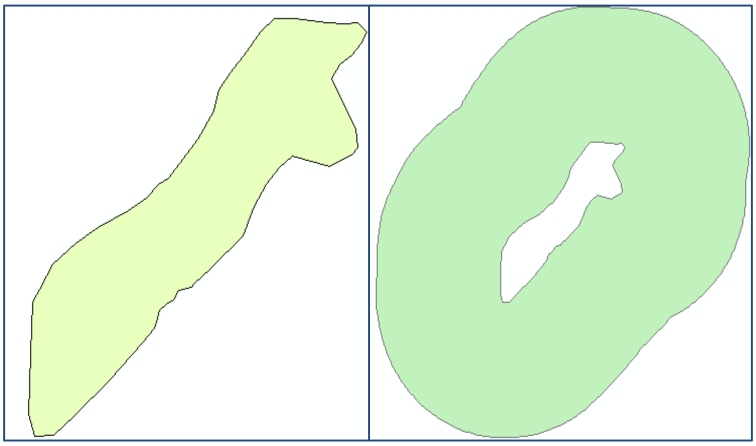

Figure 4.27: Airport Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the airport are 485813 and the number of cells representing the occupancy of the existing airport with the safe buffers are 13461. Hence, the suitable area for the development of the new petrol filling stations in accordance to airport only is 43723 hectares whereas 1211 hectares are the non-suitable land parcels in the study area.

4.3.3 Hydrological Conditions

This criterion contains different modes of hydrological features including rivers, lakes and sea water. All these modes of water transformation are very important and petrol filling stations should be sited at a certain distance from such features. All these features are discussed in detail below.

4.3.3.1 Rivers

This data layer consists detail of the rivers pass through the study area. The buffer suggested by the National Environment Protection Agency (NEPA) is 500 feet. Figure 4.28 shows the rivers details in the study area provided with the suggested buffer distance.

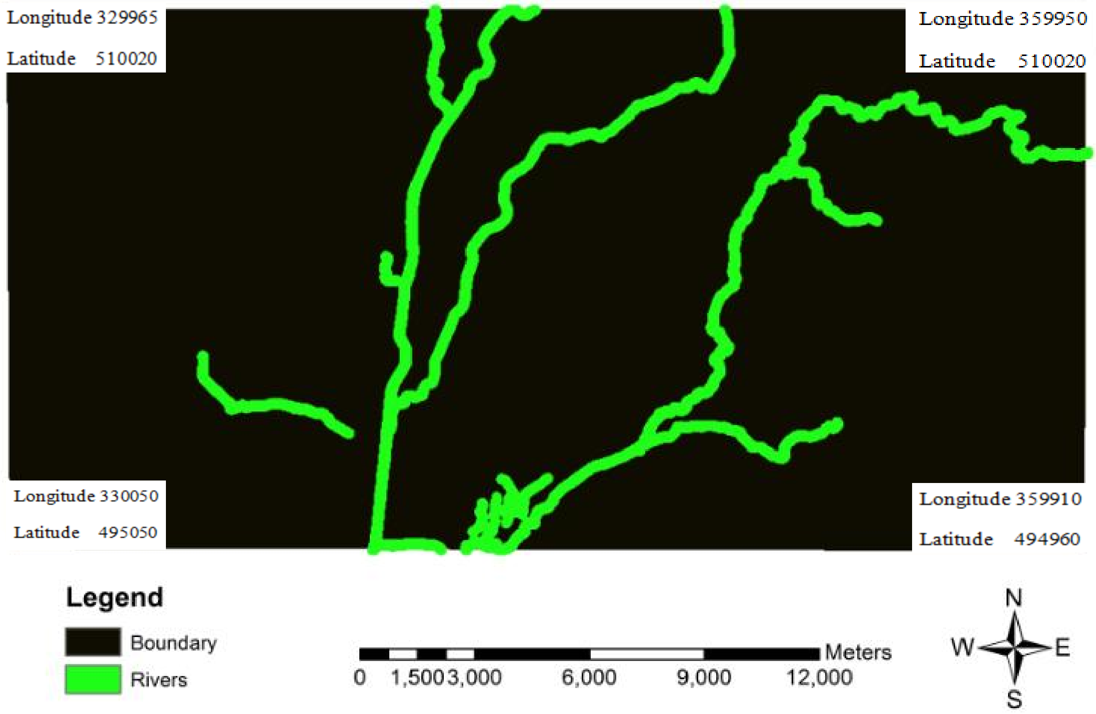

Figure 4.28: Rivers with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.29

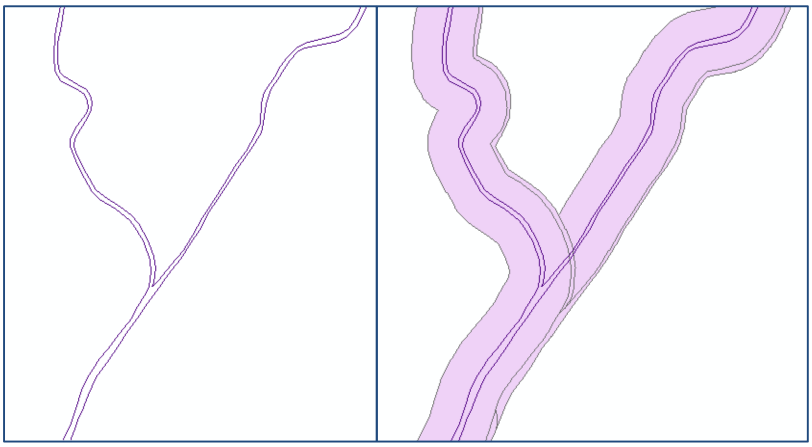

Figure 4.29: River Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the rivers are 466357 and the number of cells representing the occupancy of the existing rivers with the safe buffers are 33734. Hence, the suitable area for the development of the new petrol filling stations in accordance to rivers only is 41972 hectares whereas 3036 hectares are the non-suitable land parcels in the study area.

4.3.3.2 Lakes

This data layer consists details of the lakes in the study area. The buffer suggested by the National Environment Protection Agency (NEPA) is 500 feet. Figure 4.30 shows the lake details in the study area provided with the suggested buffer distance.

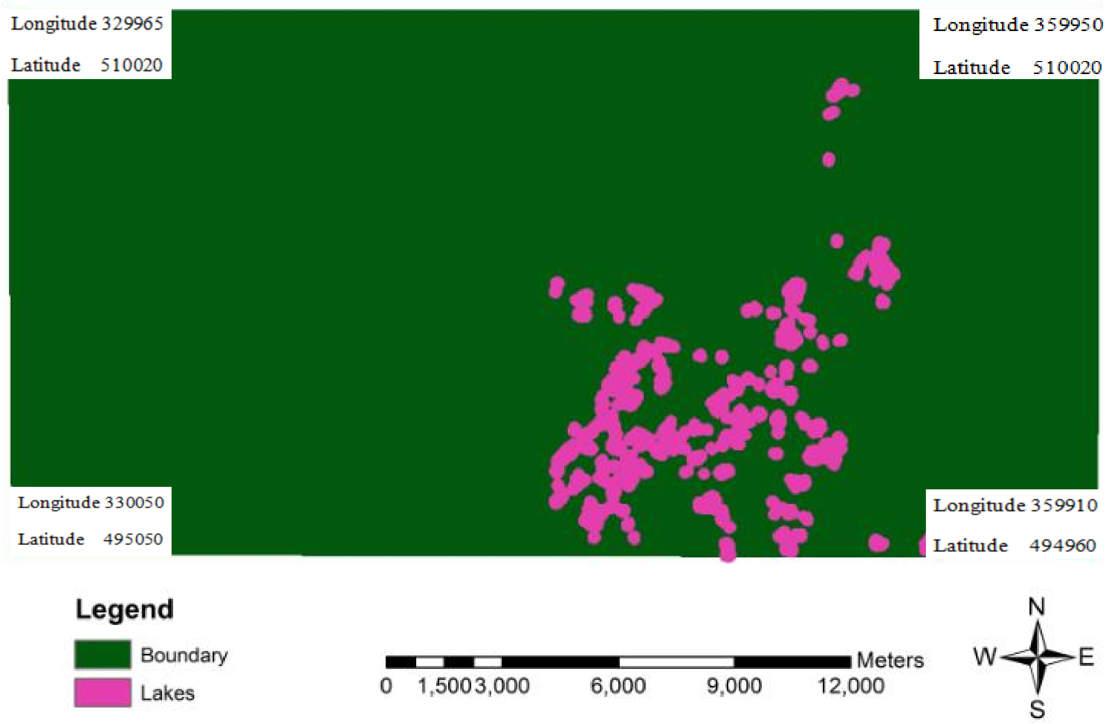

Figure 4.30: Lakes with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.31.

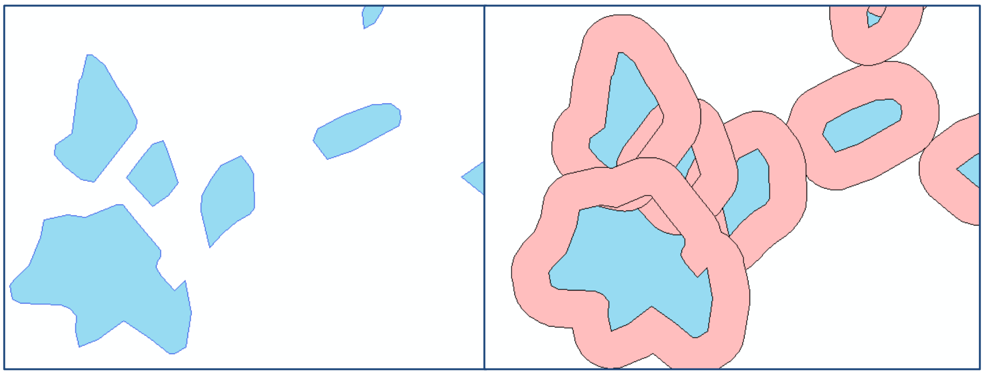

Figure 4.31: Lakes Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the lakes are 472447 and the number of cells representing the occupancy of the existing lakes with the safe buffers are 26474. Hence, the suitable area for the development of the new petrol filling stations in accordance to lakes only is 42520 hectares whereas 2382 hectares are the non-suitable land parcels in the study area.

4.3.4 Natural Environment

This criterion contains different features of the natural environment including forest, agricultural land and vacant land. All these features of the natural environment are very important and petrol filling stations should be sited at a certain distance from such features. All these features are discussed in detail below.

4.3.4.1 Vacant Land

This layer consists detail of the vacant land available in the study area. This sub criteria is the most preferable land parcel so it does not need any buffer. Figure 4.32 shows the vacant land details in the study area.

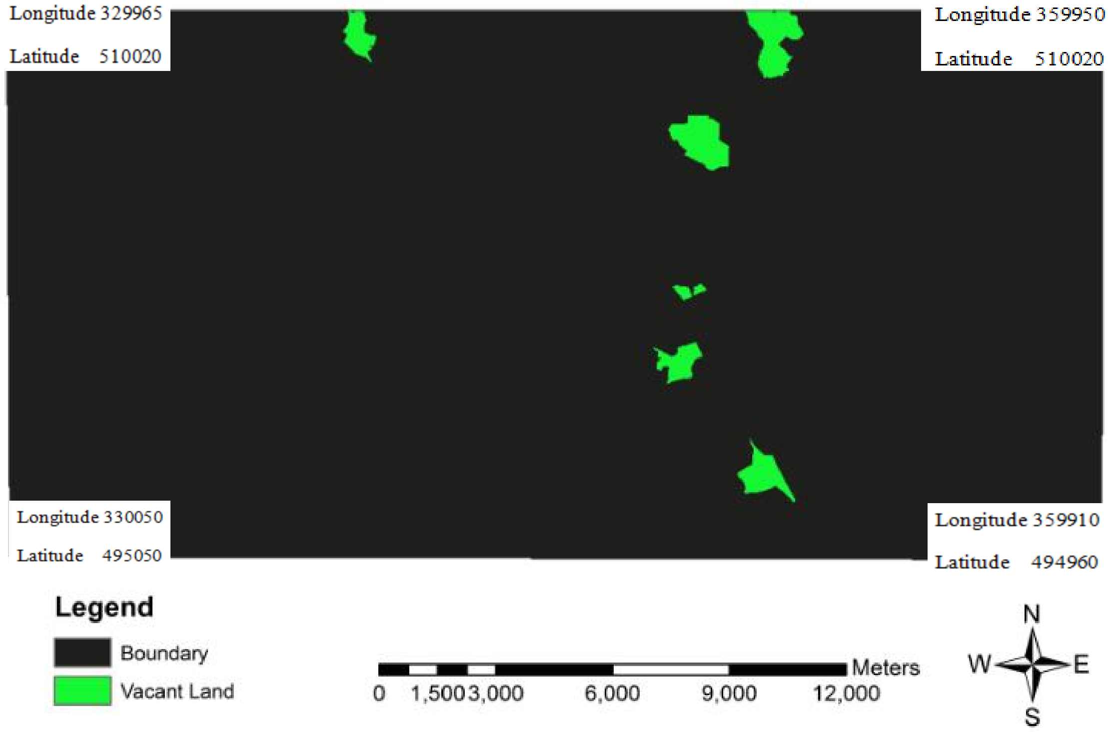

Figure 4.32: Vacant Land availability in Study Area

In this figure, the number of cells representing the preferable suitable land parcels are 6574. Hence, the preferable suitable area for the development of the new petrol filling stations is 592 hectares.

4.3.4.2 Forest

This data layer consists detail of the reserve forest in the study area. The buffer suggested by the National Environment Protection Agency (NEPA) is 1000 feet. Figure 4.33 shows the reserve forest details in the study area provided with the suggested buffer distance.

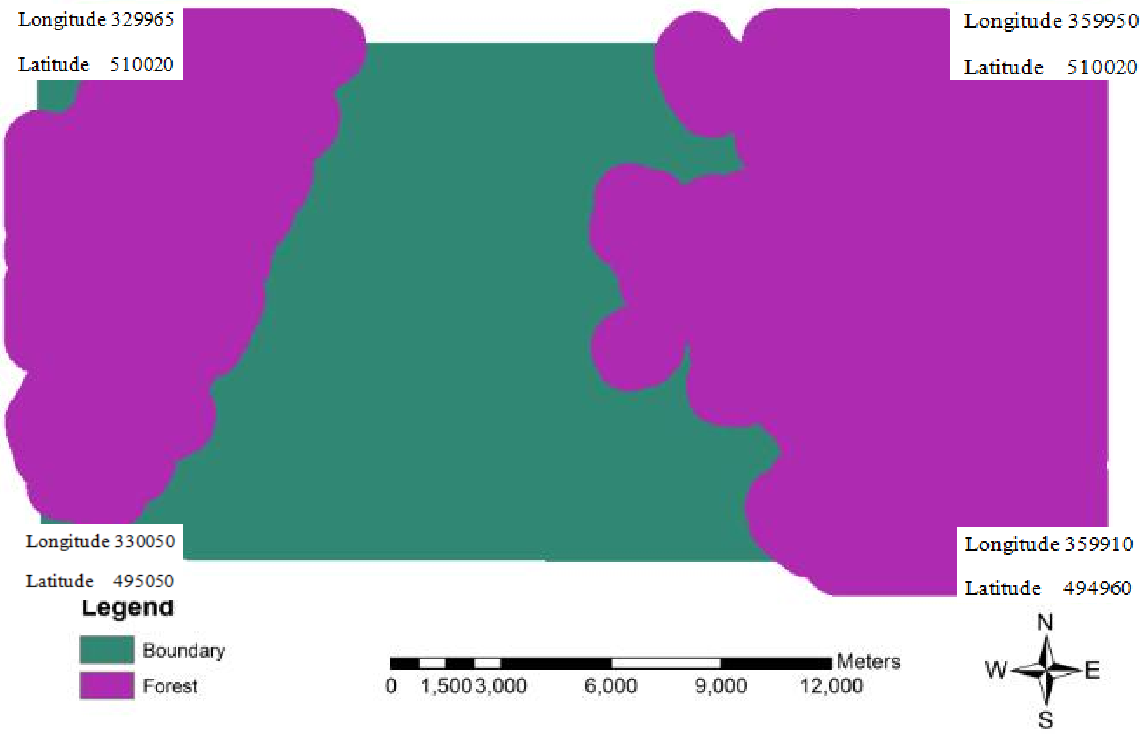

Figure 4.33: Forest with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.34

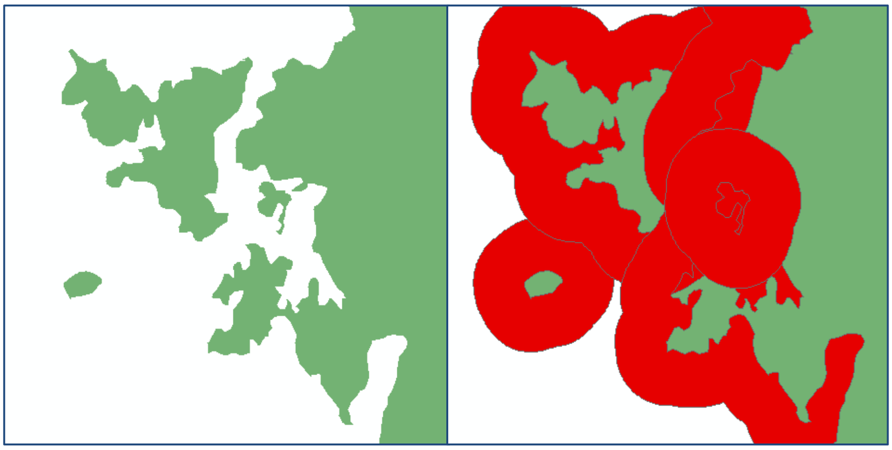

Figure 4.34: Forest Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the reserve forest are 205640 and the number of cells representing the occupancy of the existing reserve forest with the safe buffers are 353711. Hence, the suitable area for the development of the new petrol filling stations in accordance to reserve forest only is 18508 hectares whereas 31834 hectares are the non-suitable land parcels in the study area.

4.3.5 Topography

This criterion contains land level features like slope and elevation. Both of these features play an important role in the site selection of petrol filling stations and petrol filling stations should be sited at proper levels and slopes. Topographic maps are an important tool representing the three-dimensional landscape in two dimensions. These maps contain the data like the location of peaks, valleys and ridges in the area. Both features are discussed in detail below.

4.3.5.1 Elevation

The elevation of a geographic location is its height above a fixed reference point. Elevation data can be generated from existing contour maps. Contour map refers to lines representing equal points of elevation on the surface of the earth.

Triangulated Irregular Network (TIN) is a vector-based topological data model used to represent terrain. TINs contain a network of irregularly spaced triangles. Areas of high-relief will contain a higher density of small triangles while areas of low-relief will be represented by larger triangles. Figure 4.35 shows the TIN model details for elevation in the study area.

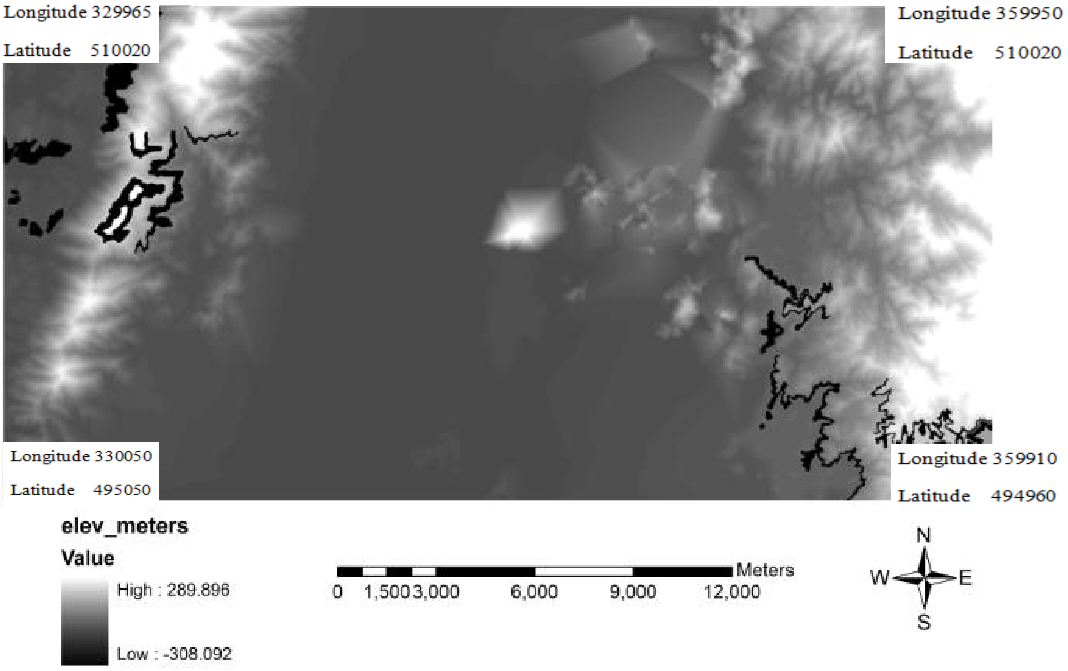

Figure 4.35: Digital Elevation Model rendering to NEPA Code

In this figure, the TIN model shows the highest point in the study area is 289.896 meters, whereas the lowest point is 306 meters. This TIN model is reclassified to get the final raster based data layer for the feature elevation. Figure 4.36 shows the elevation details in the study area.

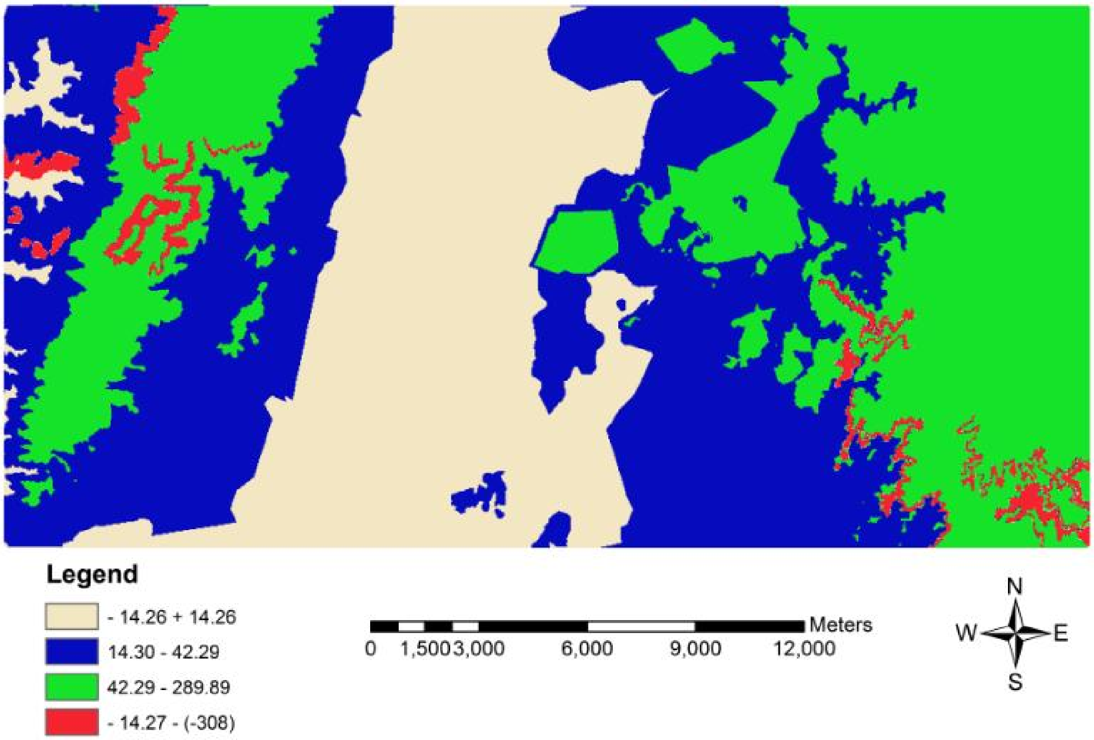

Figure 4.36: Elevation rendering to NEPA Code

4.3.5.2 Slope

Slope is the inclination or gradient of a surface, it helps to identify the maximum rate of change in surface value over a specific distance and commonly expressed in degrees and percent. It is desirable to have a topographic surface, if the slope is too steep that will not be suitable land parcel for the installation of new petrol filling stations. Slope gradient has great impact on land selection for petrol filling stations. The slope can be classified into different categories including flats, undulation plain, rolling to undulating, hill to rolling, steep and very steep. The best slope chosen for the land selection of petrol filling station is suggested by the respective code used. The TIN model is shown in the Figure 4.37

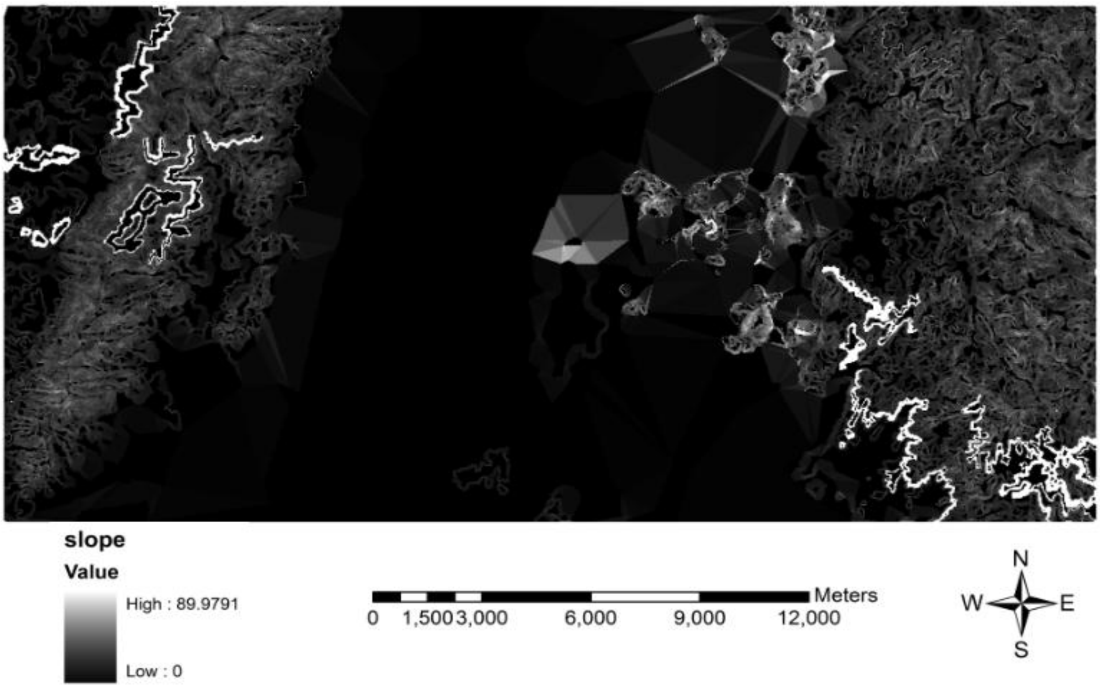

Figure 4.37: Tin Model rendering to NEPA Code

In this figure, the TIN model shows the highest slope in the study area is 90 degrees. This TIN model is reclassified to get the final raster based data layer for the feature slope. Figure 4.38 shows the slope details in the study area.

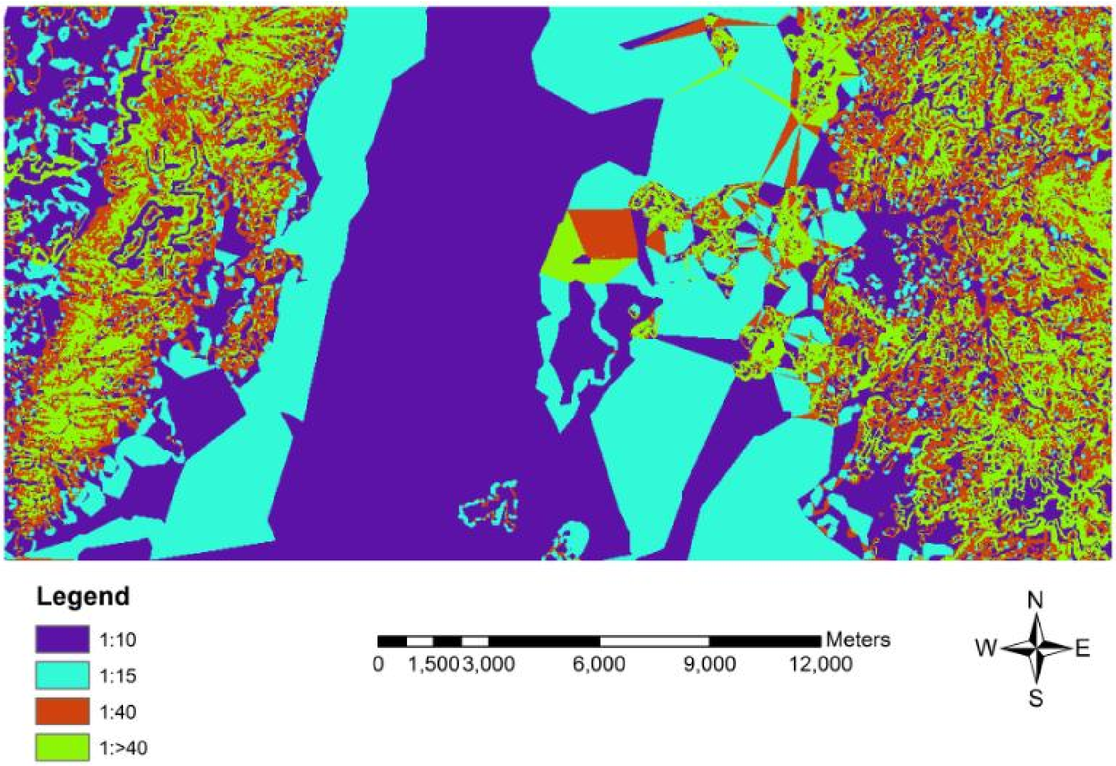

Figure 4.38: Slope rendering to NEPA Code

These final elevation and slope data layers will be incorporated in the final land suitability map generation for petrol filling station.

4.3.6 Utility Services

This criterion contains different types of utility services including high voltage transmission lines, water-supply lines, and oil/gas lines. All these types of utility services are important and petrol filling stations should be sited at a certain distance from such facilities. All these services are discussed in detail below.

4.3.6.1 High Voltage Transmission Lines

This data layer consists details of the high voltage transmission lines pass through the study area. The buffer suggested by the National Environment Protection Agency (NEPA) is 150 feet. Figure 4.39 shows the high voltage transmission line details in the study area provided with the suggested buffer distance.

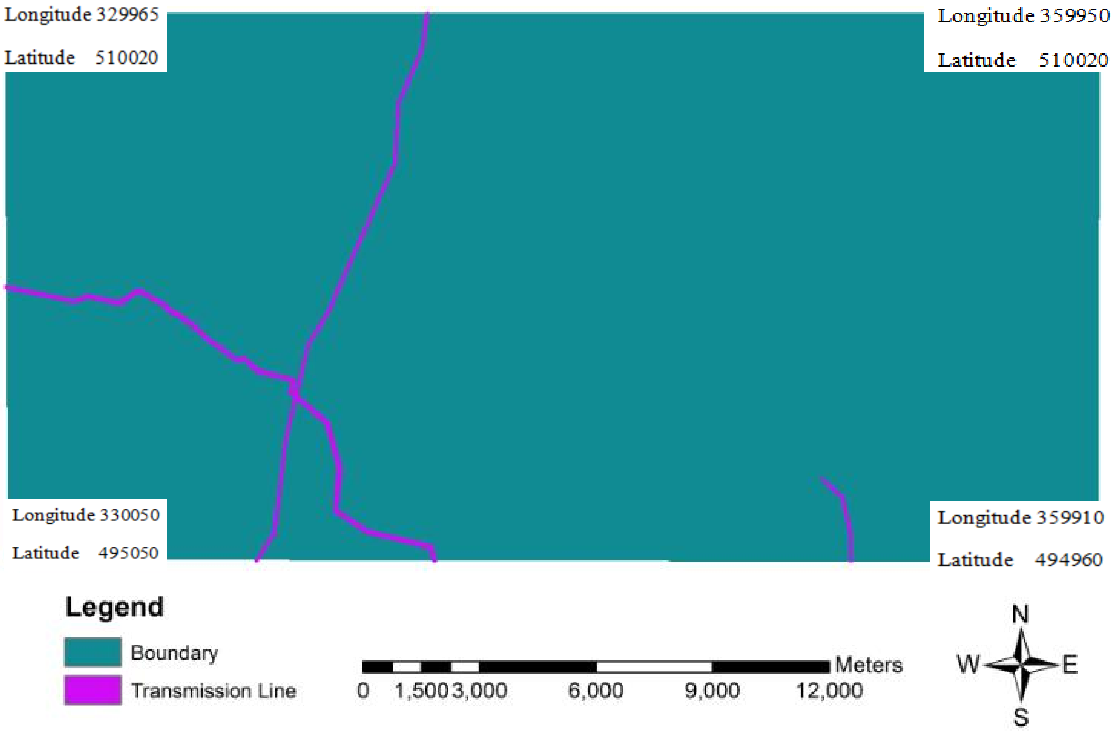

Figure 4.39: High Voltage Transmission Line with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.40.

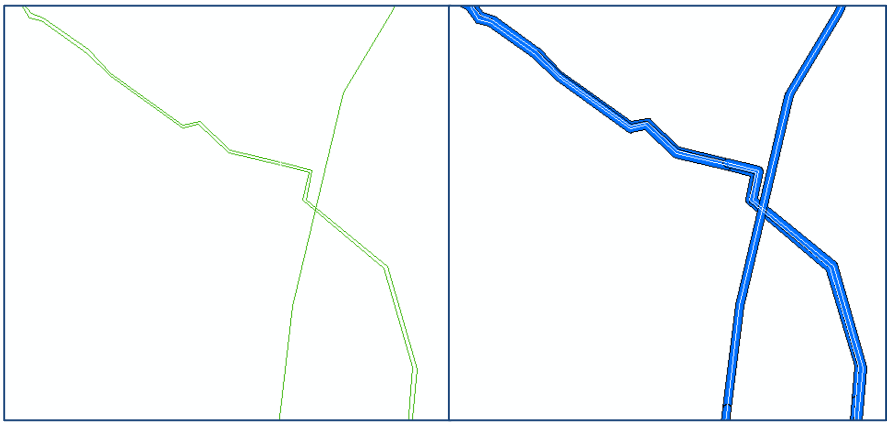

Figure 4.40: High Voltage Transmission Line Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the high voltage transmission lines are 494426 and the number of cells representing the occupancy of the existing high voltage transmission lines with the safe buffers are 4530. Hence, the suitable area for the development of the new petrol filling stations in accordance to high voltage transmission lines only is 44498 hectares whereas 408 hectares are the non-suitable land parcels in the study area.

4.3.6.2 Water Supply Lines

This data layer consists details of the main water supply lines pass through the study area. The buffer suggested by the National Environment Protection Agency (NEPA) is 33 feet. Figure 4.41 shows the main water supply line details in the study area provided with the suggested buffer distance.

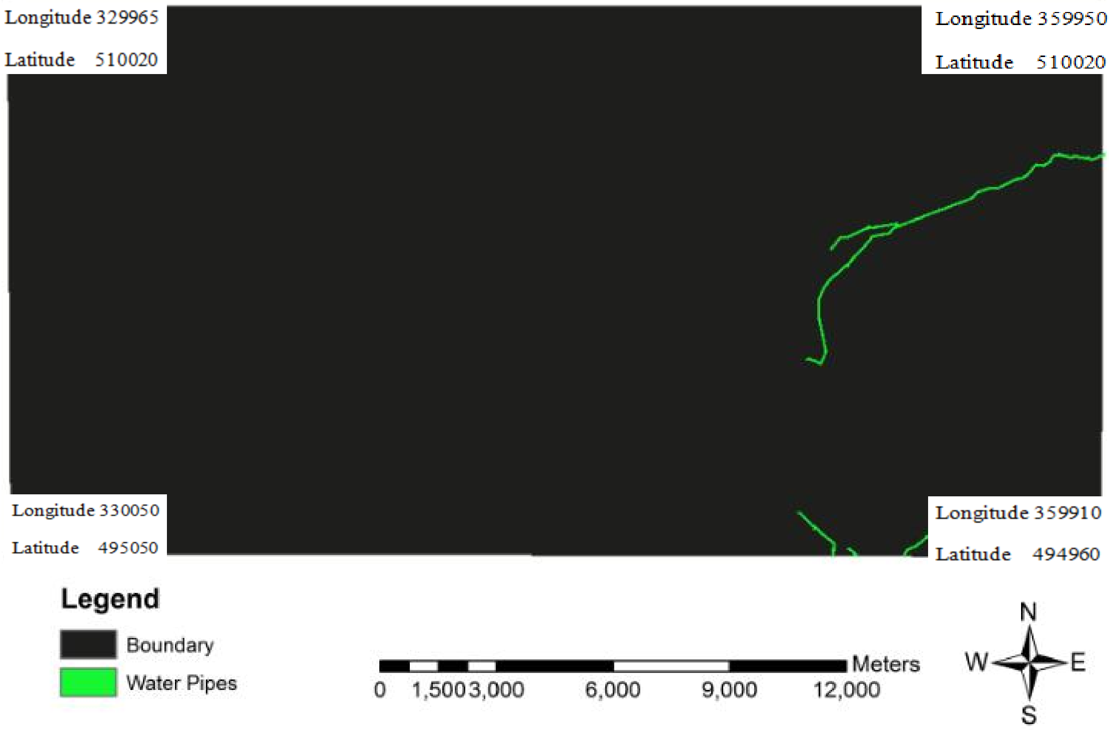

Figure 4.41: Water Pipes with Buffer using NEPA Code

The same land use feature has been zoomed in and its scenario before and after buffer placement has been shown in the Figure 4.42

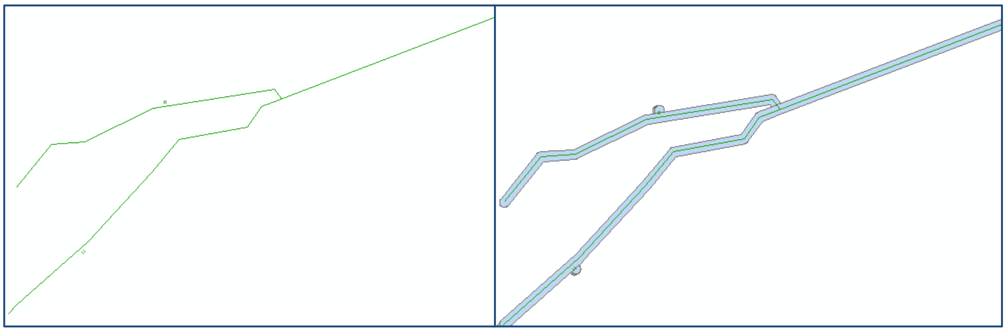

Figure 4.42: Water Pipes Before and After Buffer Placement

The number of cells representing the suitable land parcels with reference to the main water supply lines are 497964 and the number of cells representing the occupancy of the existing main water supply lines with the safe buffers are 1323. Hence, the suitable area for the development of the new petrol filling stations in accordance to main water supply lines only is 44817 hectares whereas 119 hectares are the non-suitable land parcels in the study area.

4.3.7 Final Land Suitability Map Generation for PFS Using National Environmental Protection Agency (NEPA) Code

This is the final phase of the analysis. All the data layers are prepared to get the final land suitability map. This is done by using the overlay technique to all the data layers using the weighted sum tool of the ArcGIS as shown in the Figure 4.43

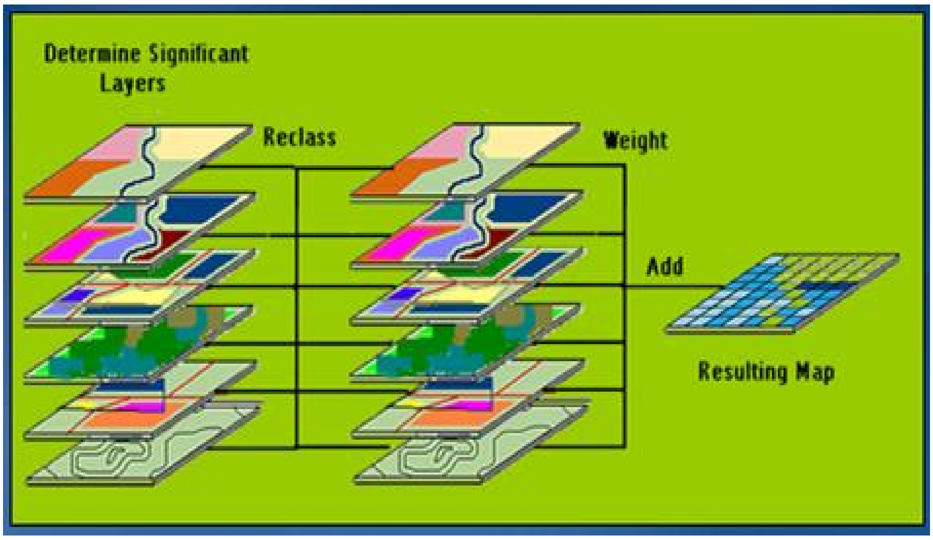

Figure 4.43: Overlay Technique

The final land suitability map for new petrol filling stations according to the code suggested by the National Environmental Protection Agency (NEPA), Jamaica is shown in the Figure. 4.44

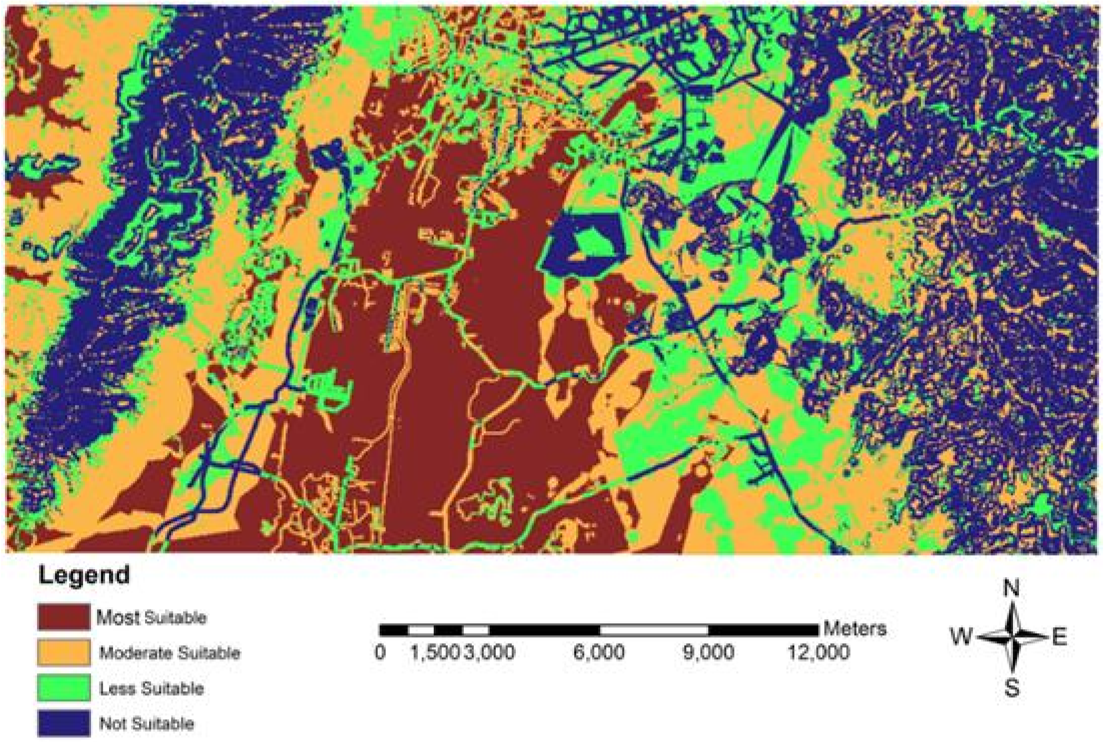

Figure 4.44: Final Land Suitability Map for PFS rendering to NEPA Code

To validate the above new land suitability map for petrol filling stations, the overlaying technique has been adopted. The data layer of existing petrol filling stations has been generated since their coordinates could be known. The coordinates were collected from the online available course provided by the Malaysian Geospatial Data Infrastructure (MyGDI). These coordinates were validated manually using the hand global positioning system (GPS). The coordinates of different random existing petrol filling stations have been collected using garmins hand GPSMAP76CX. This is done to check the validity of the data collected from MyGDI.

This new map, showing the details of the existing petrol filling stations, which have already got the approval for construction of petrol filling station from the City Planning Department, Ipoh. These petrol filling stations are supposed to pass the preliminary site suitability analysis and environmentally safe and feasible.

The validation of the newly generated land suitability map of petrol filling stations has been done on the basis of these already assessed petrol filling stations. Therefore, the map of existing petrol filling stations is overlaid with the new land suitability map as shown in the Figure 4.45

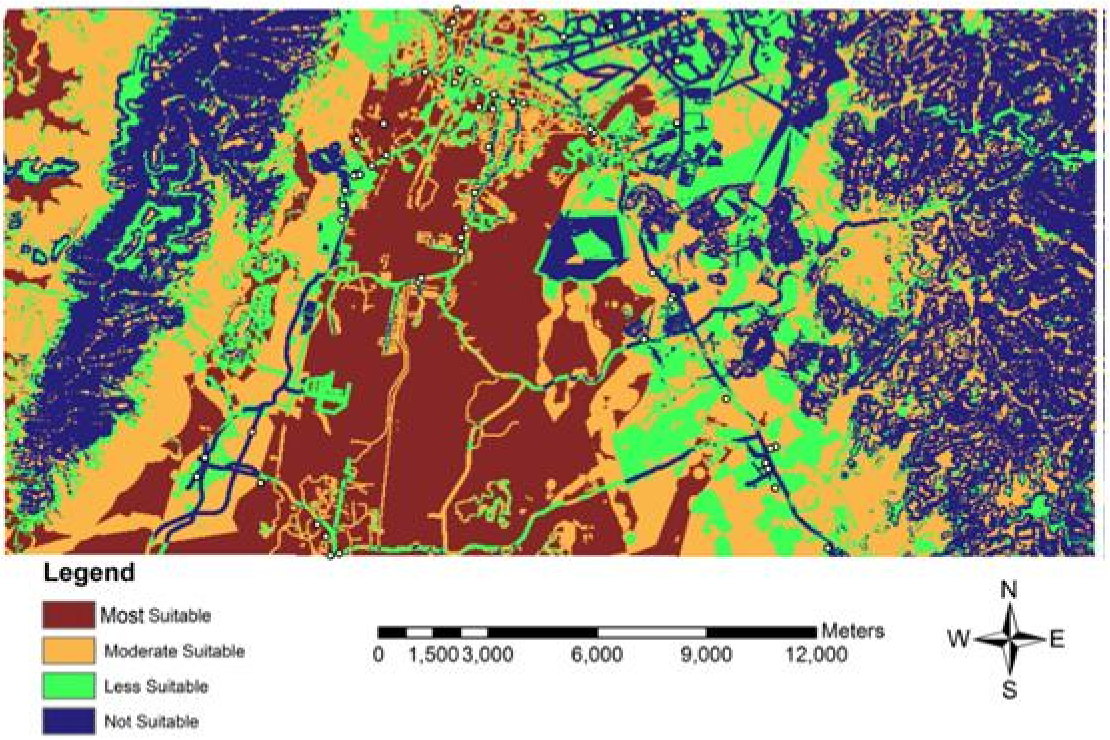

Figure 4.45: Land Suitability Map rendering to NEPA Code with Existing PFS

As mentioned earlier, there are total 62 existing petrol filling stations in the study area and there locations can be analyzed graphically from the above figure. The results of the above figure are presented in the following Table 4.4

Table 4.4: Land Suitability Index rendering to Existing PFS

S.No	Suitability Index	No: of PFS	Percentage Change
1	Most Suitable	17	27
2	Moderate Suitable	22	35
3	Less Suitable	14	23
4	Not Suitable	9	15
	Total No: of PFS	62	100

The results show that these are 17 petrol filling stations located in the most suitable zone, 22 in the moderately suitable zone, 14 in the less suitable zone and 9 in the not suitable zone. The percentage change can be clearly evident in the pie chart shown in the Figure 4.46

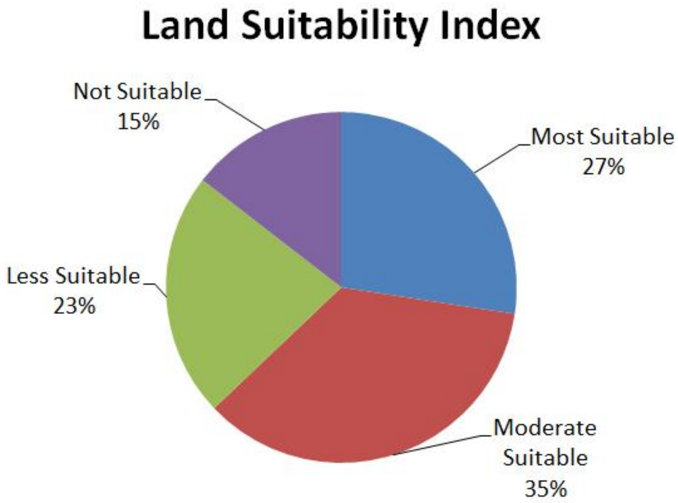

Figure 4.46: Land Suitability Index rendering to NEPA Code

It is observed that there is a sufficient percentage of the existing petrol filling stations situated in the suitable zone but still there are few petrol filling stations located in the non-suitable and less suitable zone. There is still 38% of the existing petrol filling stations located in non-satisfactory zone, which have the potential to cause the damage to our resources, which should be avoided.

4.4 Development of Land Suitability Map for PFS using Code Suggested by California City, USA

As mentioned earlier that there are criteria's and the sub criteria's considered for installing a new petrol filling station. Every criteria and sub criteria have got its importance, few are important to an environmental expert whereas others are important to a businessman. Therefore, the aggregated weights are analyzed earlier to incorporate in the final map. All these criteria's and sub criteria's data layers are shown in appendix E referring the code suggested by the Municipal Code, California City, USA.

4.4.1 Final Land Suitability Map Generation for PFS Using Municipal Code, California, USA

This is the final phase of the analysis. All the data layers are prepared to get the final land suitability map. This is done by using the overlaying technique to all the data layers using the weighted sum tool of the ArcGIS as done for the previous map. The Figure 4.47 shows the final land suitability map for new petrol filling stations according to the code suggested by the Municipal Code, California, USA.

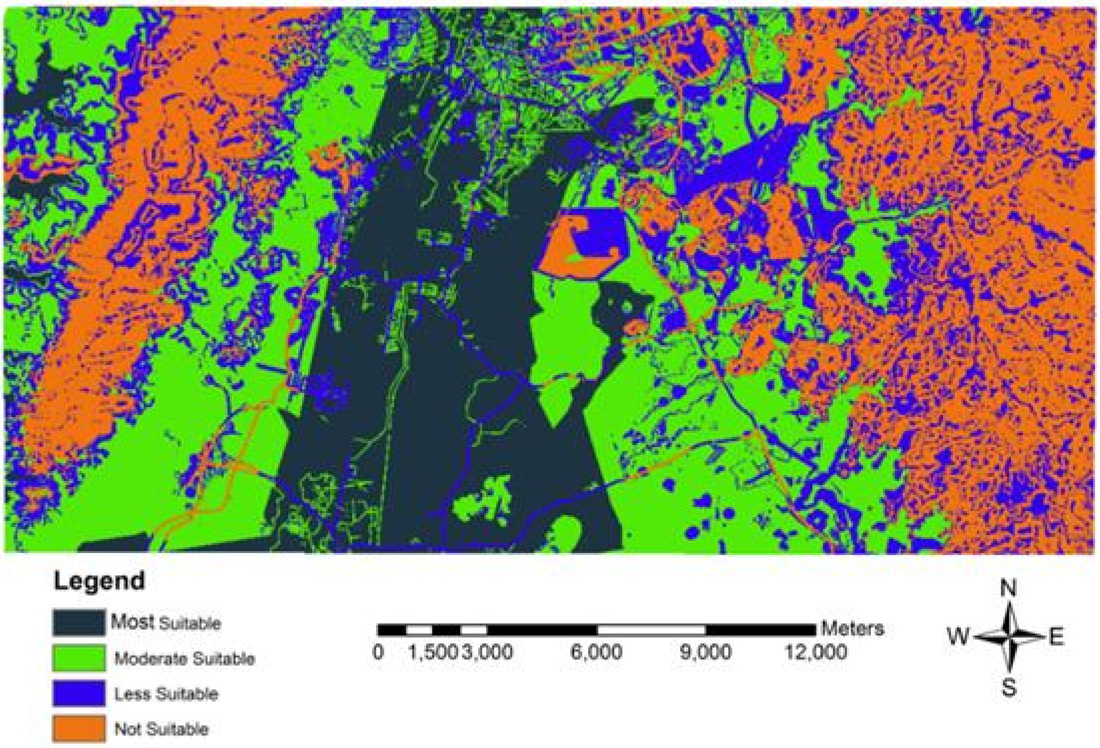

Figure 4.47: Final Land Suitability Map for PFS rendering to MCC, USA

To validate the above new land suitability map for petrol filling stations, the same overlaying technique is adopted as done for the validation of land suitability map generated using NEPA, Code. The validation of the newly generated land suitability map of petrol filling stations is carried out on the basis of these already assessed petrol filling stations. Therefore, the map of existing petrol filling stations is overlaid with the new land suitability map as shown in the Figure 4.48

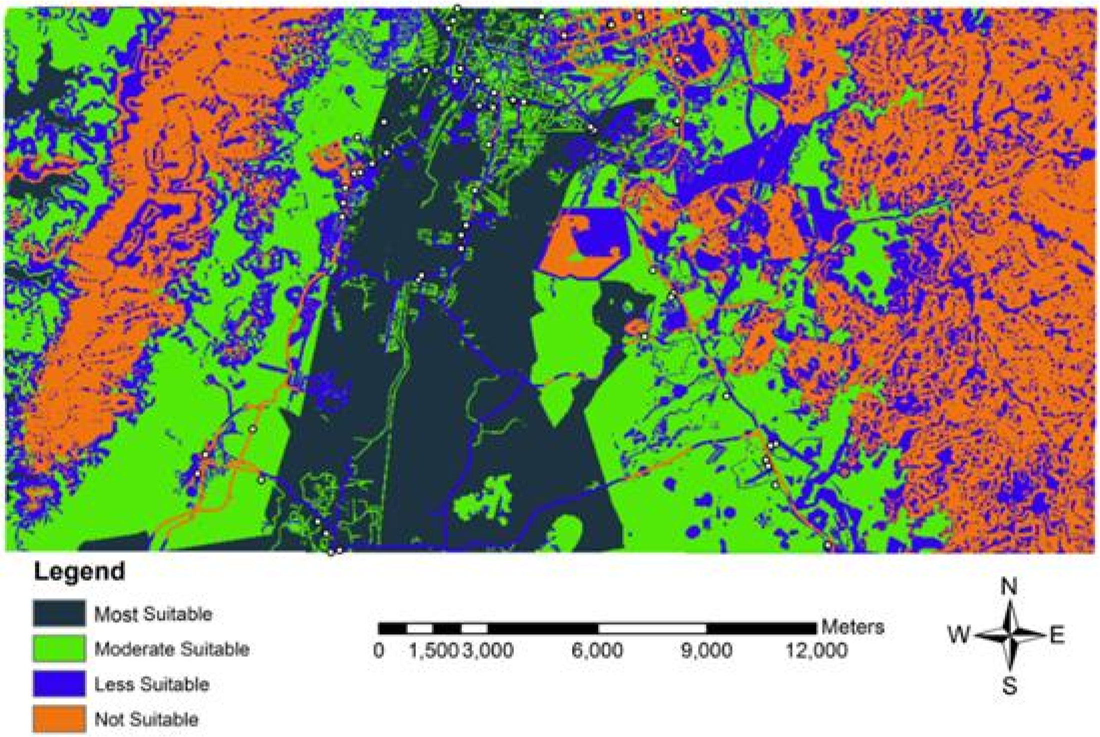

Figure 4.48: Land Suitability Map rendering to MCC, USA with Existing PFS

As mentioned earlier, there are total 62 existing petrol filling stations in the study area and there locations can be analyzed graphically from the above figure. The results of the above figure are presented in the following Table 4.5

Table 4.5: Land Suitability Index rendering to Existing PFS

S.No	Suitability Index	No: of PFS	Percentage Change
1	Most Suitable	25	40
2	Moderate Suitable	24	39
3	Less Suitable	9	15
4	Not Suitable	4	6
	Total No: of PFS	62	100

The results show that these are 25 petrol filling stations located in the most suitable zone, 24 in the moderately suitable zone, 9 in the less suitable zone and 4 in the not suitable zone. The percentage change can be clearly evident in the pie chart shown in the Figure 4.49

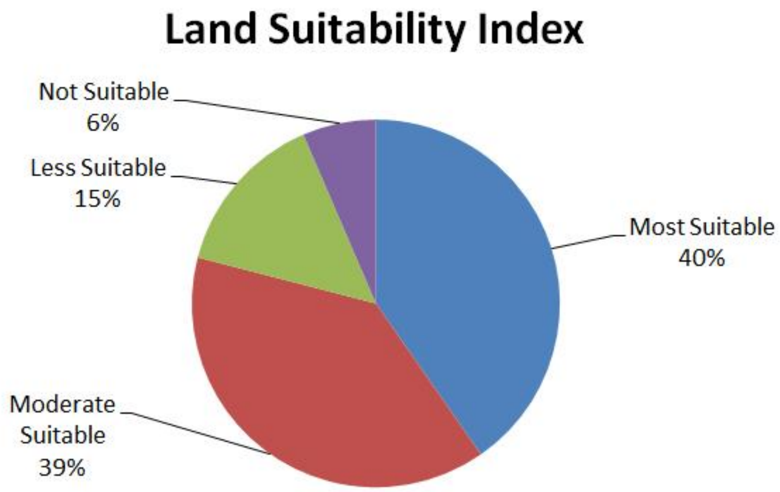

Figure 4.49: Land Suitability Index rendering to MCC, USA

It has been observed that there is a sufficient percentage of the existing petrol filling stations situated in the suitable zone but still there are few petrol filling stations located in the non-suitable and less suitable zone. There is still 21% of the existing petrol filling stations located in non-satisfactory zone, which have the potential to cause the damage to our resources, which should be avoided.

4.5 Development of Land Suitability Map for PFS using Code Suggested by the City Planning Department, Ipoh, Malaysia

As mentioned earlier that there are criteria's and the sub criteria's considered for the site selection of a new petrol filling station. Every criteria and sub criteria have got its importance, few are important to an environmental expert whereas others are important to a businessman. Therefore, the aggregated weights are analyzed earlier to incorporate in the final map. All these criteria's and sub criteria's data layers are shown in appendix E referring the code suggested by the City Planning Department, Ipoh, Malaysia

4.5.1 Final Land Suitability Map Generation for PFS using the City Planning Department, Code, Ipoh, Malaysia

This is the final phase of the analysis. All the data layers are prepared to get the final land suitability map. This is done by using the overlay technique to all the data layers using the weighted sum tool of the ArcGIS as done for the previous map. The Figure 4.50 shows the final land suitability map for new petrol filling stations according to the code suggested by the City Planning Department, Ipoh, Malaysia.

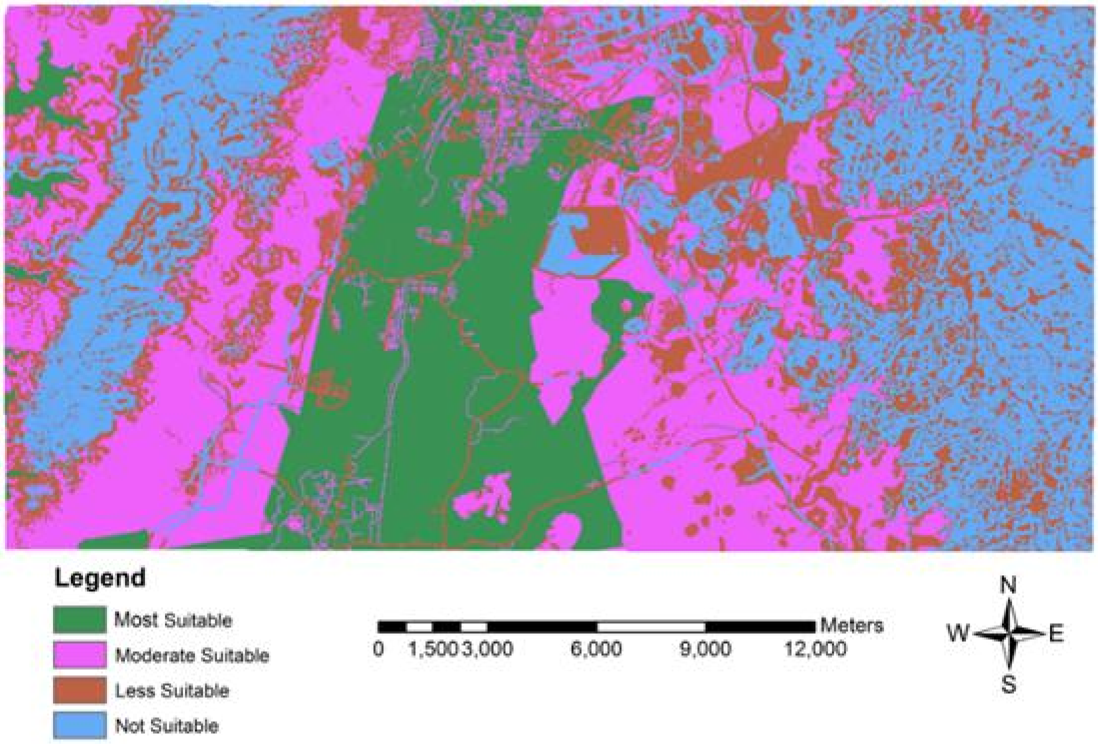

Figure 4.50: Final Land Suitability Map for PFS rendering to CPD Code, Ipoh

To validate the above new land suitability map for petrol filling stations, the same overlaying technique is adopted as done for the validation of land suitability map generated using Municipal code, USA. The validation of the newly generated land suitability map of petrol filling stations is carried out on the basis of these already assessed petrol filling stations. Therefore, the map of existing petrol filling stations is overlaid with the new land suitability map as shown in the Figure 4.51

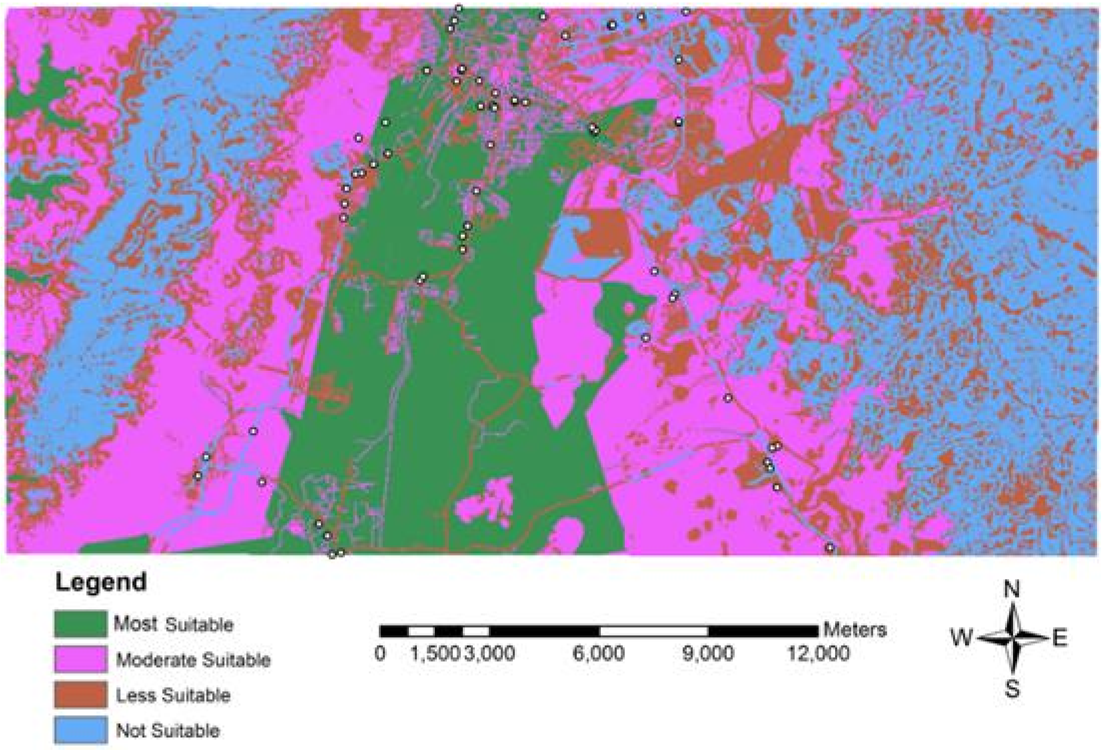

Figure 4.51: Land Suitability Map rendering to CPD Code, Ipoh with Existing PFS

As mentioned earlier, there are total 62 existing petrol filling stations in the study area and there locations can be analyzed graphically from the above figure. The results of the above figure are presented in the following Table 4.6

Table 4.6: Land Suitability Index rendering to Existing PFS

S.No	Suitability Index	No: of PFS	Percentage Change
1	Most Suitable	26	42
2	Moderate Suitable	20	32
3	Less Suitable	11	18
4	Not Suitable	5	8
	Total No: of PFS	62	100

The results show that there are 26 petrol filling stations located in the most suitable zone, 20 in the moderately suitable zone, 11 in the less suitable zone and 5 in the not suitable zone. The percentage change can be clearly evident in the pie chart shown in the Figure 4.52

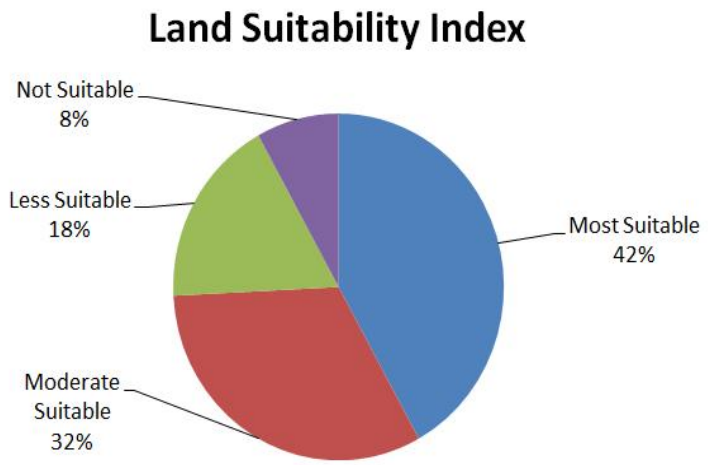

Figure 4.52: Land Suitability Index rendering to CPD, Code

It is observed that there is a sufficient percentage of the existing petrol filling stations situated in the suitable zone but still there are few petrol filling stations located in the non-suitable and less suitable zone. There is still 26% of the existing petrol filling stations located in non-satisfactory zone, which have the potential to cause the damage to our resources, which should be avoided.

4.6 Summary of the Results

Table 4.7 shows the overall results of the suitability index generated by using this EIA-based GIS approach for land suitability of petrol filling stations.

Table 4.7: Combined Results of Suitability Index

S.No	Suitability Index	No: of PFS (NEPA)	No: of PFS (MCC)	No: of PFS (CPD)
1	Most Suitable	17	25	26
2	Moderate Suitable	22	24	20
3	Less Suitable	14	9	11
4	Not Suitable	9	4	5
	Total No: of PFS	62	62	62

Though the results show most of the petrol filling station location in the most suitable and moderately suitable zones but still there are few petrol filling stations, which are in the less suitable and non-suitable zones. For a green environment, one can't neglect this issue. Hence, this problem should need attention.

It is obvious that there is a clear variance in the results. There is a close relation to the results of the city planning department, Ipoh and municipal code for California. Whereas, it is clear that the NEPA code has a certain incongruity with the other two codes. The reason behind this approach is that the buffers suggested by NEPA have higher value than the other two codes meaning that NEPA is more sophisticated and deals a safer approach towards the land suitability of petrol filling stations. It is good approaches to site such facilities at certain distance otherwise a small piece of mistake or negligence may lead to the damage of natural resources and environment. Whereas, as stated earlier that there is a significant relation among the code suggested by city planning department, Ipoh, Malaysia and municipal code, California, USA. The reason behind this approach is there significant closer buffer values. Both are offering less buffer distance therefore there are higher numbers of petrol filling stations on risk.

This new EIA-based GIS approach for land suitability approach is the way out for such land suitability problems. This approach of land suitability will assist the sites for installing new petrol filling stations, which will be environmentally sound and feasible. This approach should be implemented in the planning and governing departments to assist the sites for proposed petrol filling stations in future.

CHAPTER 5

CONCLUSION

5.1 Conclusion

A sustainable approach to the natural environment protection remains the topic of interest for the developers. There has been a growing concern that development activities have the potential to cause severe damage to the environment. Development activities like industries, high speed railway projects, airports, high rise buildings, retail petrol filling station, commercial centers, and high tech laboratories can cause damage to the natural resources including soil contamination, environmental pollution, water pollution and etc. if they were not planned and sited properly.

These days one of the main concerns of transportation planners is inter-city communications and the rapid growth in urbanization offered an ample demand for vehicles which results, more fuel consumption. A petrol filling station is the place, which caters this fuel needs. A petrol filling station is no doubt a very important but it has high potential of hazards, resulting the degradation and contamination of the natural resources like environmental, hydrological, geological and socioeconomic hazards. The land suitability analysis became complex because there are a number of factors involved in land selection process. The location of petrol filling stations could influence human life tremendously, and even minor biases in selecting the location could lead to remediable losses.

Therefore, site selection is one of the most important aspects of success for any business project. The petrol retail industry and the relevant authority have become increasingly aware of the environmental issues and its impact on the global environment. Environmental protection agencies are seeking to incorporate sound environmental policies. Thus EIA was introduced as an effective planning and management tool, which assists the environmental and socioeconomic viability of the new proposed development projects.

EIA entails the examination, analysis and assessment of planned activities in order to ensure them environmentally sound and sustainable for the proposed new development projects. It has been observed that EIA studies for land suitability process is a time and cost consuming job. However, the previous site suitability approaches alone could not meet the need of land suitability analysis in decision making of selecting a site for the new petrol filling station.

Thus, this study provides an integrated EIA-based GIS land suitability model using Analytic Hierarchy Process (AHP) as a Multi Criteria Decision Making (MCDM) approach for viable site selection of the new petrol filling stations. A case study has been conducted to develop and validate the theoretical approach into the practical end.

The results of this EIA-based GIS model shows that some existing locations of petrol filling stations are not in the suitable zone. Yet, there is a gap in the existing approach, which should be improved. This study has highlighted this gap clearly and provided a sustainable solution to deal with such land suitability problems in future. The results of this case study shows that in Ipoh, they are 74% of the total existing petrol filling stations in the satisfactory zone but still there are 26% of the total existing petrol filling stations, which are not located in the satisfactory zone. The results of municipal codes of California shows that they are 79% of the total existing petrol filling stations in the satisfactory zone but still there are 21% of the total existing petrol filling stations, which are not located in the satisfactory zone. The results of national environmental protection agency shows that they are 62% of the total existing petrol filling stations in the satisfactory zone but still there are 38% of the total existing petrol filling stations, which are not located in the satisfactory zone.

A comparative study is also carried out to analyze the performance of the codes suggested by governmental agencies of the different countries including City Planning Department, Ipoh, Malaysia; Municipal code for California city, USA and

National Environmental and Protection Agency, Jamaica. The reason to select these particular three codes is the availability and open sourced.

The results show that there is a close significance in the codes of City Planning Department, Ipoh and Municipal Code for California City, USA, because they are suggesting a lower buffer value. However, National Environmental and Protection Agency, Jamaica are suggesting the higher values for the buffers, which should be adopted for green and safe Malaysia.

5.2 Recommendations for Future Work

It is recommended that the City Planning Department, Ipoh and Department of Environment, Malaysia are suggested to implement this model to assist the land suitability for the new petrol filling stations. It is also suggested to implement EIA for the assessment of the location of petrol filling stations if the model can't be implemented due to unforeseen reasons. Such facilities should be given focus because they can influence human life terrifically, and even minor biases in selecting the location could lead to remediable losses as most of the petrol filling stations are located in the city centers. This model will prove to be a contribution in the developed Malaysia, 2020.

This EIA-based GIS model of land suitability analysis can be extended in the future for the land suitability analysis of the other development activities including construction of new airports, heavy industries, infrastructure development, mining, ports and petroleum industry. This study has focused on the factors considered in an EIA. However this study be extended to Strategic Environmental Assessment (SEA), which is the advance level of EIA. GIS-based modeling will be a more appropriate approach towards spatial problems so it should be implemented as an important element for such land suitability problems.

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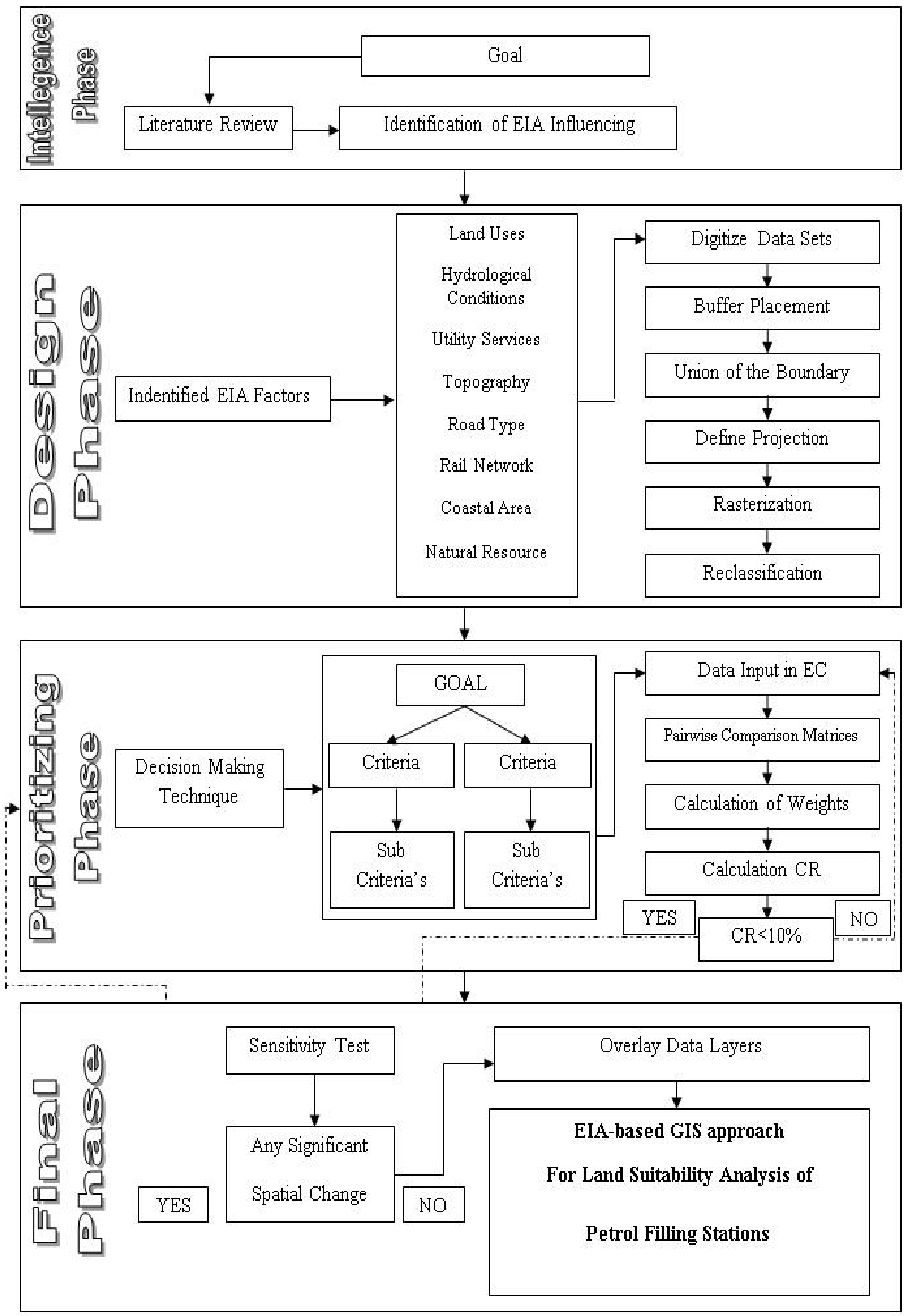
APPENDIX A

RESEARCH FLOW


Intellegence Phase
Goal
Literature Review
Identification of EIA Influencing
Design Phase
Indentified EIA Factors
Land Uses
Hydrological Conditions
Utility Services
Topography
Road Type
Rail Network
Coastal Area
Natural Resource
Digitize Data Sets
Buffer Placement
Union of the Boundary
Define Projection
Rasterization
Reclassification
Prioritizing Phase
Decision Making Technique
GOAL
Criteria
Criteria
Sub Criteria's
Sub Criteria's
Data Input in EC
Pairwise Comparison Matrices
Calculation of Weights
Calculation CR
YES
CR<10%
NO
Final Phase
Sensitivity Test
Any Significant Spatial Change
YES
NO
Overlay Data Layers
EIA-based GIS approach
For Land Suitability Analysis of
Petrol Filling Stations

APPENDIX B

QUESTIONNAIRE

Dear Respondent,

The Civil Engineering Department of **Universiti Teknologi PETRONAS** (UTP) is conducting a study on "EIA based GIS-Approach for Land Suitability Analysis of Petrol Filling Stations": A case study of Ipoh city, Perak, Malaysia.

It is analyzed that sustainability of development projects socio-economically and environmentally is a major challenging issue for developing countries. The recent rapid growth of urbanization has created greater demand for vehicles on road and shaded its results in more fuel consumption, hence increased number of petrol filling stations. A petrol filling station is an important but meanwhile it's a hazardous facility so it needs special attention for site selection.

Environmental Impact Assessment (EIA) study is carried out before construction of such hazardous facilities, where as it is found that EIA cannot meet alone the need of land suitability analysis in decision making of proposed site for a new project. Geographical Information System (GIS) is widely & successfully used tool to solve the spatial problems. So an integrated EIA based GIS modeling would be more effective for land suitability analysis of such development projects.

In this regard, this set of questions is designed to complete this study. It will take 20 minutes to fill the questionnaire. You are requested to fill this questionnaire and send it back within 2 weeks of time. Your response & time is greatly appreciated and this data will be used for academic purpose only.

Your Sincerely

Shabir Hussain Khahro
MSc Research student, UTP
H/No: 0060149033008
Email:shkhahro@gmail.com

Supervisor:

Dr. Abd Nasir Bin Matori
Associate Professor, Civil Engineering Department
Universiti Teknologi PETRONAS, Tronoh, Perak, Malaysia.

<table>
<tr><td colspan="9">Respondent Profile</td></tr>
<tr><td>Name</td><td colspan="8"></td></tr>
<tr><td>Gender
(Please Tick)</td><td colspan="2">Male</td><td colspan="2"></td><td colspan="2">Female</td><td colspan="2"></td></tr>
<tr><td>Age</td><td colspan="6"></td><td colspan="2">Years</td></tr>
<tr><td>Highest Degree
(Please Tick)</td><td>Bachelors</td><td></td><td>Masters</td><td></td><td>PhD</td><td></td><td>Others</td><td></td></tr>
<tr><td>Profession</td><td colspan="8"></td></tr>
<tr><td rowspan="3">Organization/
Institution/
Company

(Please Tick)</td><td colspan="4" rowspan="3"></td><td colspan="2">Public Sector</td><td colspan="2"></td></tr>
<tr><td colspan="2">Private Sector</td><td colspan="2"></td></tr>
<tr><td colspan="2">Others</td><td colspan="2"></td></tr>
<tr><td>Working
Experience</td><td colspan="6"></td><td colspan="2">Years</td></tr>
</table>

Instructions:

This questionnaire is designed to rank the criteria/sub criteria by using Analytical Hierarchy Process (AHP) technique. In this regard, you are requested to rank the factors by using the following pairwise comparison scale shown in Table 1.

Table 1: Scale for pairwise comparison

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between adjacent scale values

Referring to the above scale, please compare two factors in each table below as a pair, select one that is more important than the other and Bold/Underline the corresponding ranking number.

Example.1

Two factors are given below in a pairwise comparison manner according to AHP. If in your opinion "Land Use" is of strong importance than "Accessibility" for land suitability of new petrol filling station, now the rank assigned to strong importance is 5 in the pairwise comparison scale, finally Bold/Underline number 5 in the following table towards Land use.

Land Use	9	7	**5**	3	1	3	5	7	9	Accessibility

And if in your opinion "Accessibility" is of strong importance than "Land Use" for land suitability of new petrol filling station, now the rank assigned to strong importance is 5 in the pairwise comparison scale, finally Bold/Underline number 5 in the following table towards Accessibility.

Land Use	9	7	5	3	1	3	**5**	7	9	Accessibility

And if in your opinion "Accessibility" is of equal importance than "Land Use" for land suitability of new petrol filling station, now the rank assigned to equal importance is 1 in the pairwise comparison scale, finally Bold/Underline number 1 in the following table.

Land Use	9	7	5	3	**1**	3	5	7	9	Accessibility

Phase One - Criteria

Please rank the following six criteria's, which are more prior/important to other for the land suitability of a petrol filling station and bold/underline the weight given in the scale.

A. Land Use
   Land use criteria includes residential zone, educational zone, health caring zone, commercial zone, industrial zone, religious buildings zone, historical buildings zone, parks and playgrounds from a petrol filling station.

B. Accessibility
   Accessibility/reach of a petrol filling station from different types of transportation modes includes roads, railways, airports and jetties

C. Hydrological Conditions
   Protection of the hydrological feature includes sea water, rivers and lakes.

D. Natural Environment
   Protection of natural resources includes forest and vacant land.

E. Topography
   Importance of contour levels to install a new petrol filling station.

F. Utility Services
   Protection of different utility services includes high voltage transmission electric lines, gas/oil lines and water pipes.

A	Land Use	9	7	5	3	1	3	5	7	9	Accessibility	B
A	Land Use	9	7	5	3	1	3	5	7	9	Hydrological Conditions	C
A	Land Use	9	7	5	3	1	3	5	7	9	Natural Environment	D
A	Land Use	9	7	5	3	1	3	5	7	9	Topography	E
A	Land Use	9	7	5	3	1	3	5	7	9	Utility Services	F

B	Accessibility	9	7	5	3	1	3	5	7	9	Hydrological Conditions	C
B	Accessibility	9	7	5	3	1	3	5	7	9	Natural Environment	D
B	Accessibility	9	7	5	3	1	3	5	7	9	Topography	E
B	Accessibility	9	7	5	3	1	3	5	7	9	Utility Services	F

C	Hydrological Conditions	9	7	5	3	1	3	5	7	9	Natural Environment	D
C	Hydrological Conditions	9	7	5	3	1	3	5	7	9	Topography	E
C	Hydrological Conditions	9	7	5	3	1	3	5	7	9	Utility Services	F

D	Natural Environment	9	7	5	3	1	3	5	7	9	Topography	E
D	Natural Environment	9	7	5	3	1	3	5	7	9	Utility Services	F

E	Topography	9	7	5	3	1	3	5	7	9	Utility Services	F

Phase Two – Sub criteria

Please rank the following sub-criteria's, which are more prior/important to other for the land suitability of petrol filling station and bold/underline the weight given in the scale.

A. Land Use

Following are the different land use zones. Please rank the following factors on the basis of protection of land uses from installation of a new petrol filling station.

A1. Residential Zone
A2. Educational Zone
A3. Health Caring Zone

A4. Commercial Zone
A5. Industrial Zone
A6. Religious Buildings
A7. Historical Buildings
A8. Parks and Playgrounds

A1	Residential Zone	9	7	5	3	1	3	5	7	9	Educational Zone	A2
A1	Residential Zone	9	7	5	3	1	3	5	7	9	Health Caring Zone	A3
A1	Residential Zone	9	7	5	3	1	3	5	7	9	Commercial Zone	A4
A1	Residential Zone	9	7	5	3	1	3	5	7	9	Industrial Zone	A5
A1	Residential Zone	9	7	5	3	1	3	5	7	9	Religious Buildings	A6
A1	Residential Zone	9	7	5	3	1	3	5	7	9	Historical Buildings	A7
A1	Residential Zone	9	7	5	3	1	3	5	7	9	Parks and Playgrounds	A8

A2	Educational Zone	9	7	5	3	1	3	5	7	9	Health Caring Zone	A3
A2	Educational Zone	9	7	5	3	1	3	5	7	9	Commercial Zone	A4
A2	Educational Zone	9	7	5	3	1	3	5	7	9	Industrial Zone	A5
A2	Educational Zone	9	7	5	3	1	3	5	7	9	Religious Buildings	A6
A2	Educational Zone	9	7	5	3	1	3	5	7	9	Historical Buildings	A7
A2	Educational Zone	9	7	5	3	1	3	5	7	9	Parks and Playgrounds	A8

A3	Health Caring Zone	9	7	5	3	1	3	5	7	9	Commercial Zone	A4
A3	Health Caring Zone	9	7	5	3	1	3	5	7	9	Industrial Zone	A5
A3	Health Caring Zone	9	7	5	3	1	3	5	7	9	Religious Buildings	A6
A3	Health Caring Zone	9	7	5	3	1	3	5	7	9	Historical Buildings	A7
A3	Health Caring Zone	9	7	5	3	1	3	5	7	9	Parks and Playgrounds	A8

A4	Commercial Zone	9	7	5	3	1	3	5	7	9	Industrial Zone	A5
A4	Commercial Zone	9	7	5	3	1	3	5	7	9	Religious Buildings	A6
A4	Commercial Zone	9	7	5	3	1	3	5	7	9	Historical Buildings	A7
A4	Commercial Zone	9	7	5	3	1	3	5	7	9	Parks and Playgrounds	A8

A5	Industrial Zone	9	7	5	3	1	3	5	7	9	Religious Buildings	A6
A5	Industrial Zone	9	7	5	3	1	3	5	7	9	Historical Buildings	A7
A5	Industrial Zone	9	7	5	3	1	3	5	7	9	Parks and Playgrounds	A8

A6	Religious Buildings	9	7	5	3	1	3	5	7	9	Historical Buildings	A7
A6	Religious Buildings	9	7	5	3	1	3	5	7	9	Parks and Playgrounds	A8

A7	Historical Buildings	9	7	5	3	1	3	5	7	9	Parks and Playgrounds	A8

B. Accessibility

Following are the different modes of transportation. Please rank the following factors on the basis of accessibility/reach from a new petrol filling station.

B1. Dual Highway
B2. Primary Road
B3. Secondary Road
B4. Railway
B5. Airport

B1	Dual Highway	9	7	5	3	1	3	5	7	9	Primary Road	B2
B1	Dual Highway	9	7	5	3	1	3	5	7	9	Secondary Road	B3
B1	Dual Highway	9	7	5	3	1	3	5	7	9	Railway	B4
B1	Dual Highway	9	7	5	3	1	3	5	7	9	Airport	B5

B2	Primary Road	9	7	5	3	1	3	5	7	9	Secondary Road	B3
B2	Primary Road	9	7	5	3	1	3	5	7	9	Railway	B4
B2	Primary Road	9	7	5	3	1	3	5	7	9	Airport	B5

B3	Secondary Road	9	7	5	3	1	3	5	7	9	Railway	B4
B3	Secondary Road	9	7	5	3	1	3	5	7	9	Airport	B5

B4	Railway	9	7	5	3	1	3	5	7	9	Airport	B5

C. Hydrological Conditions

Following are the different hydrological conditions. Please rank the following factors on the basis of protection of hydrological components from installation of a new petrol filling station.

C1. River

C3. Lake

C2	River	9	7	5	3	1	3	5	7	9	Lake	C3

D. Natural Environment

Following are the different components of natural resources. Please rank the following factors on the basis of preferable land parcel to install a new petrol filling station so as to save the natural resources.

D1. Vacant Land

D2. Forest

D1	Vacant Land	9	7	5	3	1	3	5	7	9	Forest	D2

E. Topography

Following are the different topographical conditions. Please rank the following factors on the basis of preferable contour level to install a new petrol filling station.

E1. Slope

E2. Elevation

E1	Slope	9	7	5	3	1	3	5	7	9	Elevation	E2

F. Utility Services

Following are the different modes of utility services. Please rank the following factors on the basis of protection of these utility services from installation of a new petrol filling station.

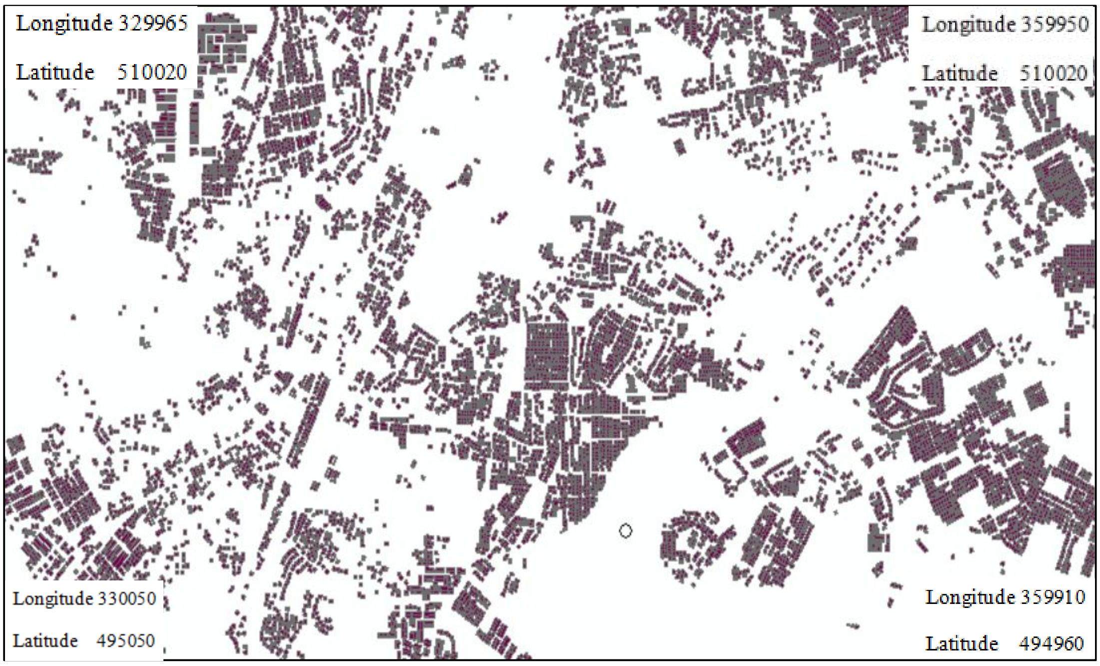
F1. High Voltage Transmission Electric Lines

F2. Water Pipes

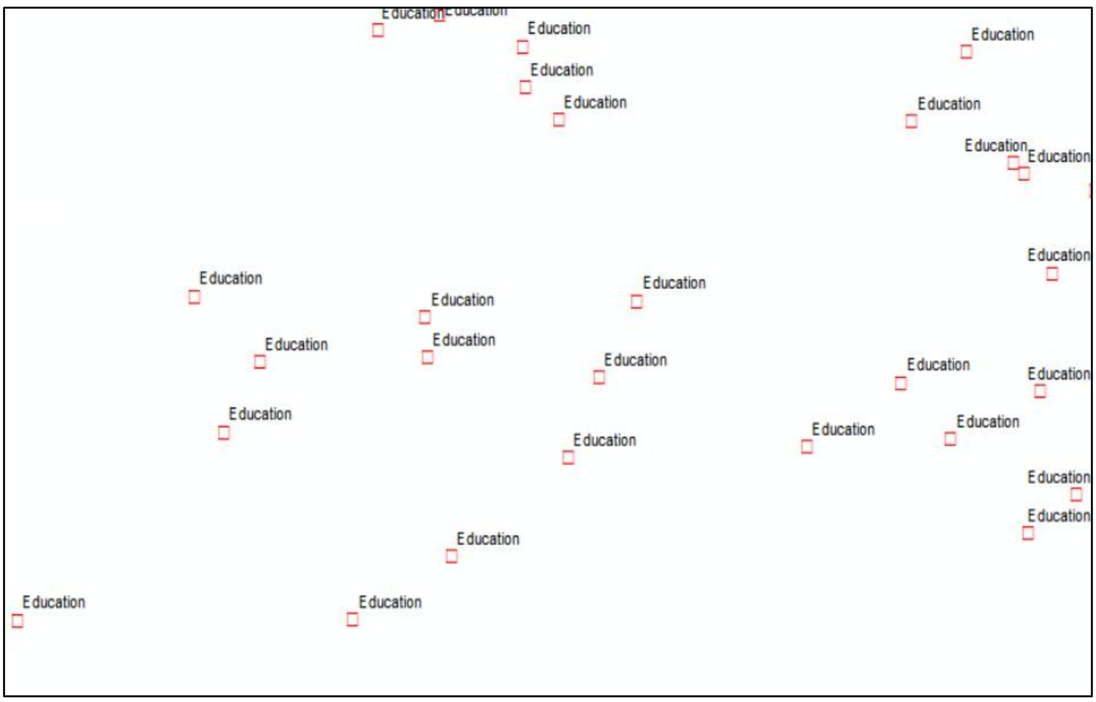
F1	Electric Lines	9	7	5	3	1	3	5	7	9	Water Pipes	F2

APPENDIX C

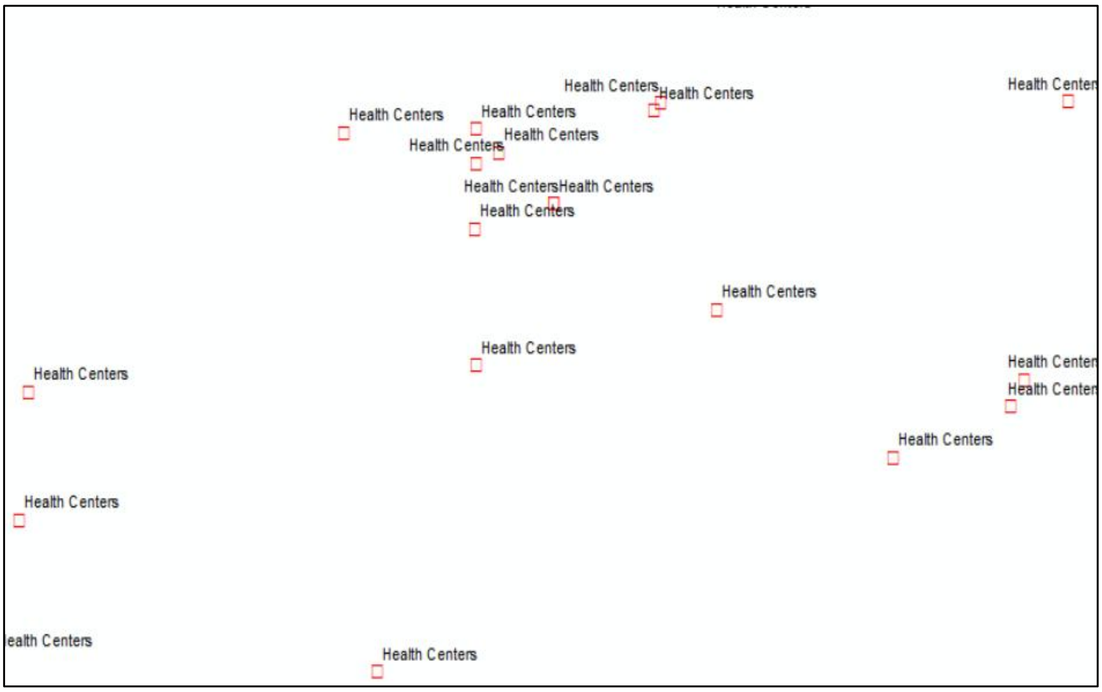
RAW DATA COLLECTED FROM MAPPING AND SURVEYING DEPARTMENT, MALAYSIA



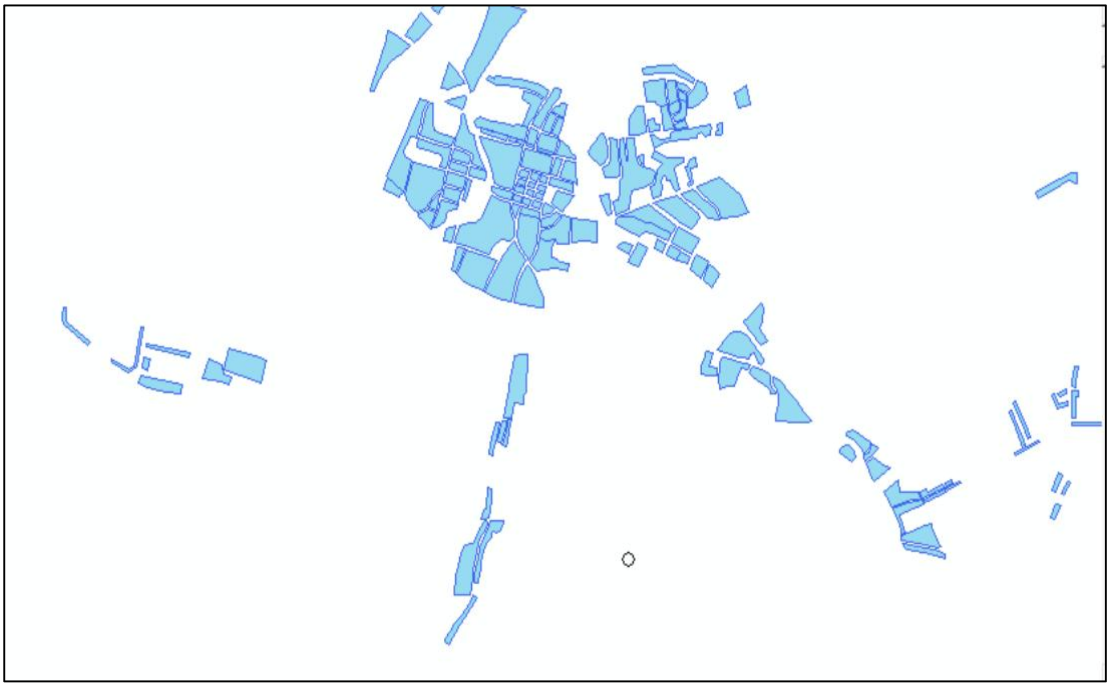
Residential Data Layer



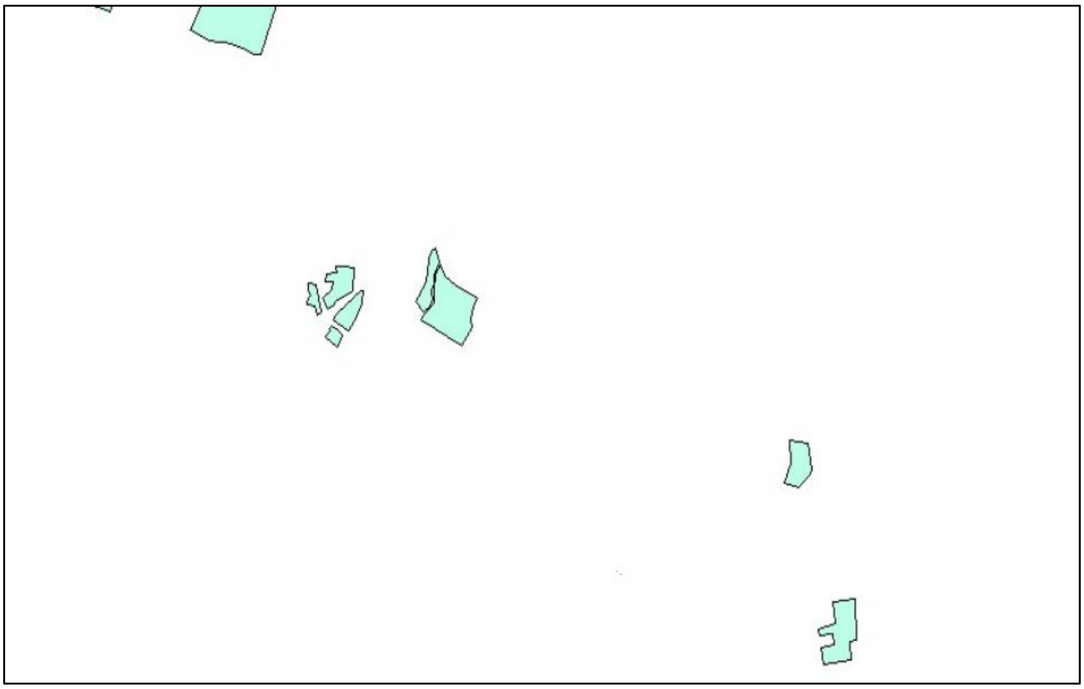
Educational Data Layer



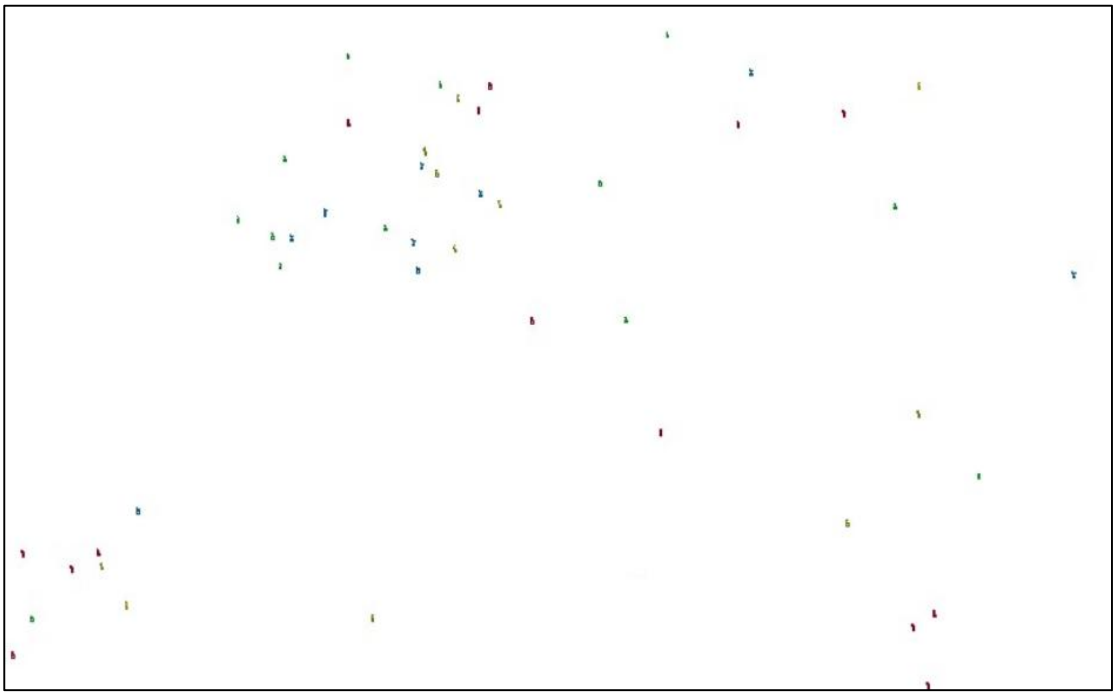
Health Care Facilities Data Layer



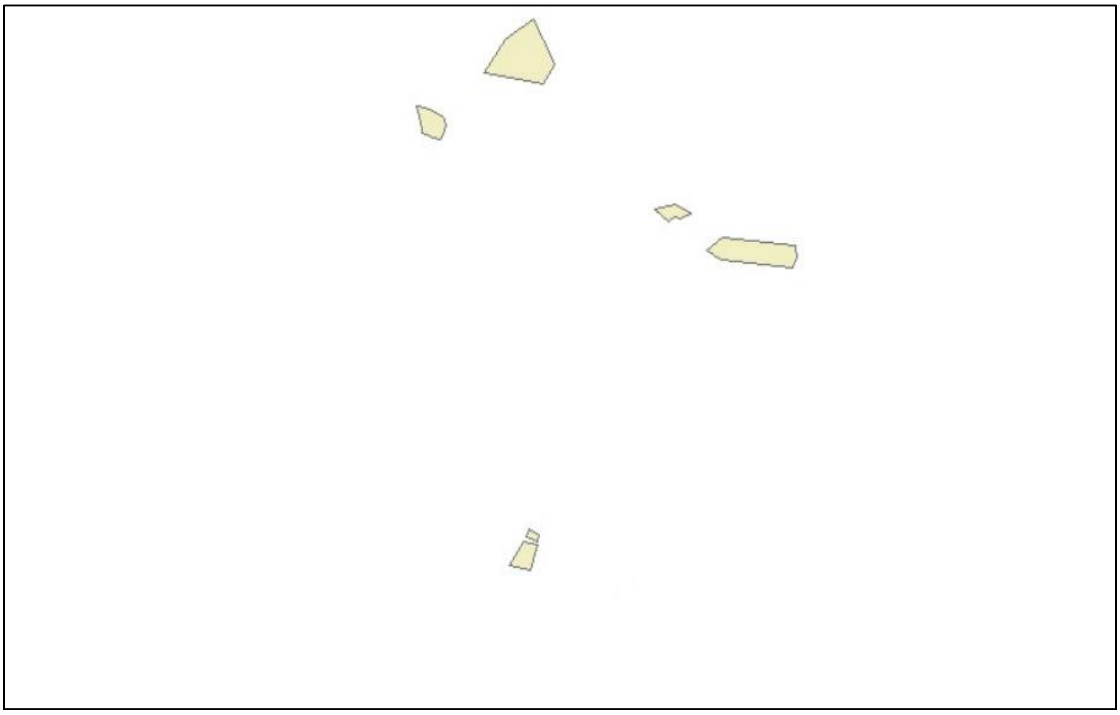
Commercial Places Data Layer



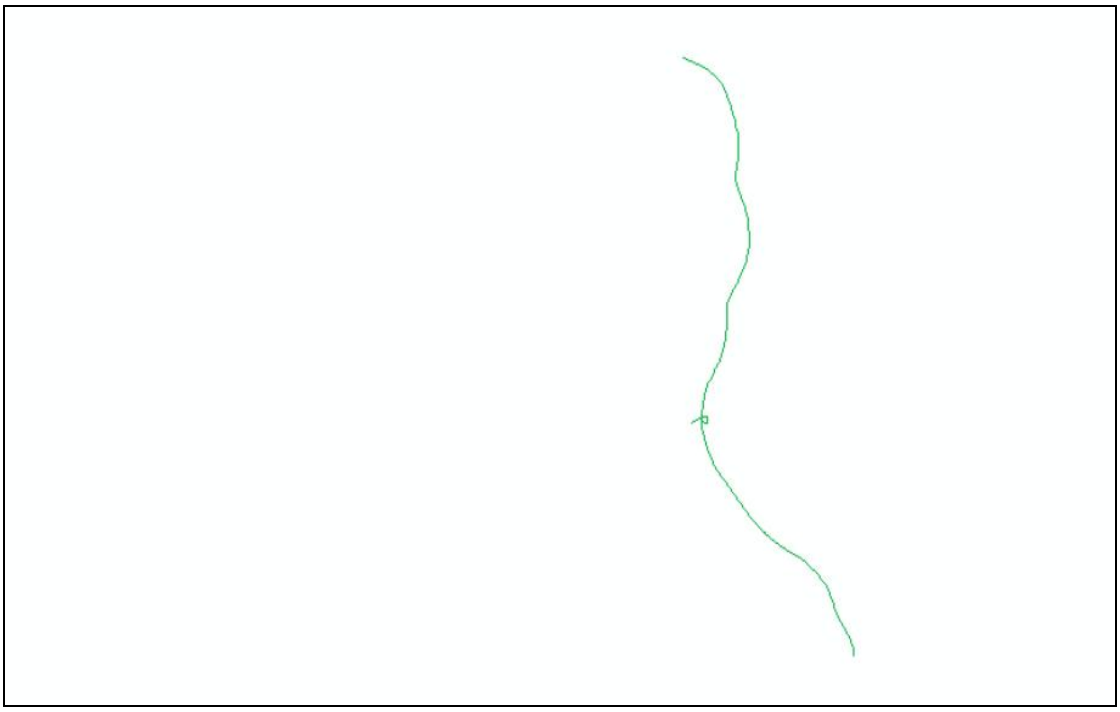
Industrial Data Layer



Religious Places Data Layer



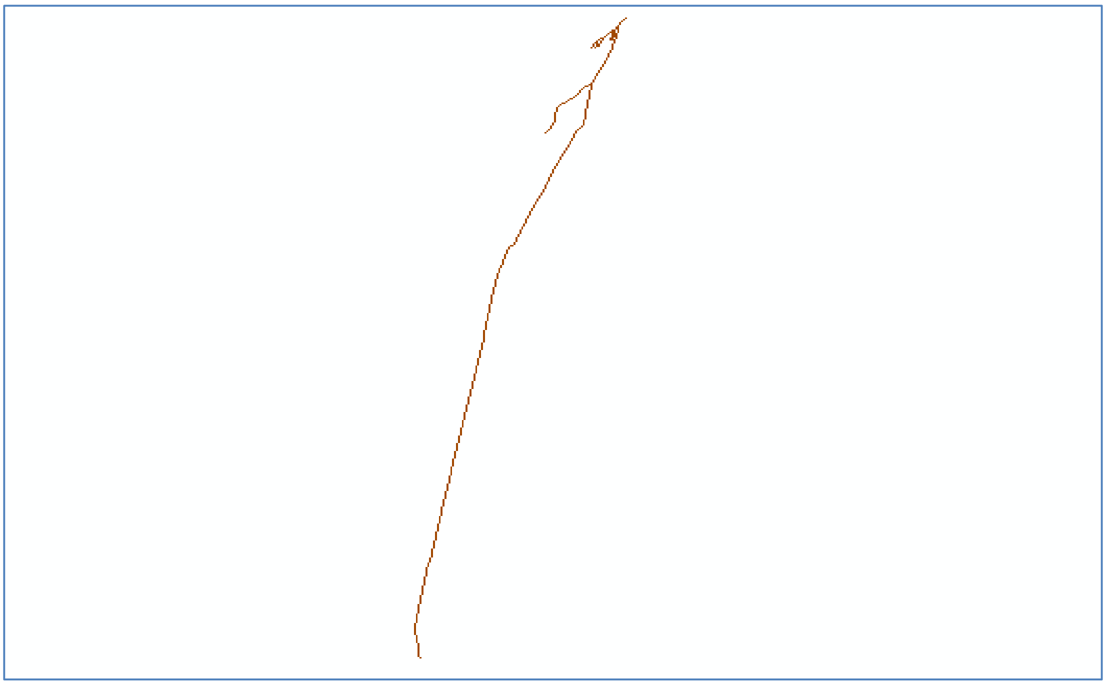
Parks & Play Grounds Data Layer



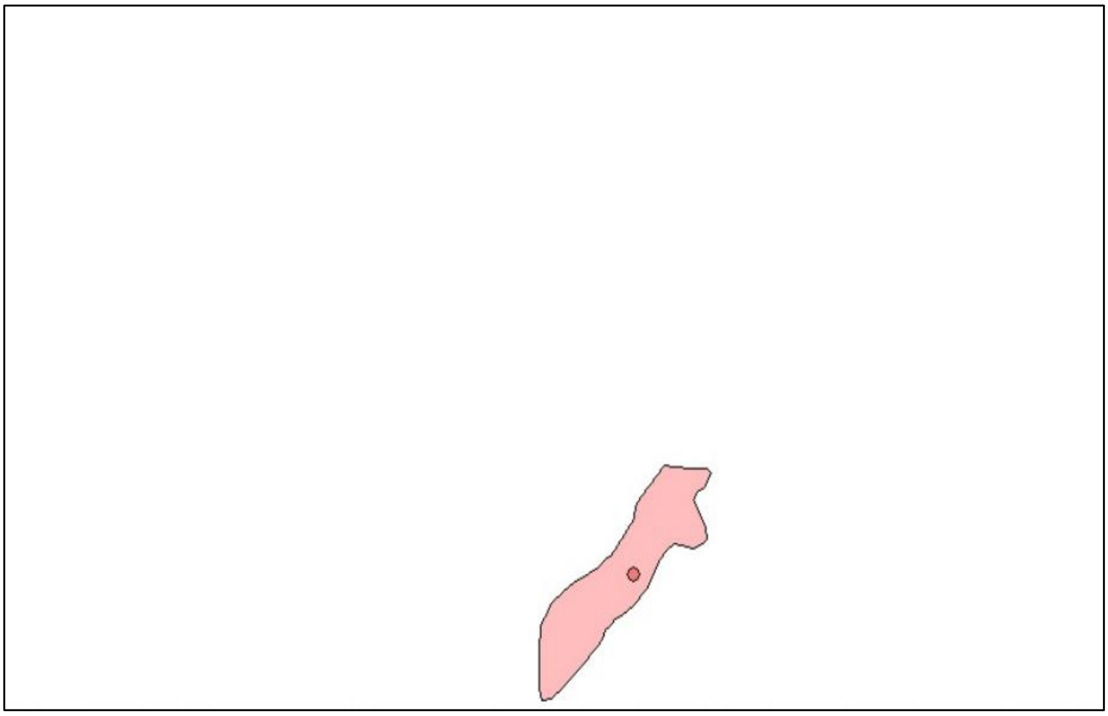
Highway Data Layer

Primary Roads Data Layer

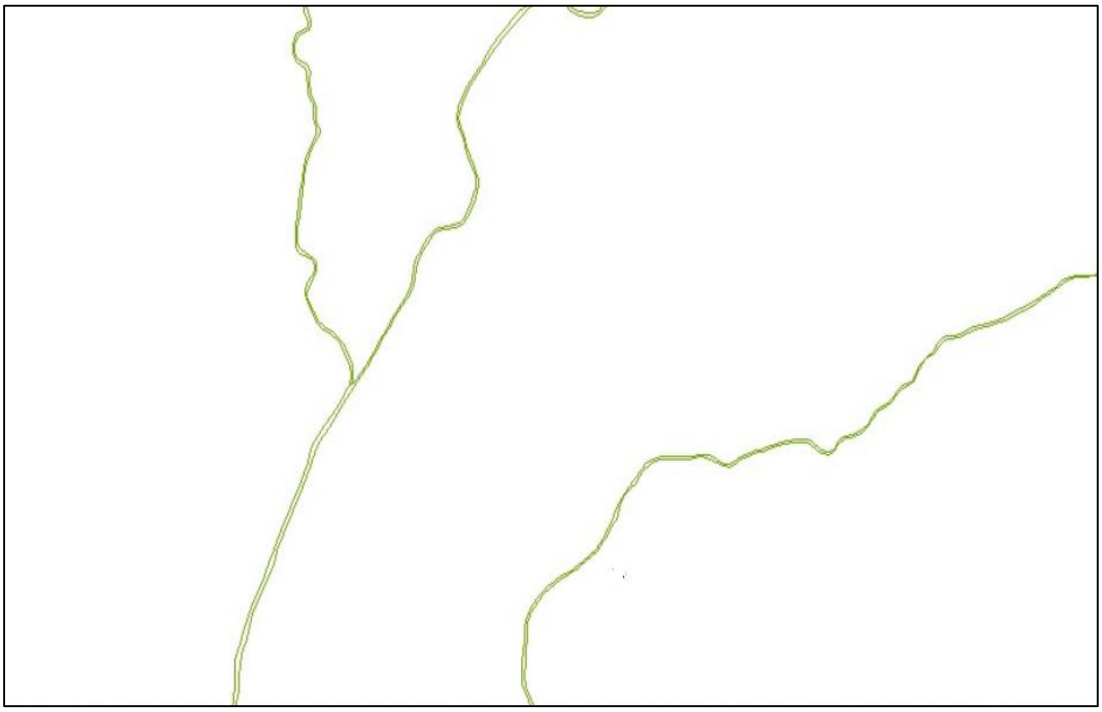
Secondary Roads Data Layer



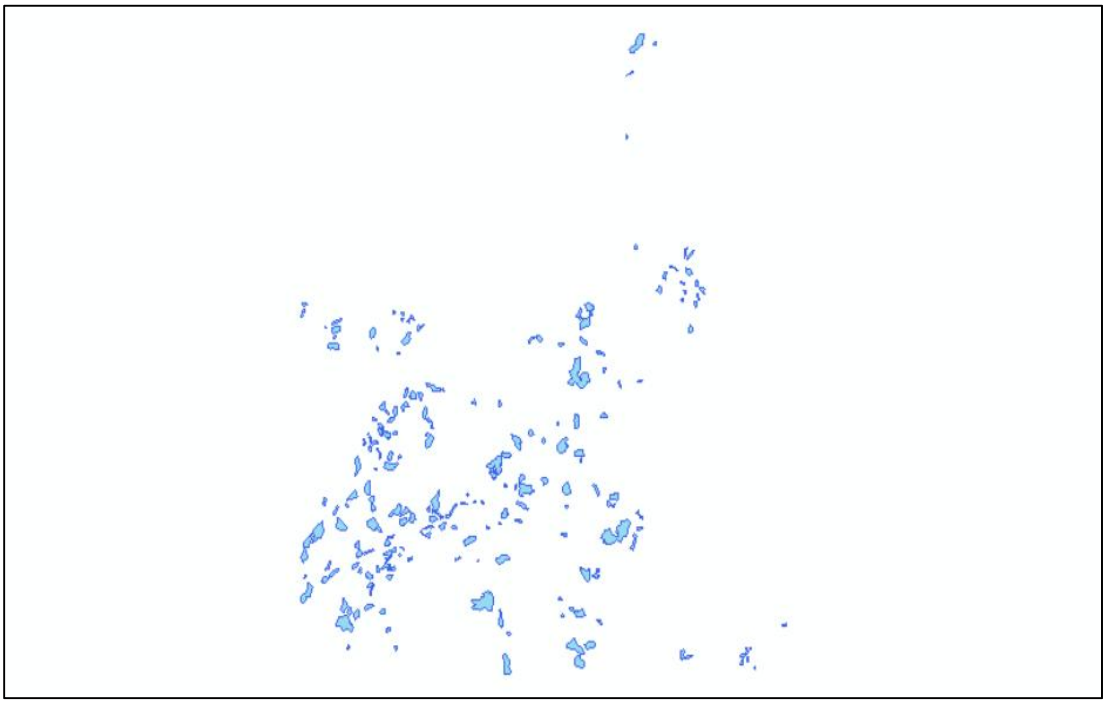
Railway Line Data Layer



Airport Data Layer

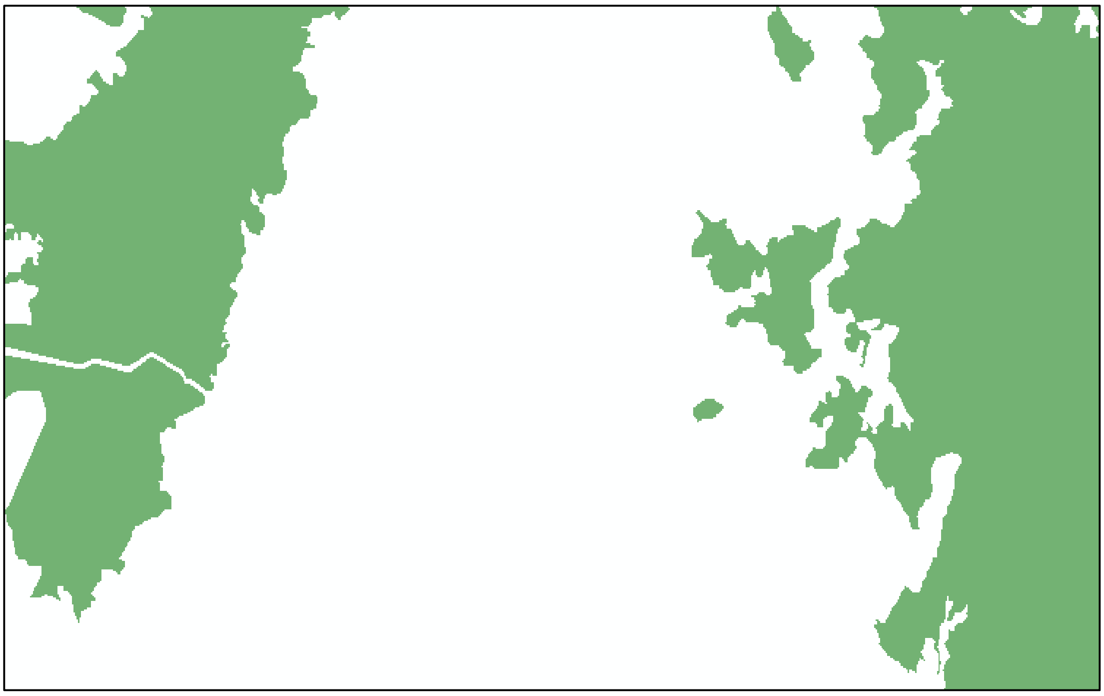


Rivers Data Layer

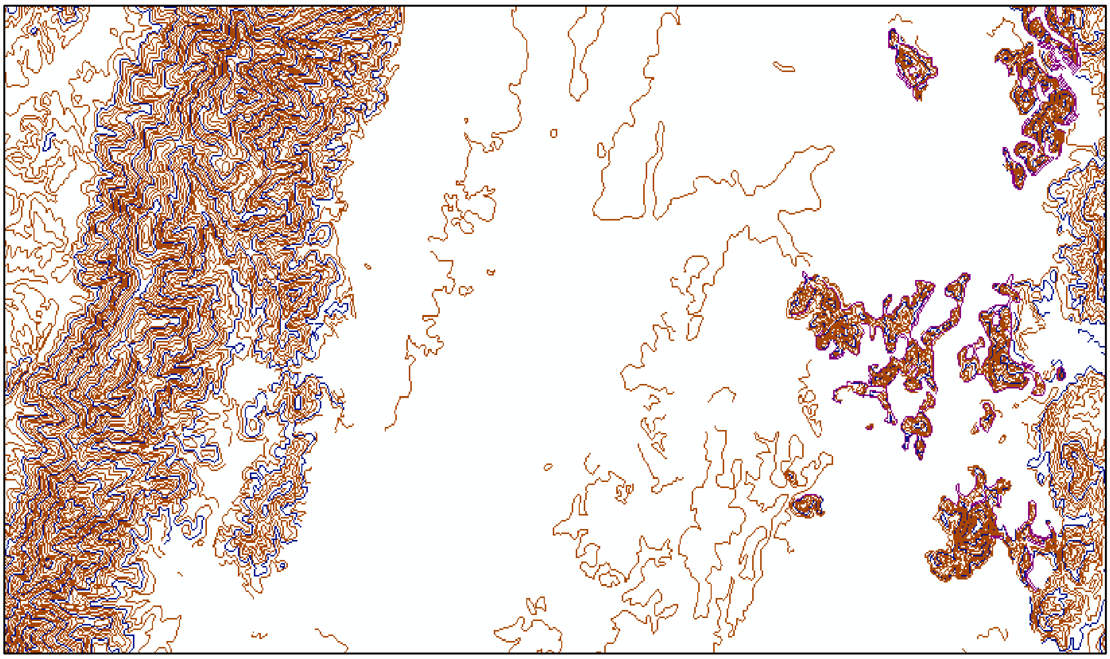


Lakes Data Layer

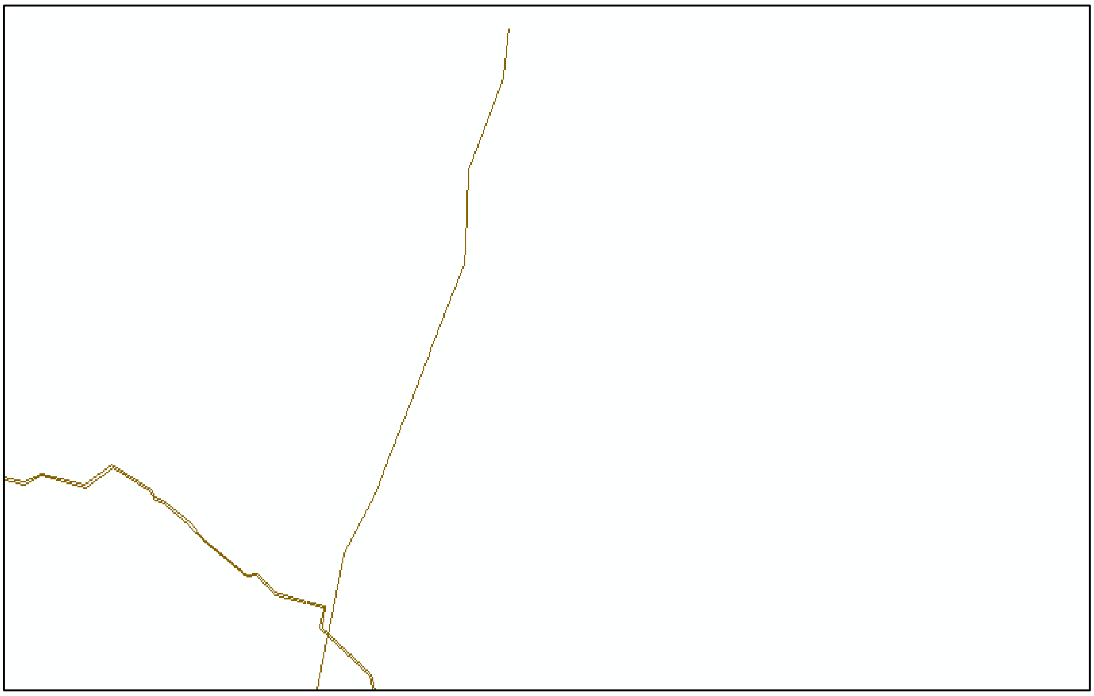
Vacant Land Data Layer



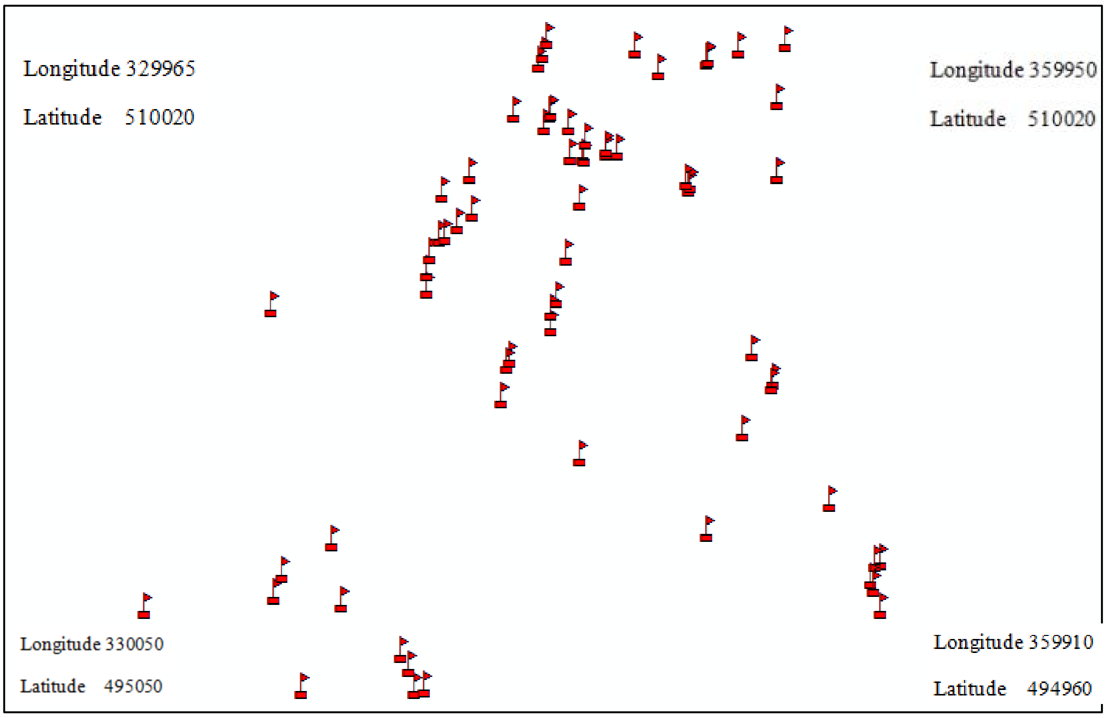
Forest Data Layer



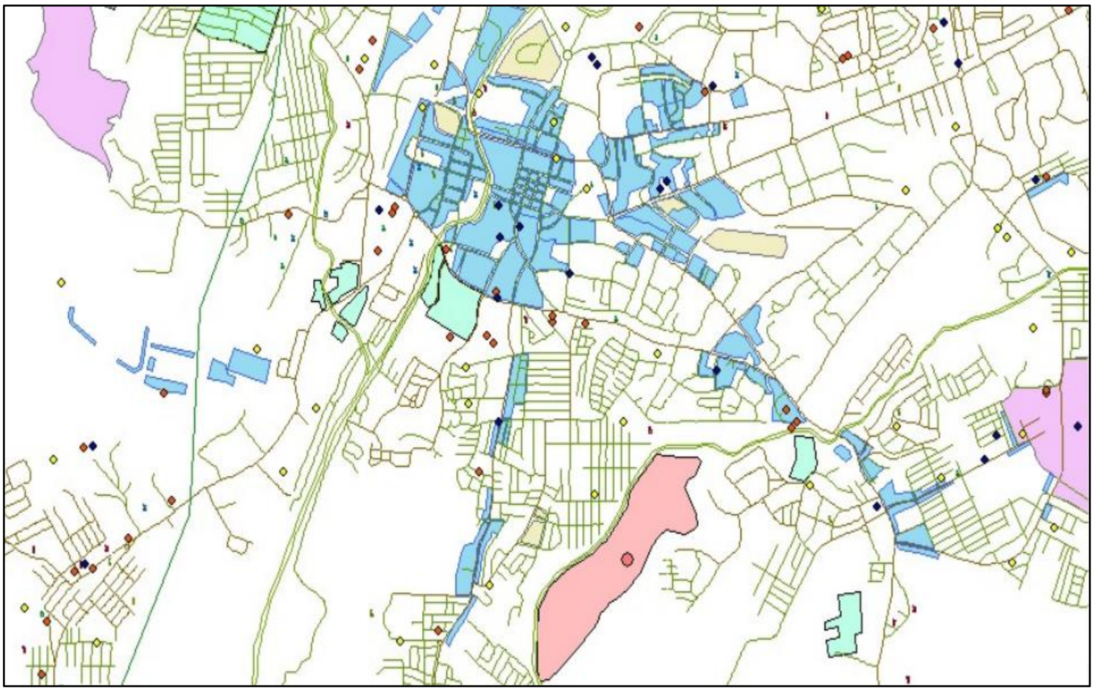
Contours Data Layer



Transmission Line Data Layer



Existing PFS Data Layer



Combined Data Layers

APPENDIX D

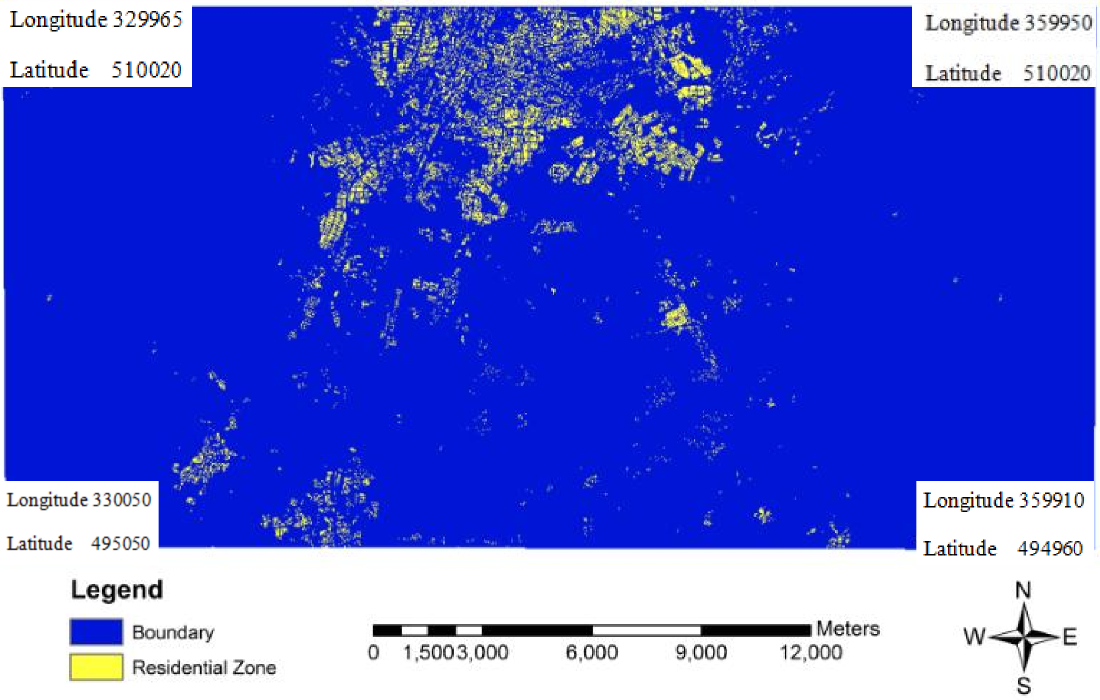
COORDINATES OF THE EXISTING PETROL FILLING STATIONS

S. No	Longitude	Latitude	S. No	Longitude	Latitude
1	338962	495032	32	342521	508318
2	339204	495088	33	342994	507990
3	338601	495876	34	341552	508265
4	338834	495548	35	342195	509416
5	335298	497191	36	342314	509636
6	335523	497712	37	342433	509972
7	337053	497017	38	344743	509741
8	336817	498412	39	345348	509226
9	339273	504239	40	346645	509515
10	339300	504624	41	347423	509736
11	339357	505041	42	348653	509877
12	339604	505437	43	348458	508564
13	339770	505461	44	346133	506575
14	340095	505706	45	346178	506628
15	340490	506001	46	348452	506849
16	339685	506423	47	347787	502775
17	340420	506852	48	348348	502148
18	341369	502519	49	349804	499320
19	341452	502635	50	347555	500952
20	342538	503373	51	351159	498007
21	342672	504015	52	351015	497959
22	342913	504973	53	350887	497566
23	344254	507402	54	350952	497402
24	343958	507418	55	351147	496875
25	343959	507460	56	352586	495230
26	343027	507297	57	331905	496880
27	343359	507303	58	335220	503799
28	343414	507246	59	346609	498646
29	343438	507657	60	336013	495042
30	342368	507976	61	341239	501709
31	342495	508279	62	343293	500376

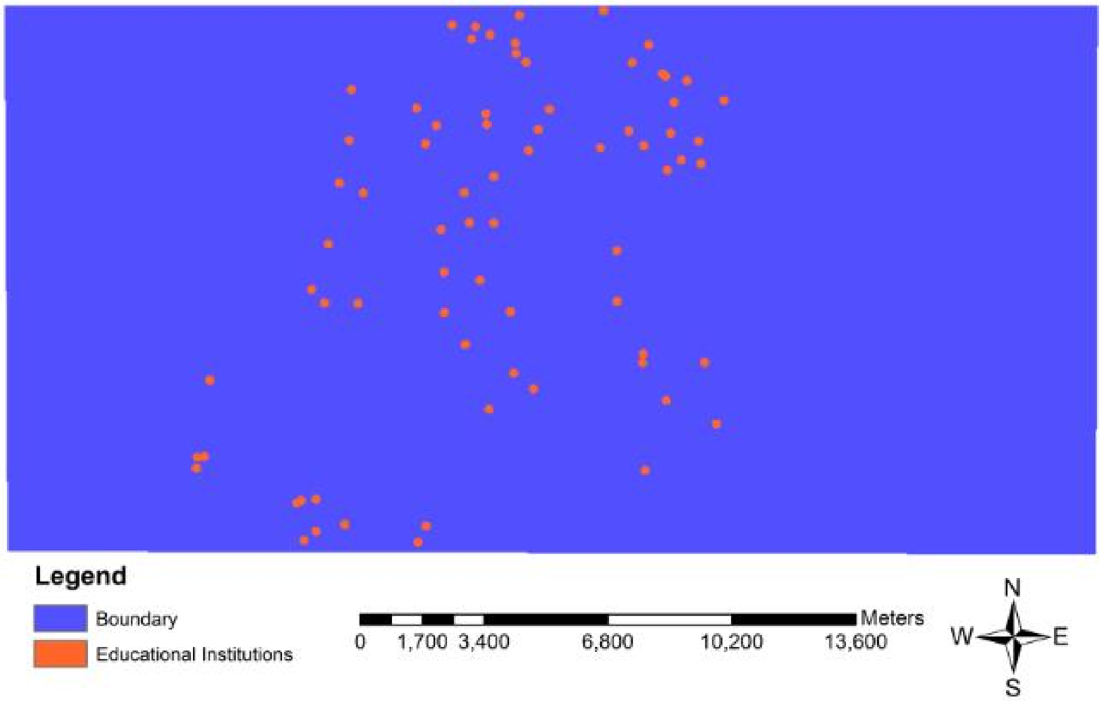
APPENDIX E

DATA LAYER ACCORDING TO THE TWO CODES

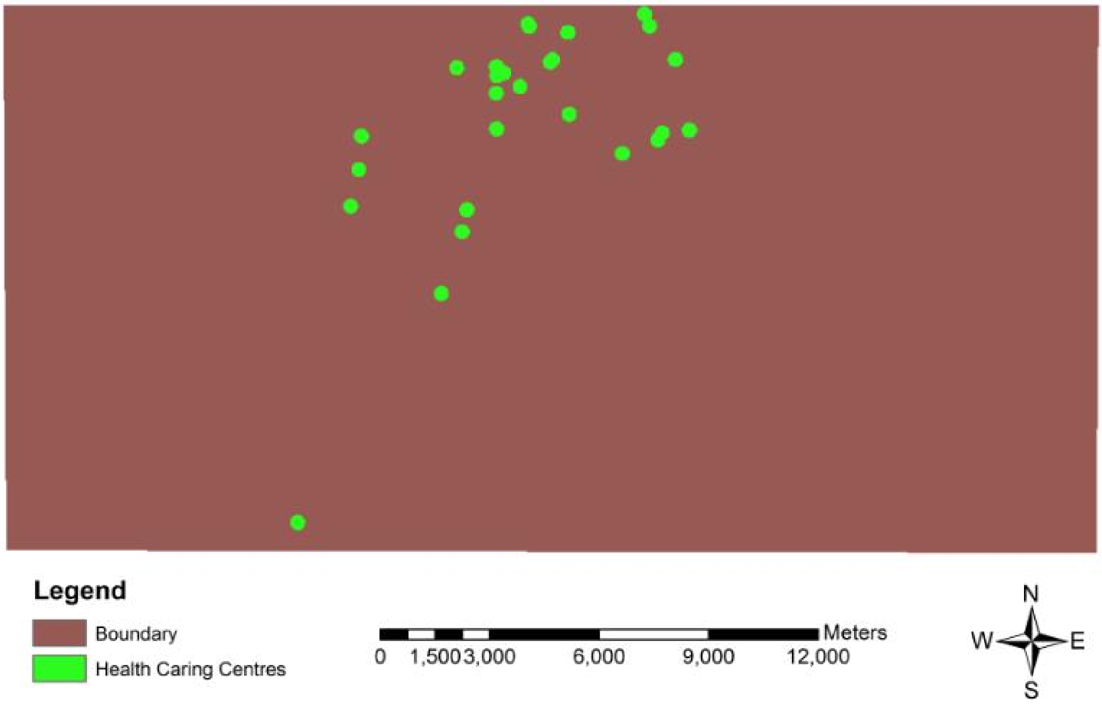
Data Layers Rendering to Code of City Planning Department, Ipoh



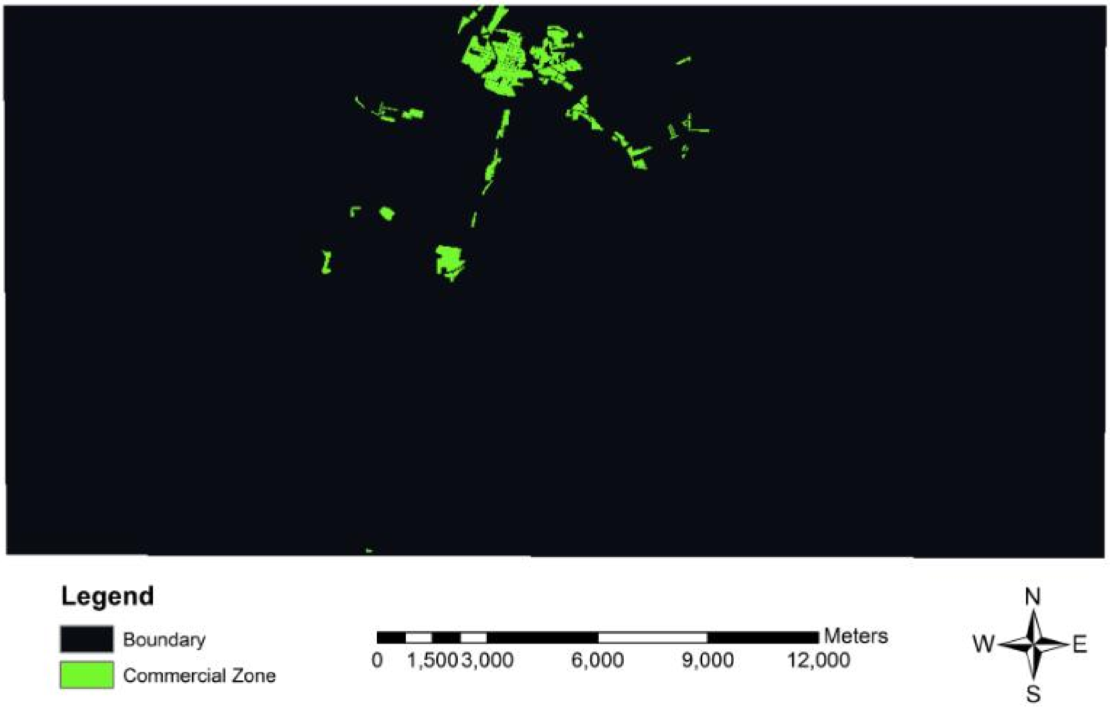
Residential Zone Buffer (CPD, Ipoh Code)



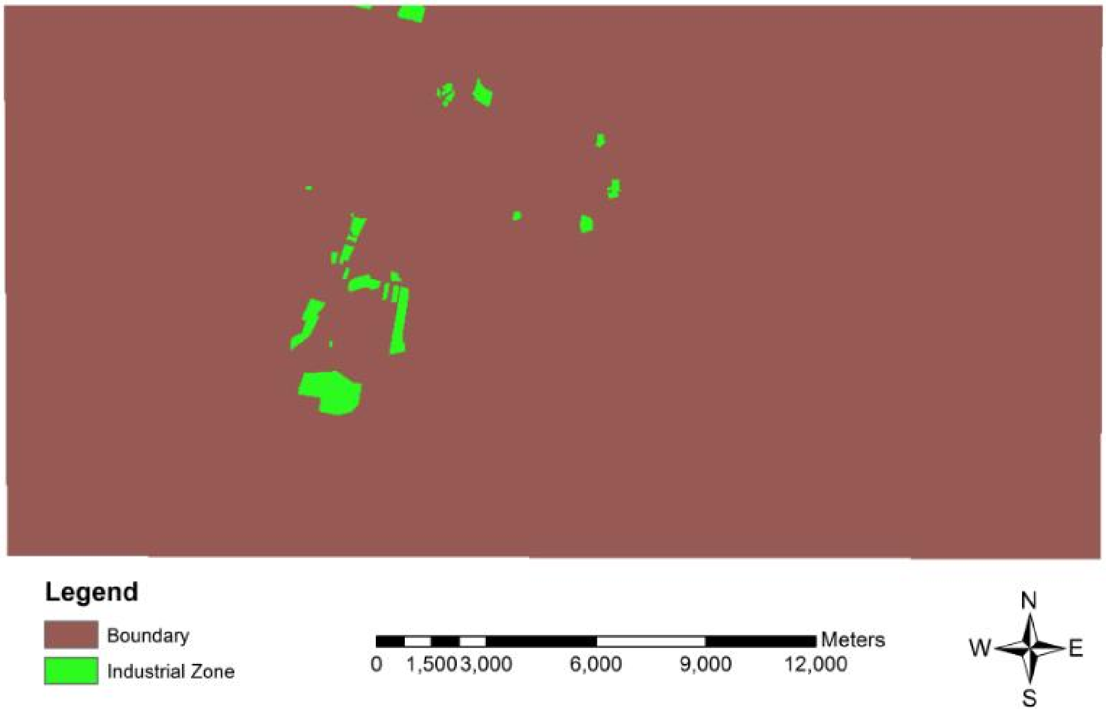
Educational Zone Buffer (CPD, Ipoh Code)



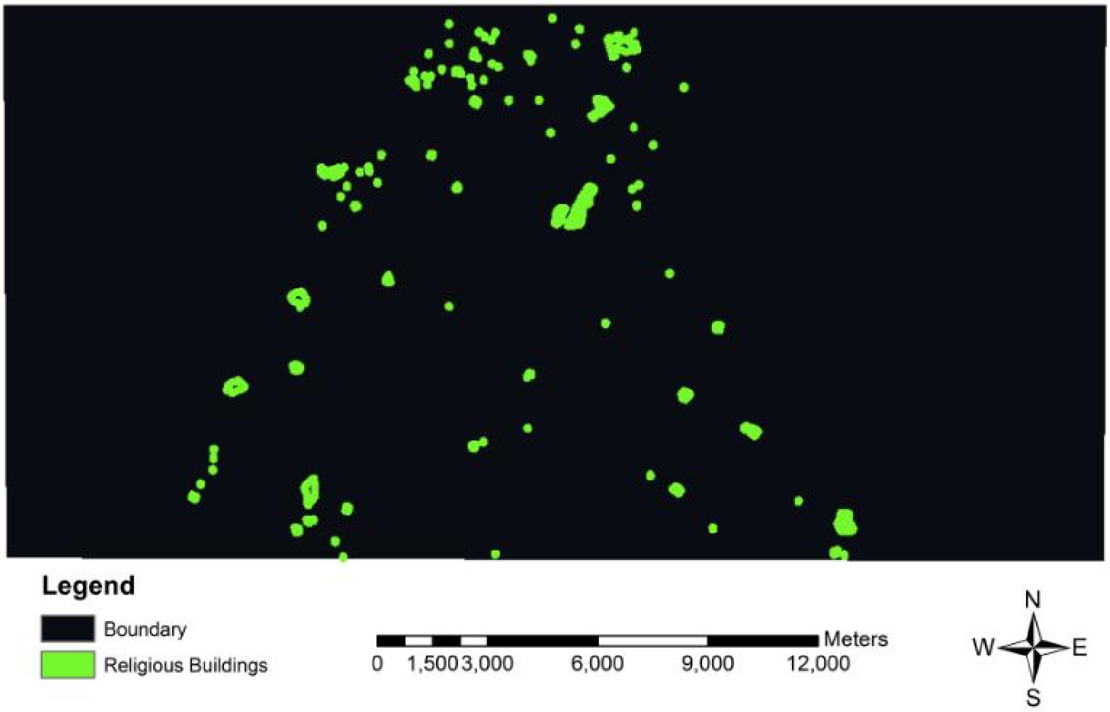
Health Caring Zone Buffer (CPD, Ipoh Code)



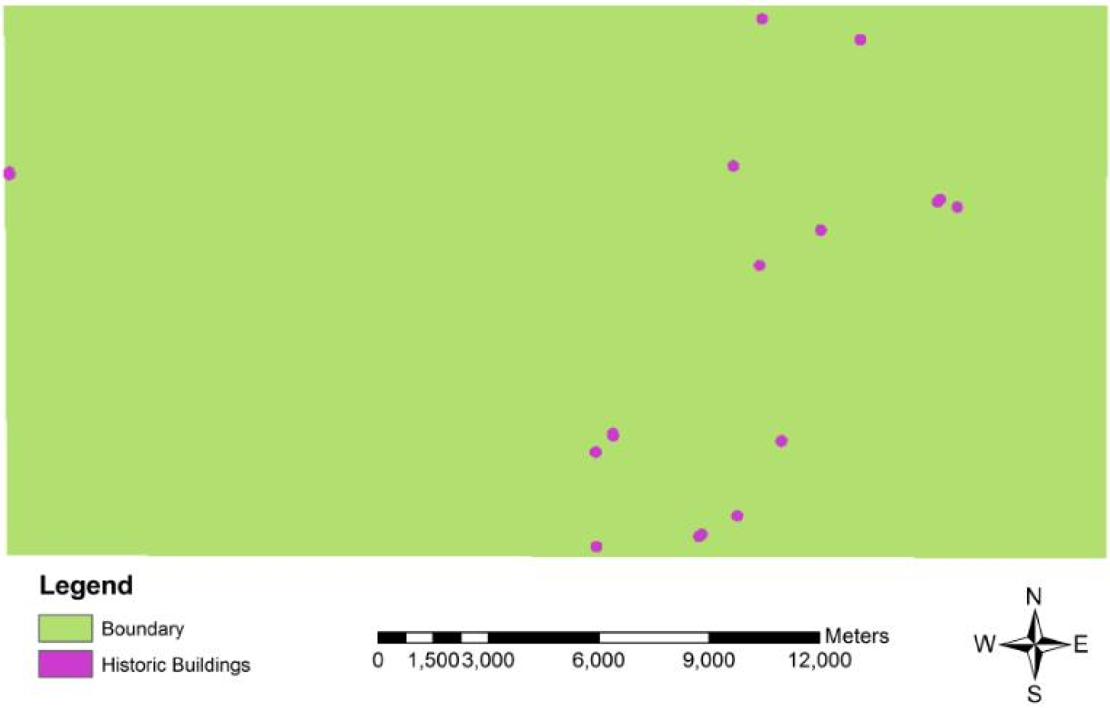
Commercial Zone Buffer (CPD, Ipoh Code)



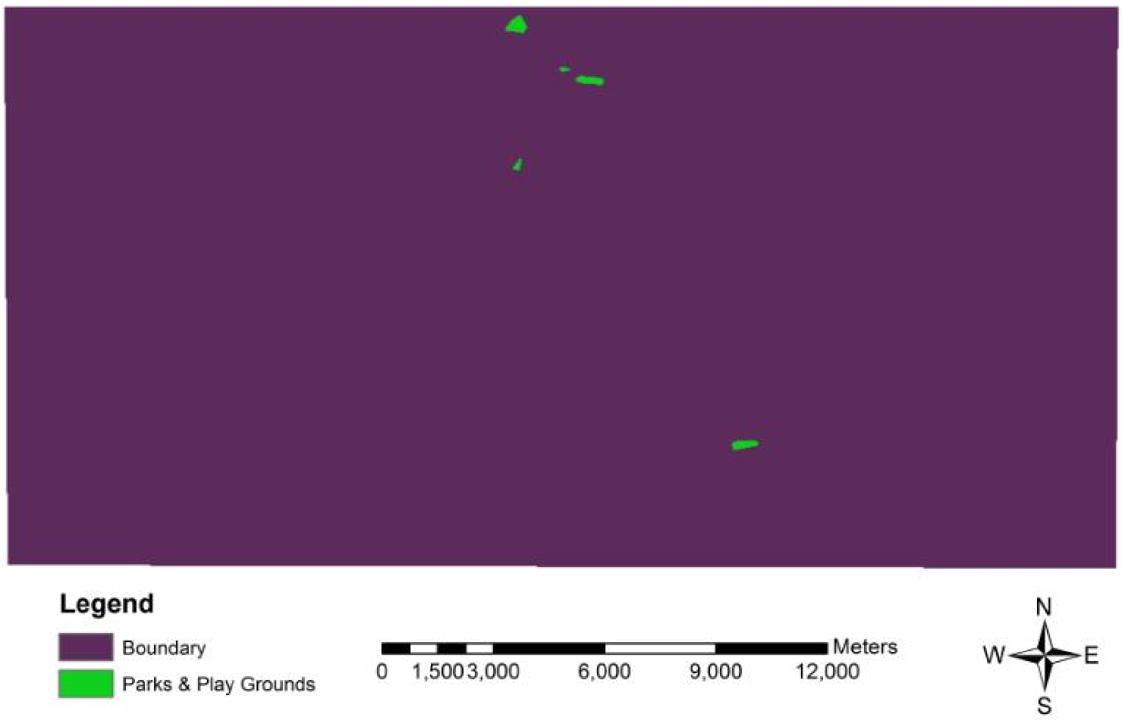
Industrial Zone Buffer (CPD, Ipoh Code)



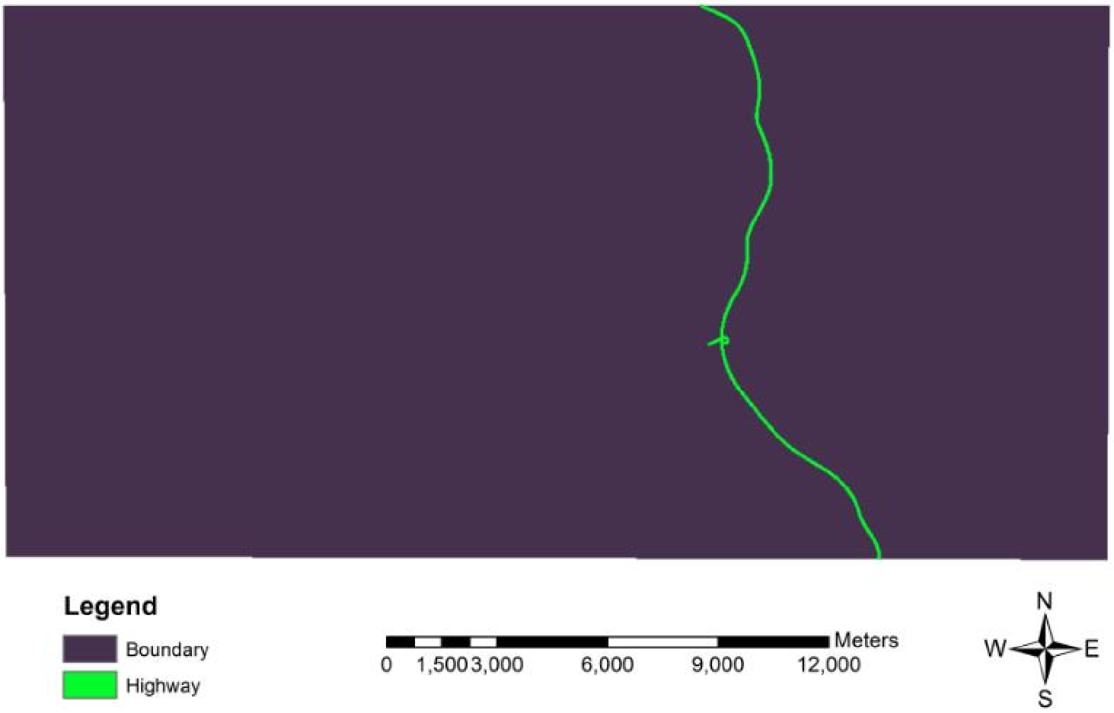
Religious Zone Buffer (CPD, Ipoh Code)



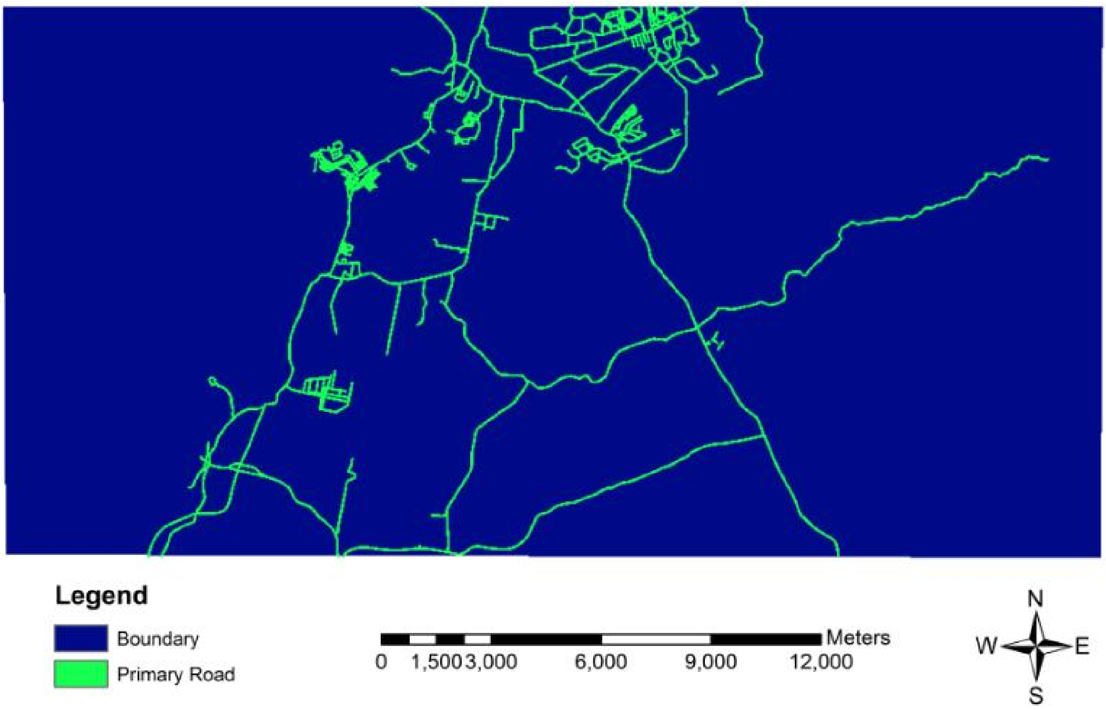
Historic Buildings Zone Buffer (CPD, Ipoh Code)



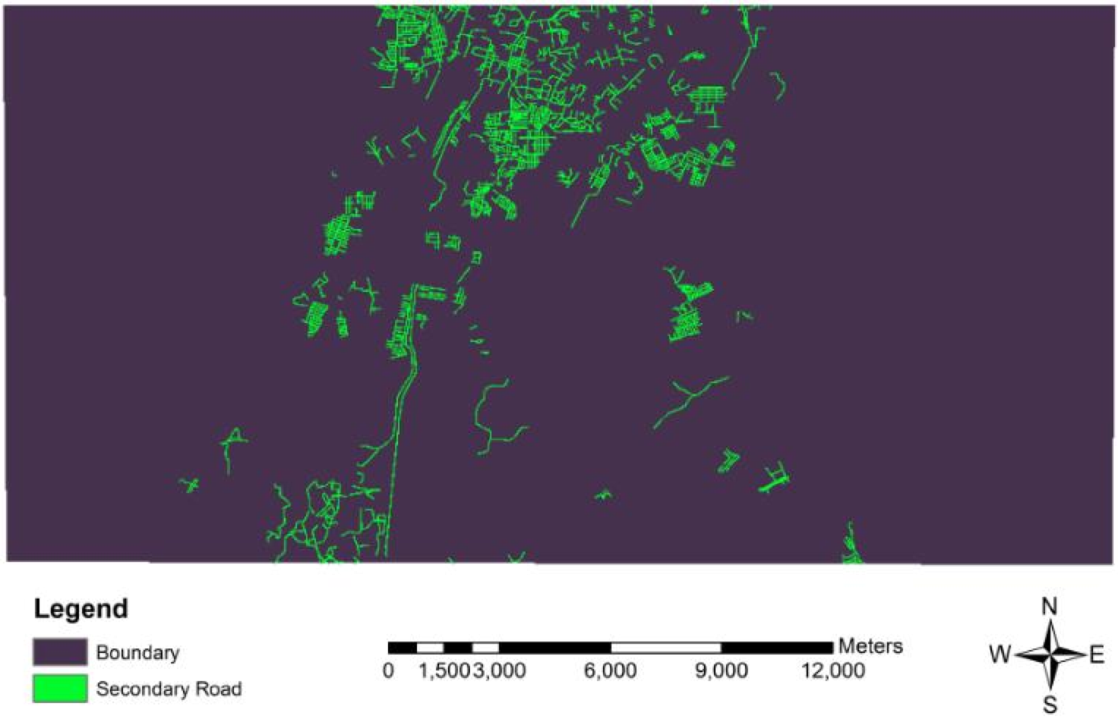
Parks and Playgrounds Zone Buffer (CPD, Ipoh Code)



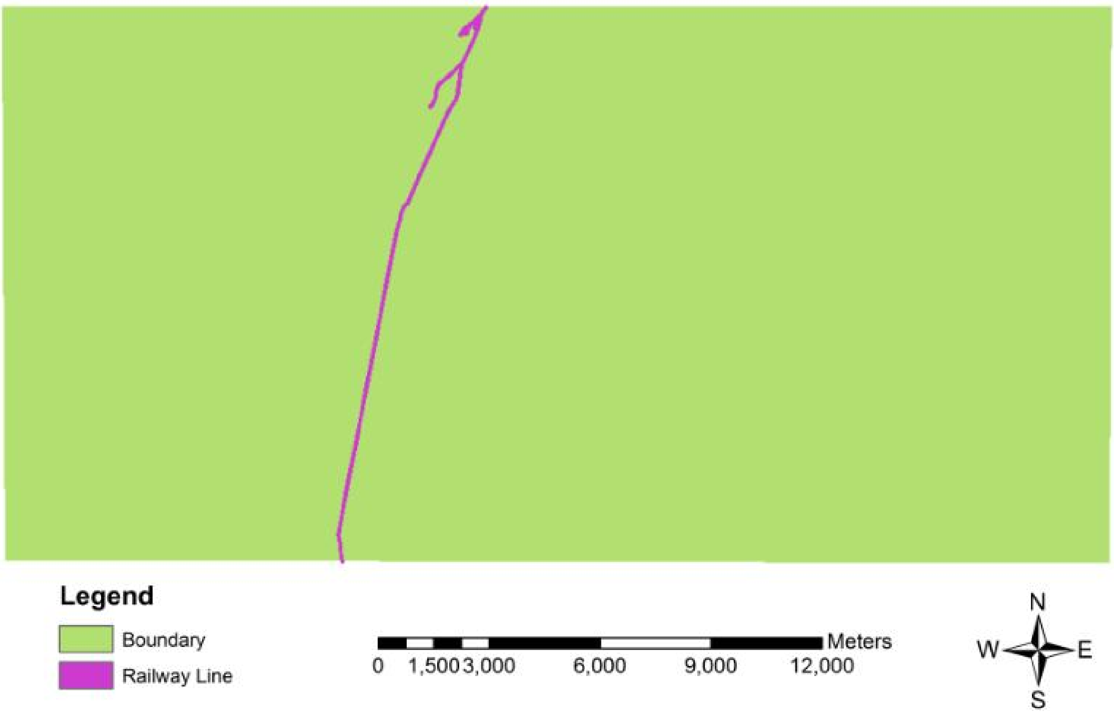
Highway Buffer (CPD, Ipoh Code)



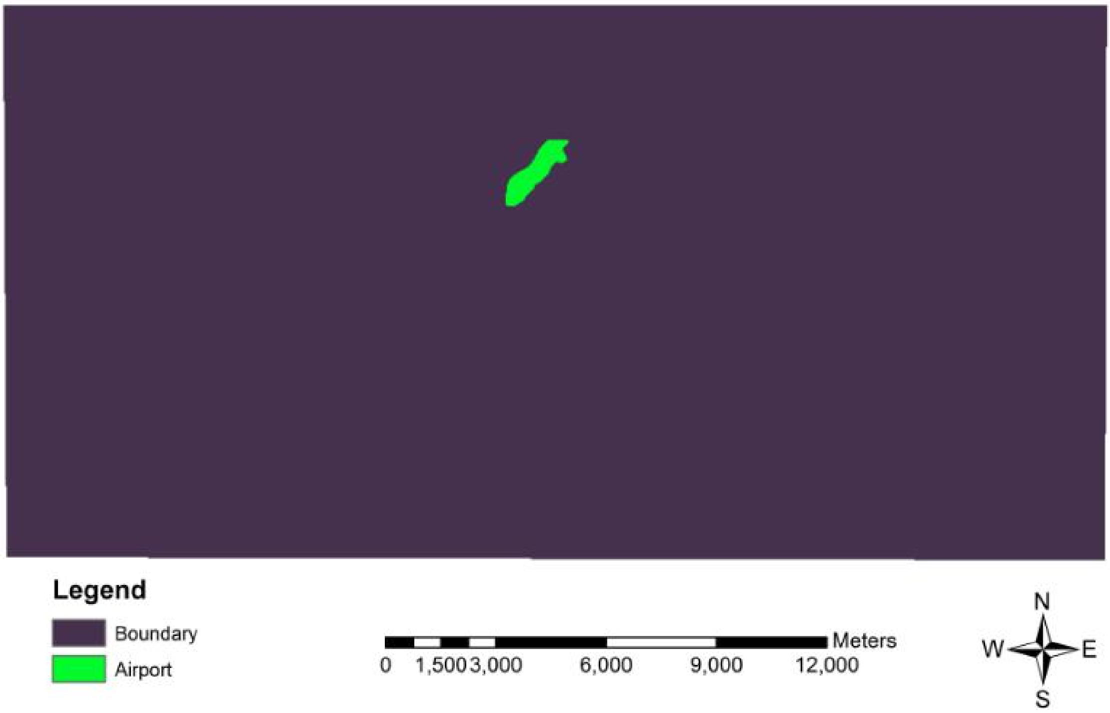
Primary Roads Buffer (CPD, Ipoh Code)



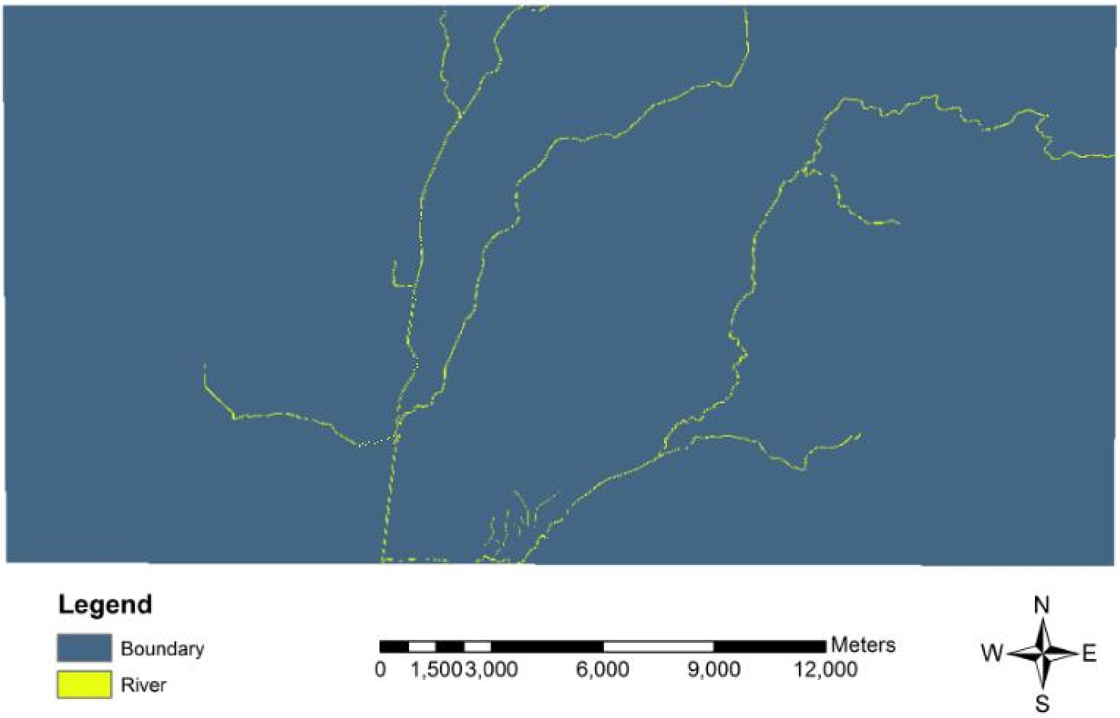
Secondary Roads Buffer (CPD, Ipoh Code)



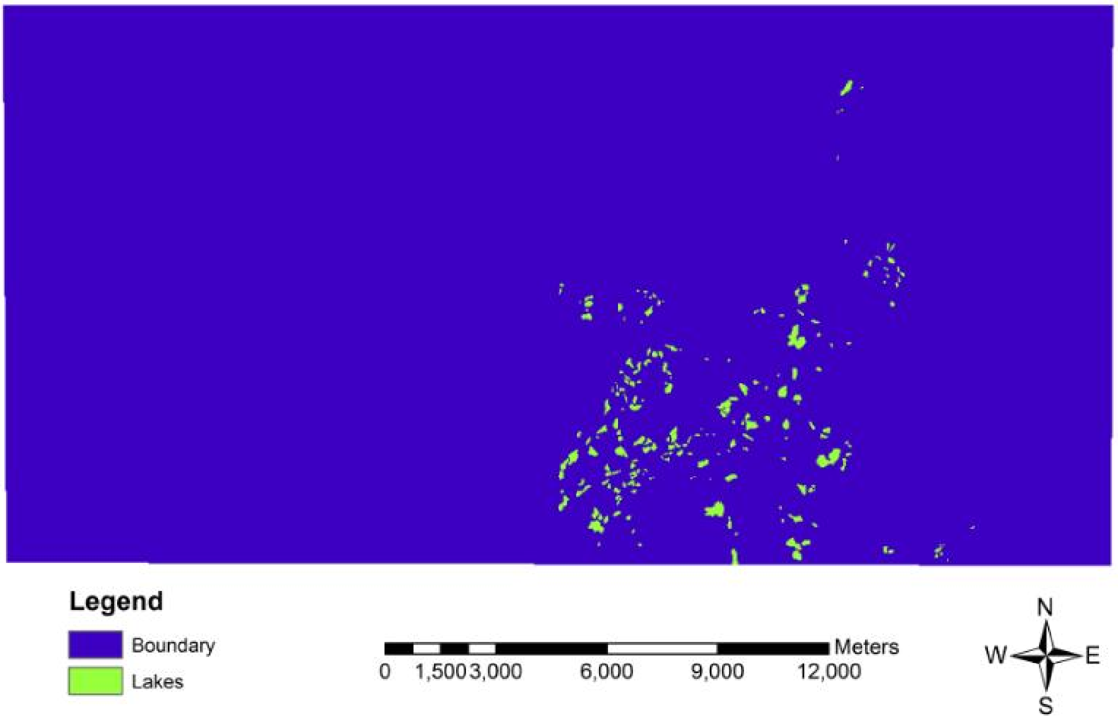
Railway Line Buffer (CPD, Ipoh Code)



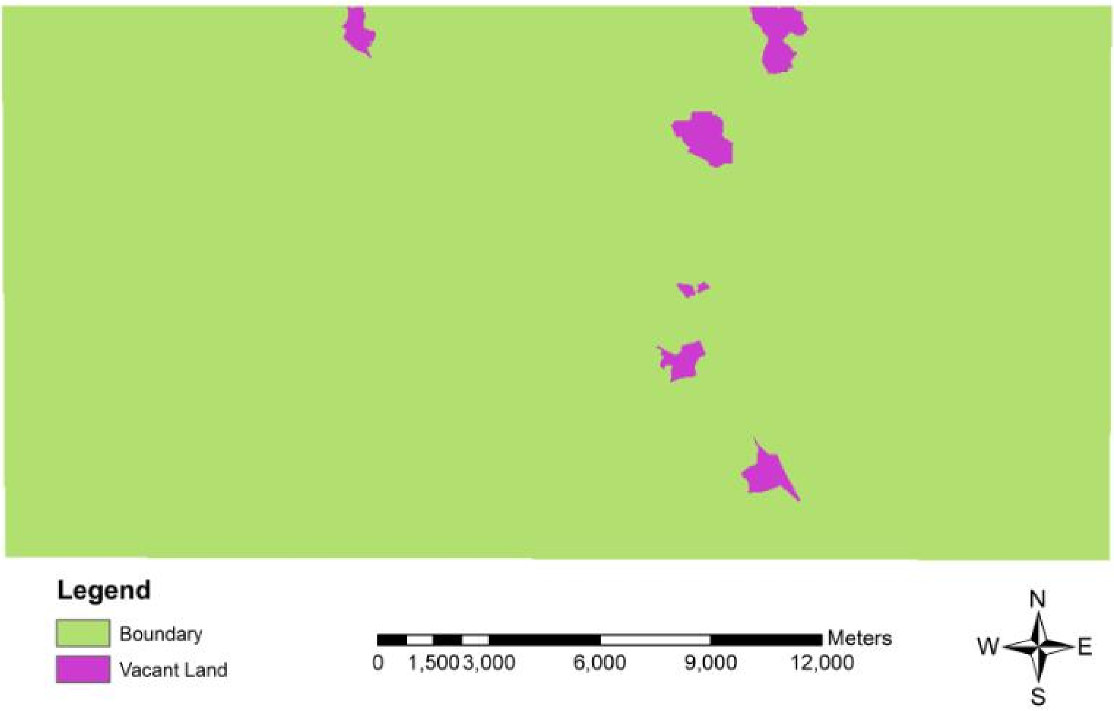
Airport Buffer (CPD, Ipoh Code)



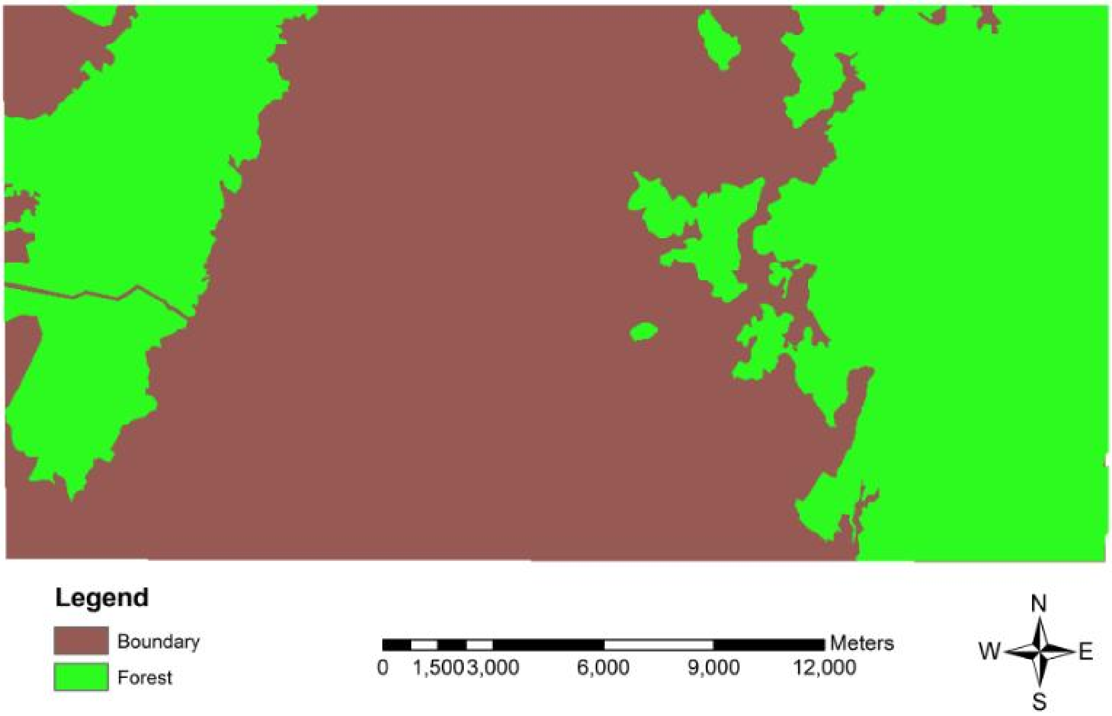
Rivers Buffer (CPD, Ipoh Code)



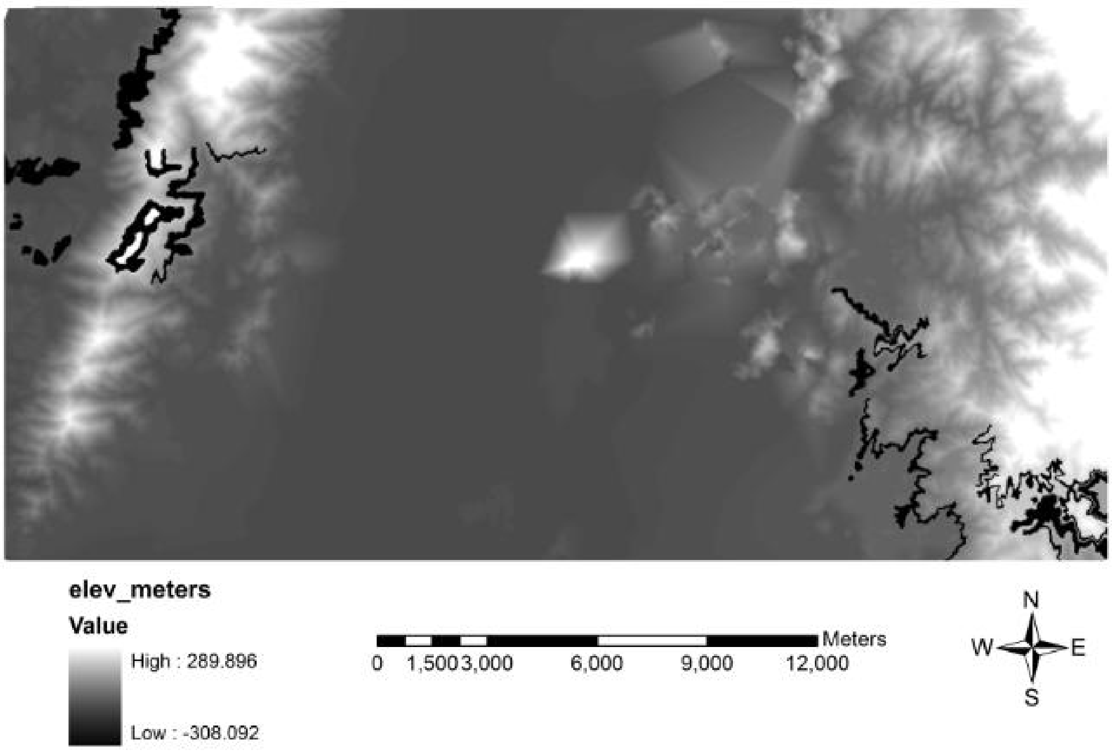
Lakes Buffer (CPD, Ipoh Code)



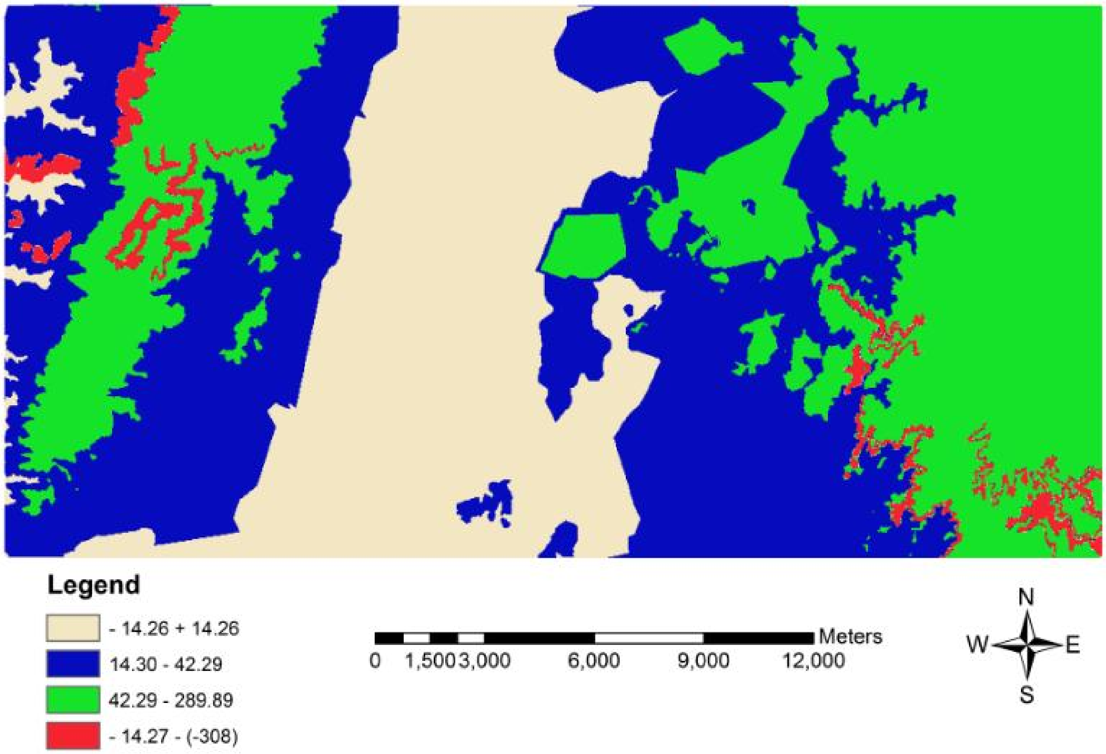
Vacant Land available in the Study Area



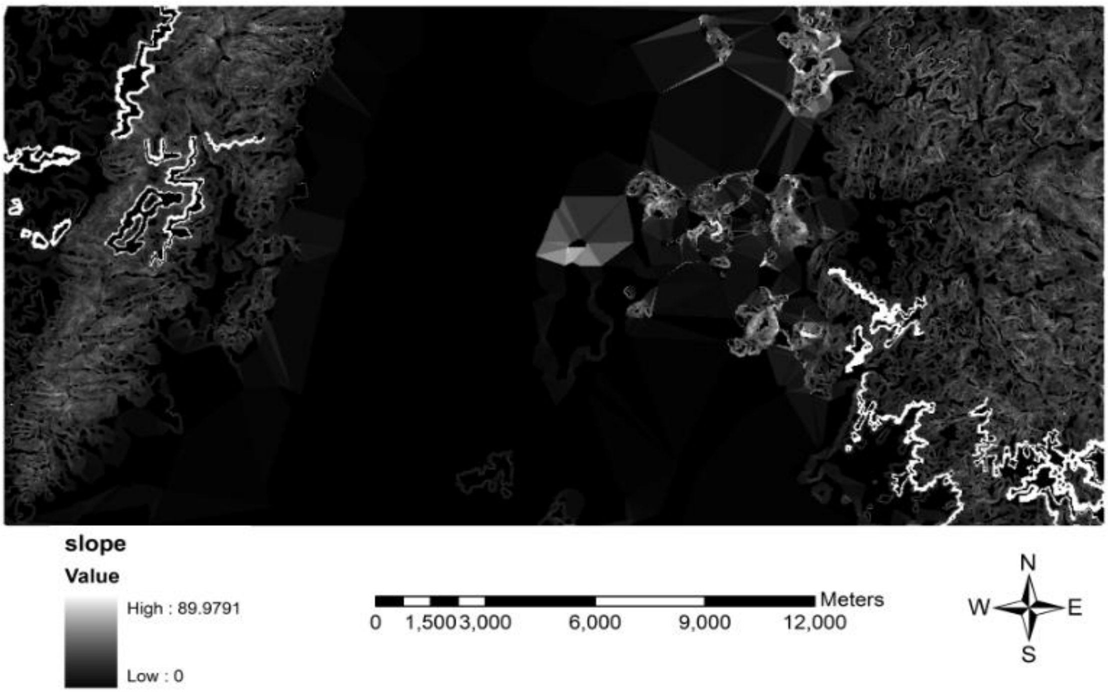
Forest Buffer (CPD, Ipoh Code)



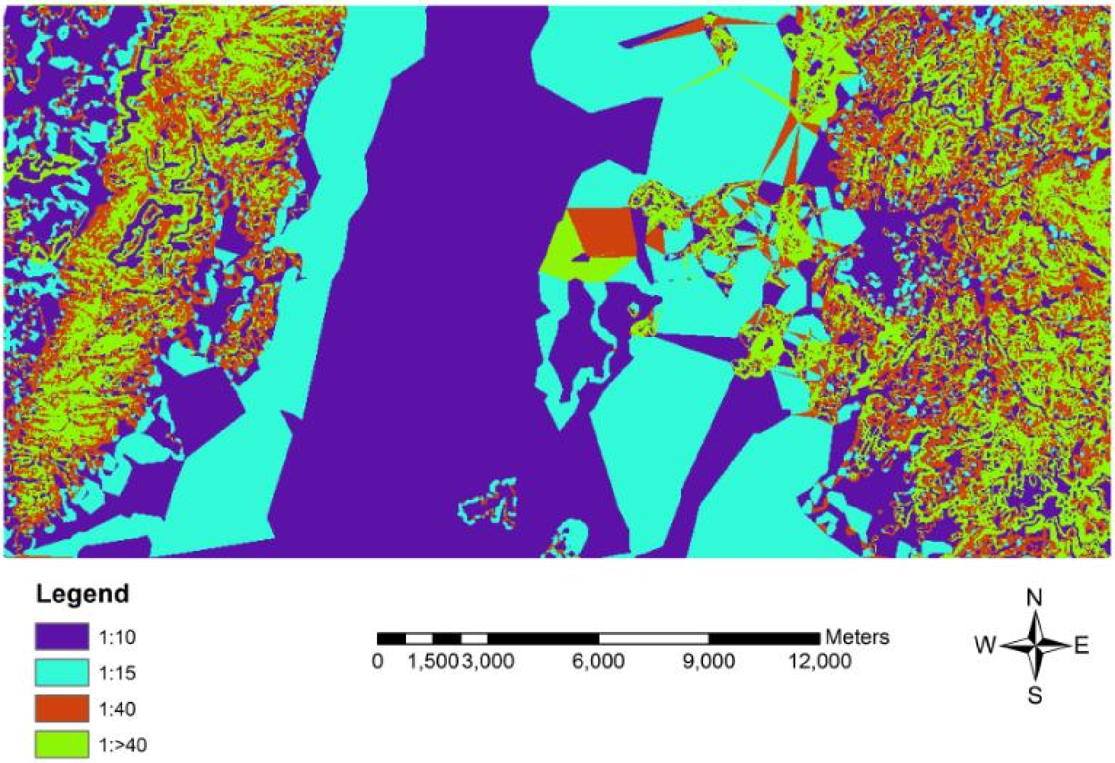
Digital Elevation Buffer (CPD, Ipoh Code)



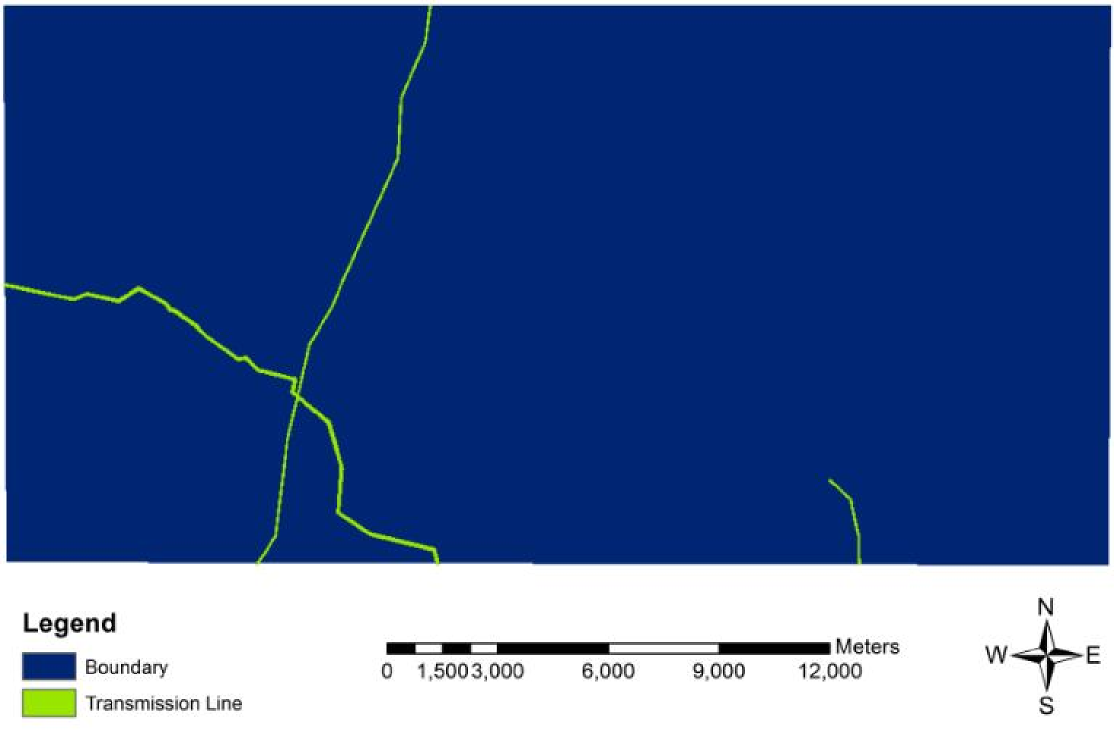
Elevation Buffer (CPD, Ipoh Code)



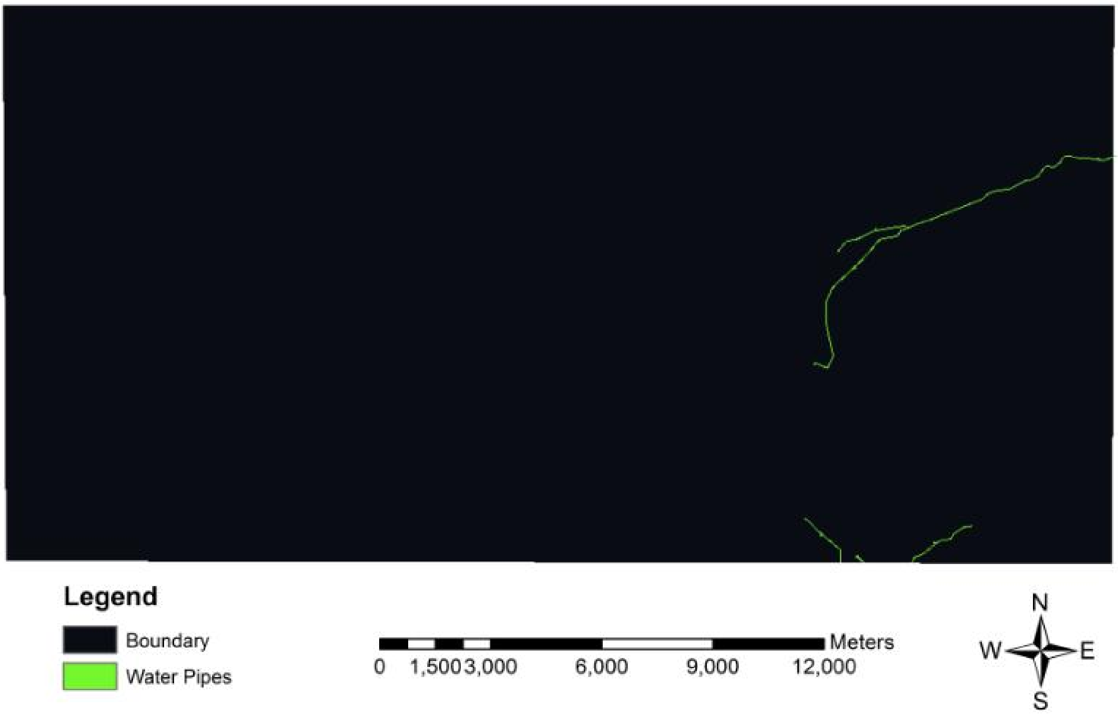
Tin Model Buffer (CPD, Ipoh Code)



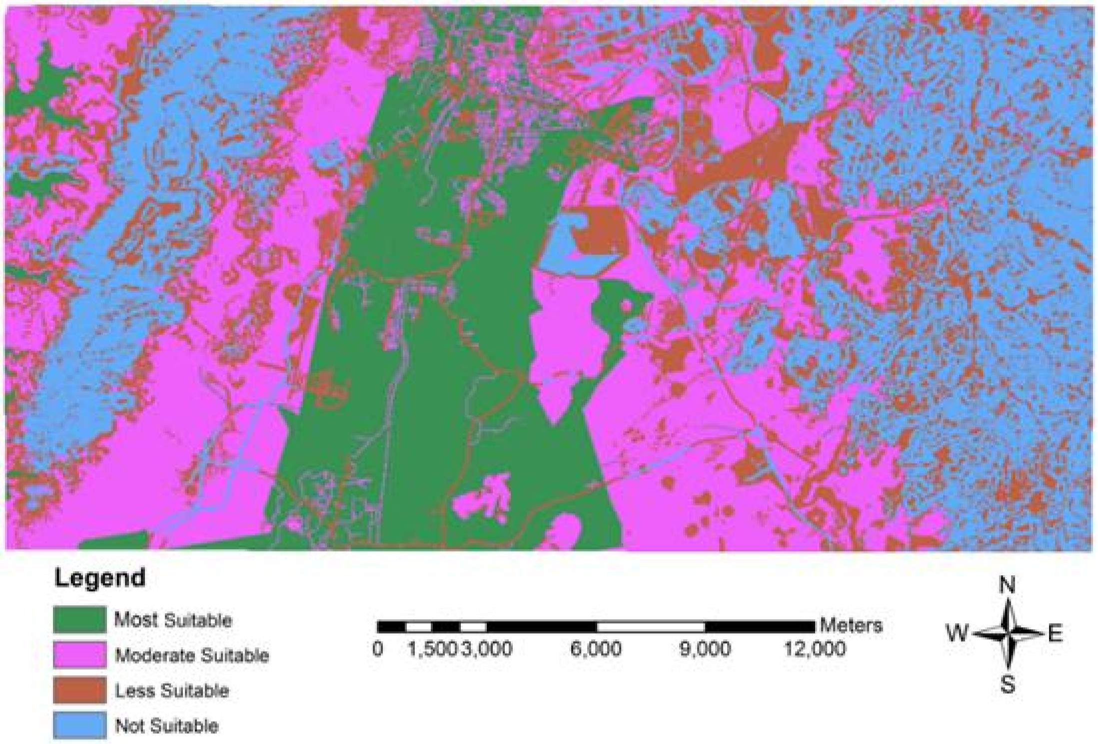
Slope Buffer (CPD, Ipoh Code)



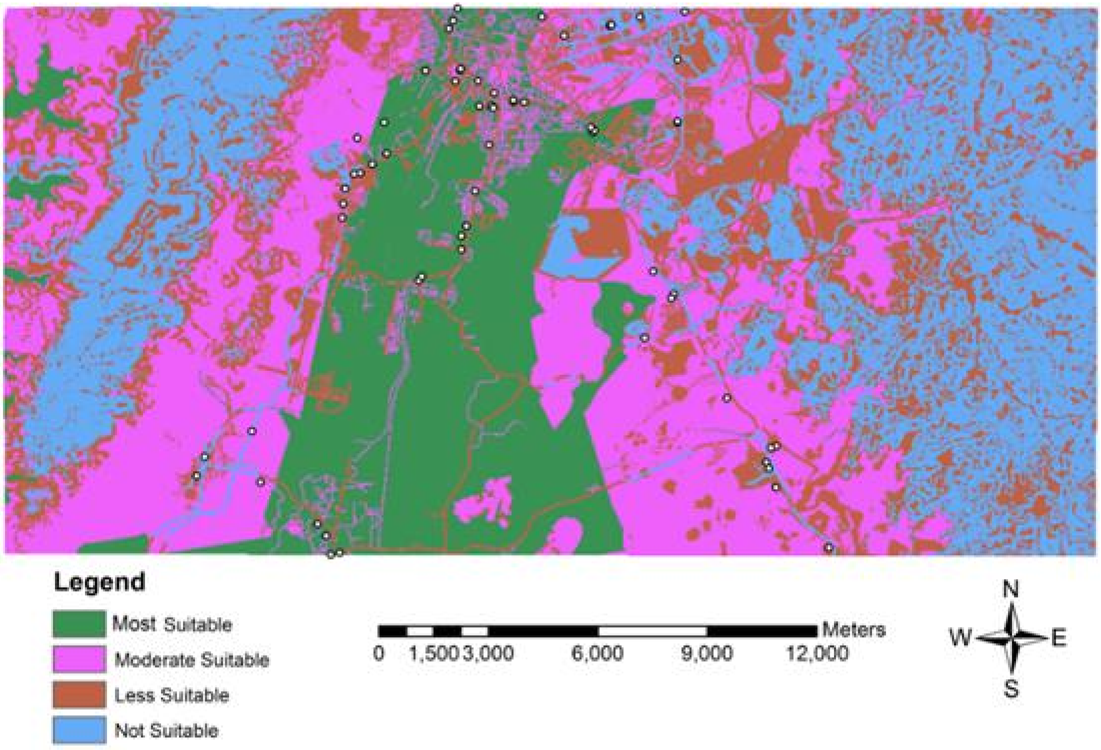
High Voltage Transmission Line Buffer (CPD, Ipoh Code)



Water Pipe Buffer (CPD, Ipoh Code)

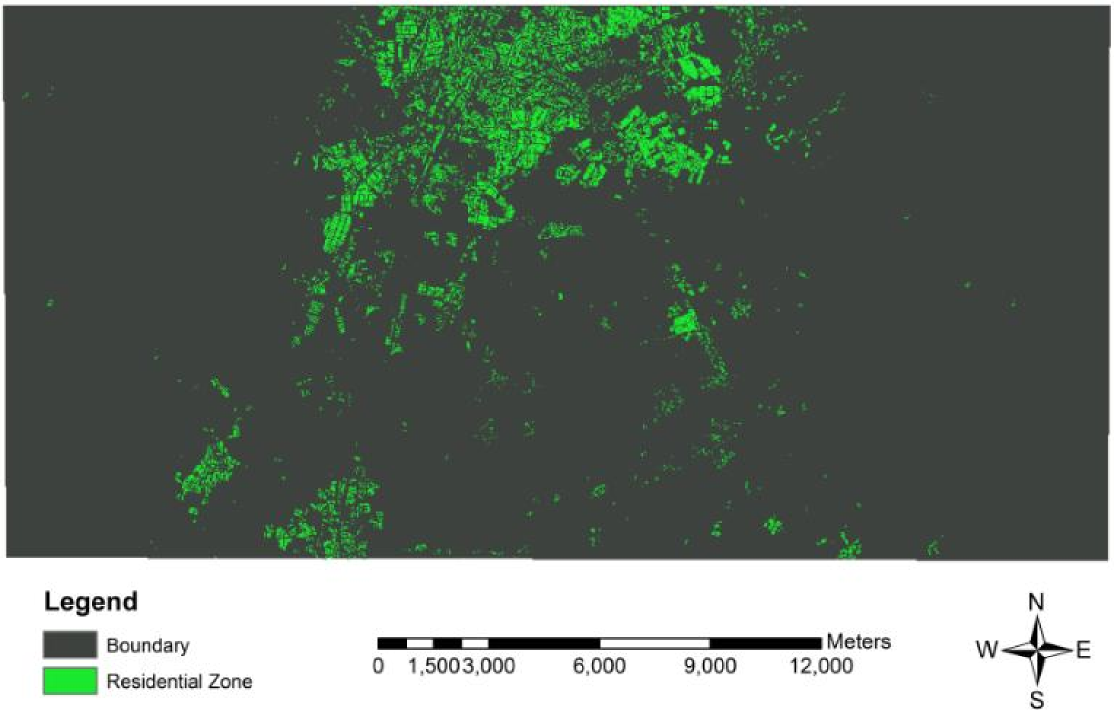


Final Land Suitability Map for PFS rendering to CPD Code, Ipoh

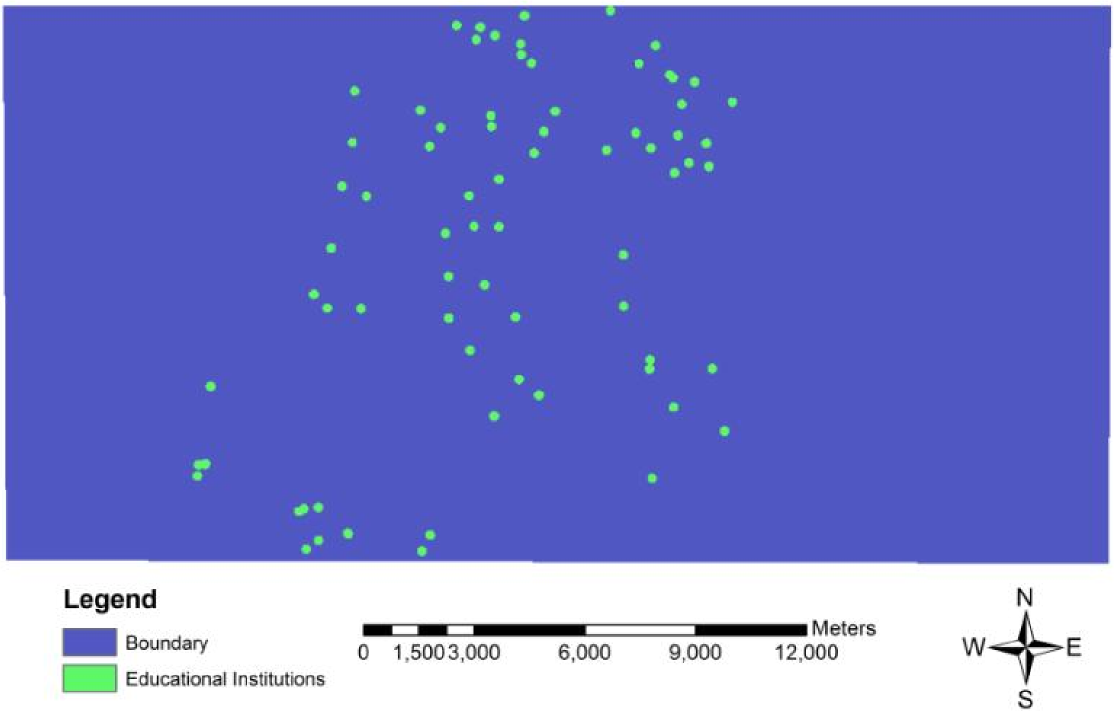


Land Suitability Map rendering to CPD Code, Ipoh with Existing PFS

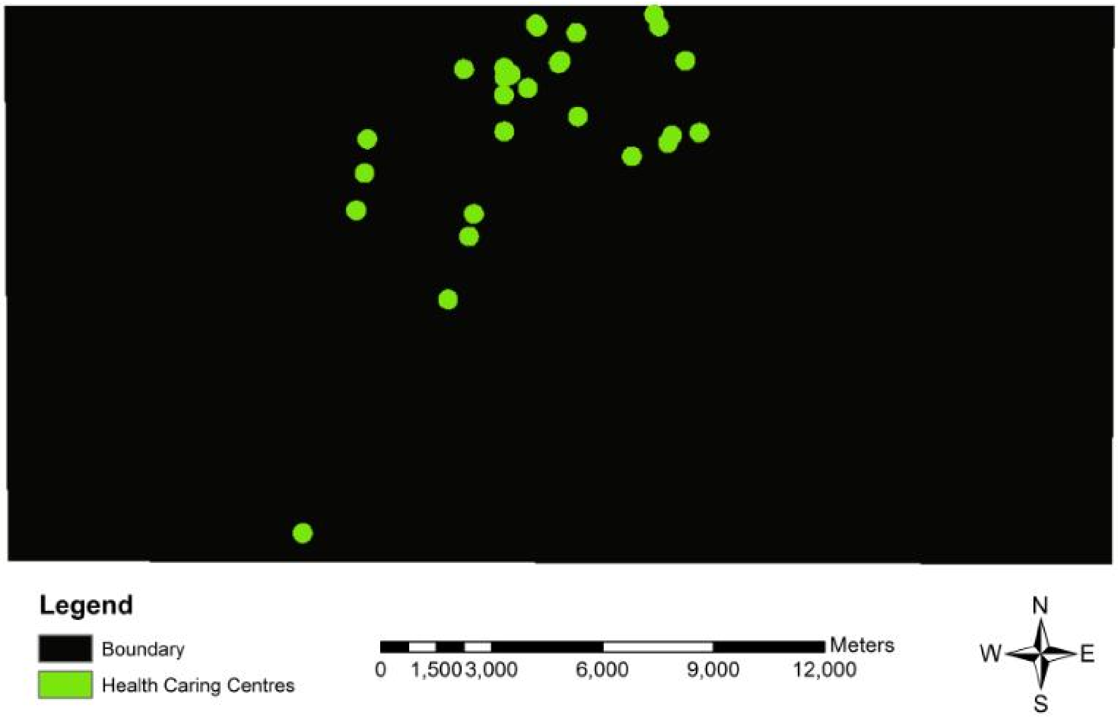
Data Layers Rendering to Municipal Code, California



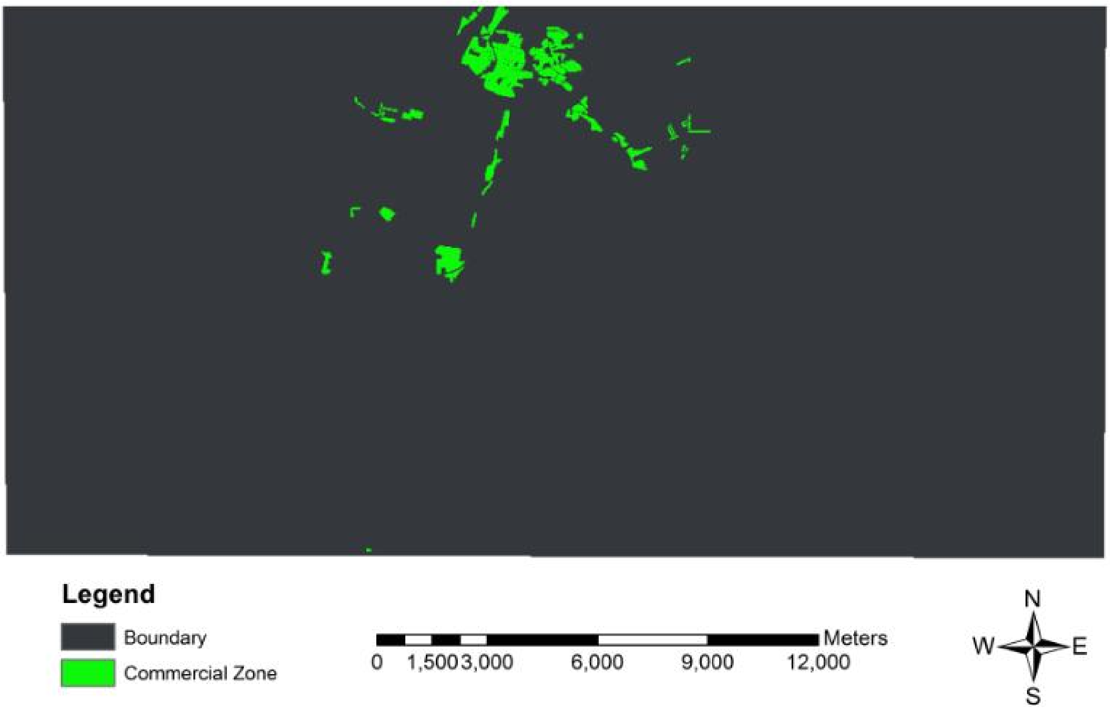
Residential Zone Buffer (MCC, USA)



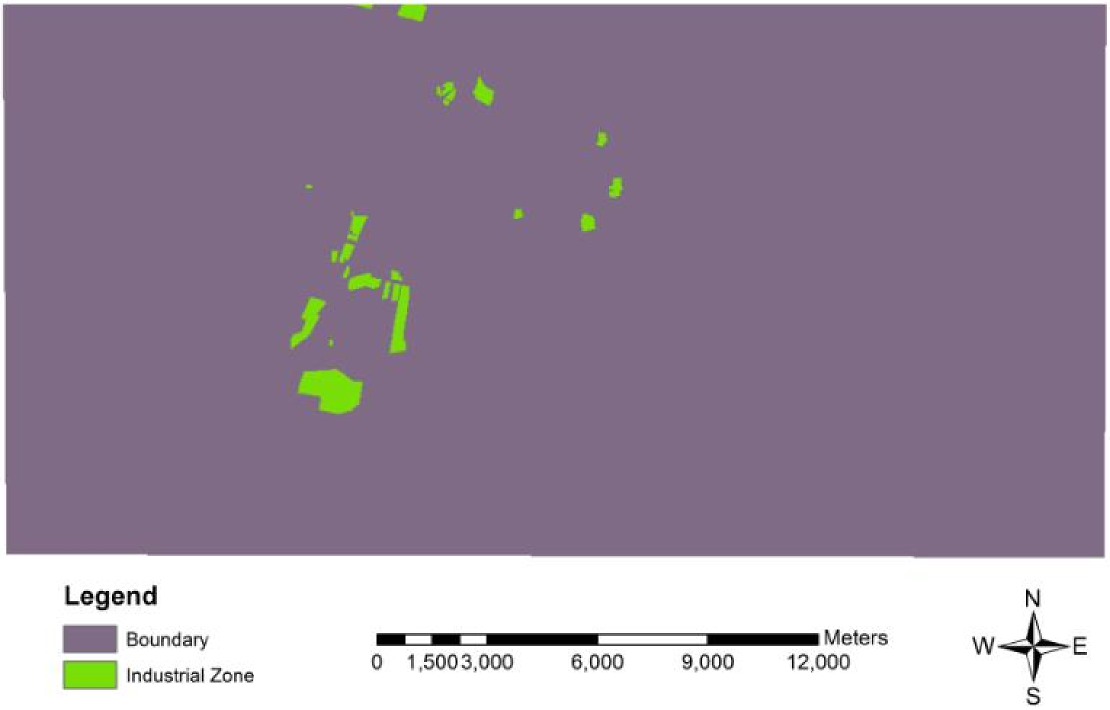
Educational Zone Buffer (MCC, USA)



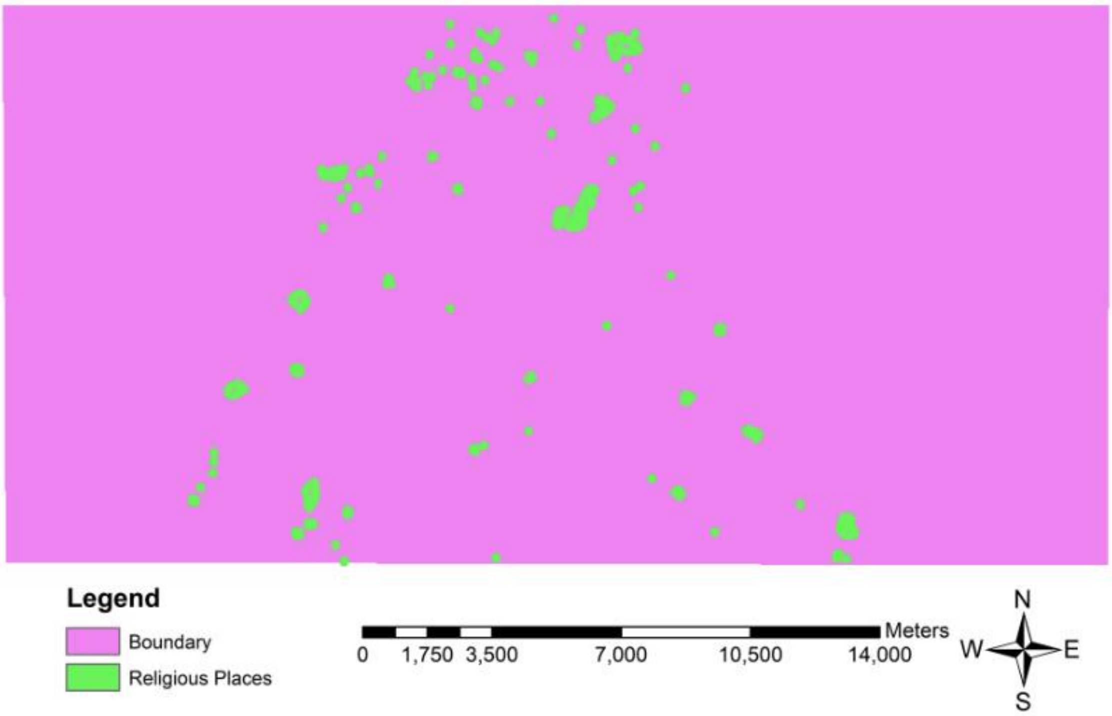
Health Care Zone Buffer (MCC, USA)



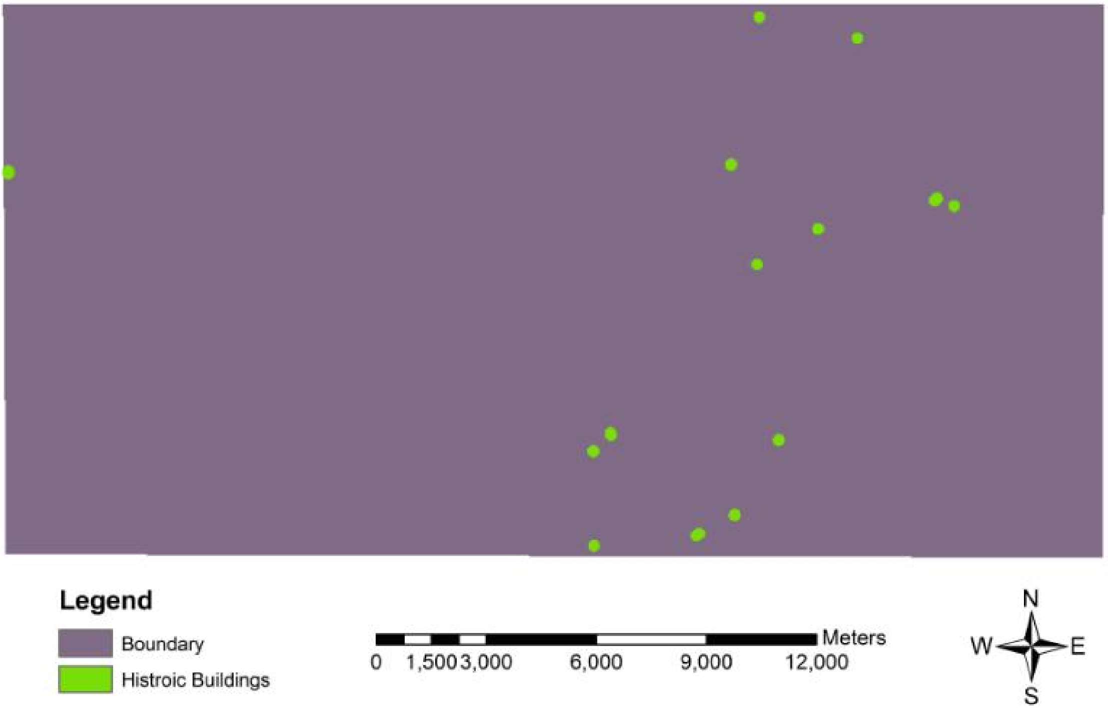
Commercial Zone Buffer (MCC, USA)



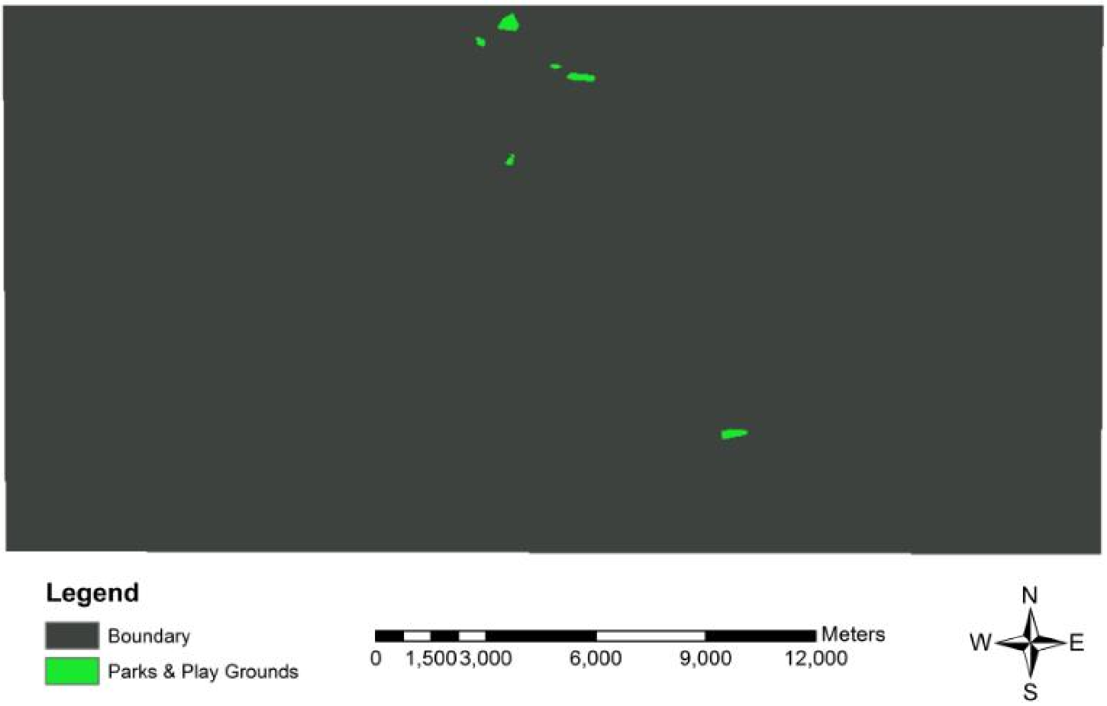
Industrial Zone Buffer (MCC, USA)



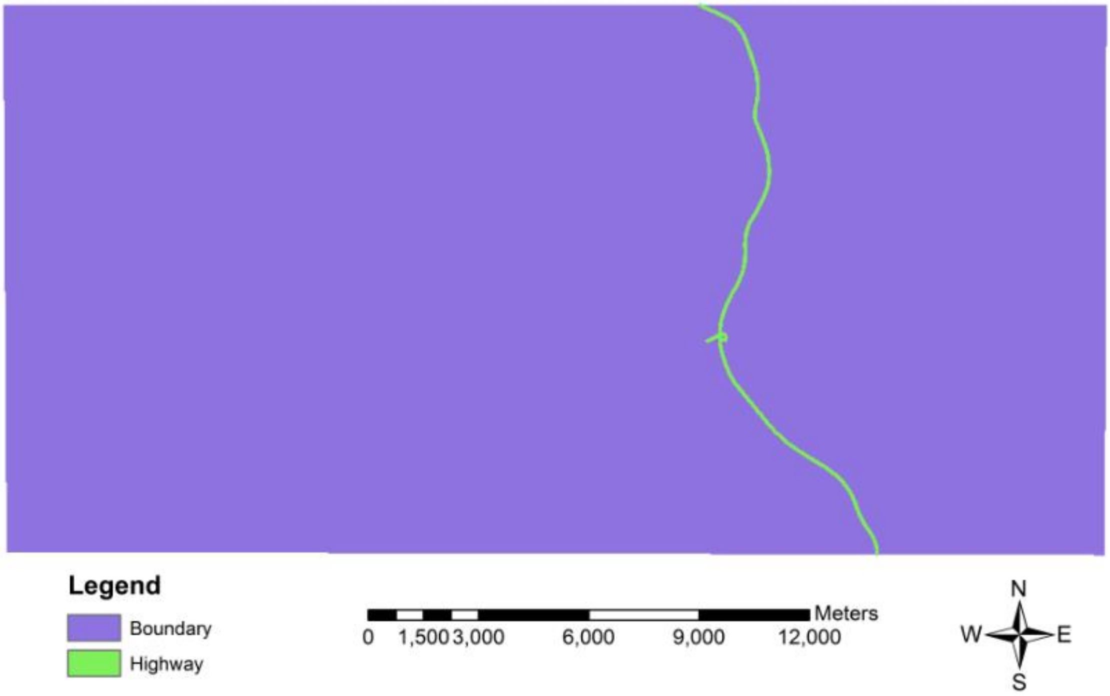
Religious Zone Buffer (MCC, USA)



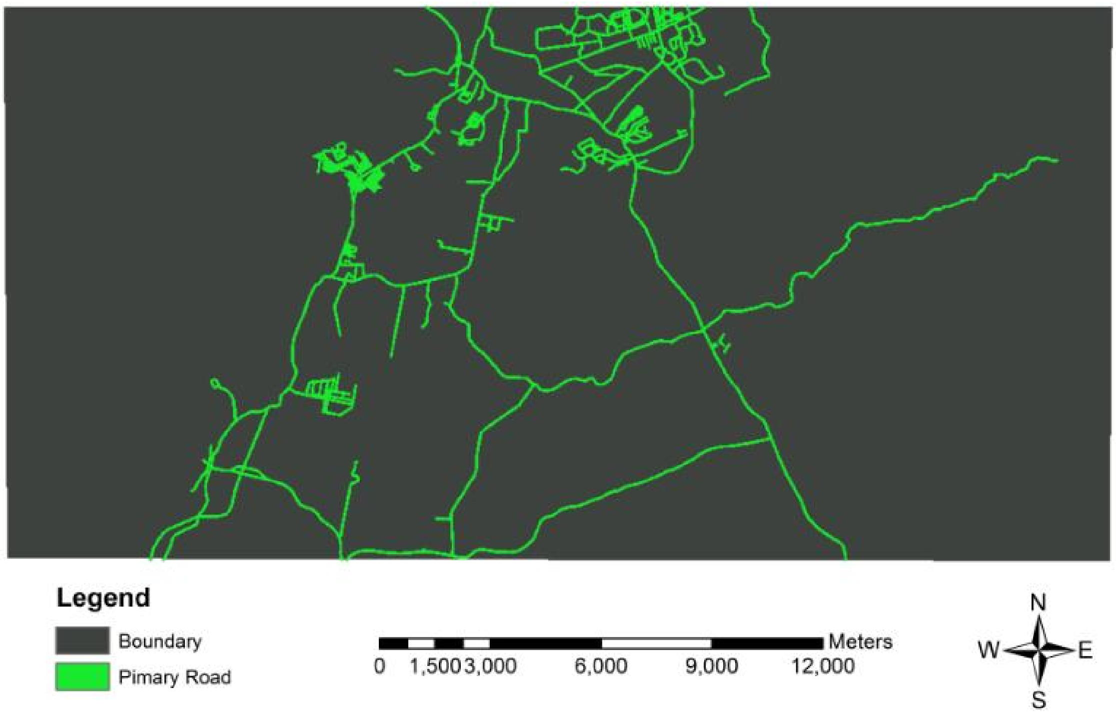
Historic Zone Buffer (MCC, USA)



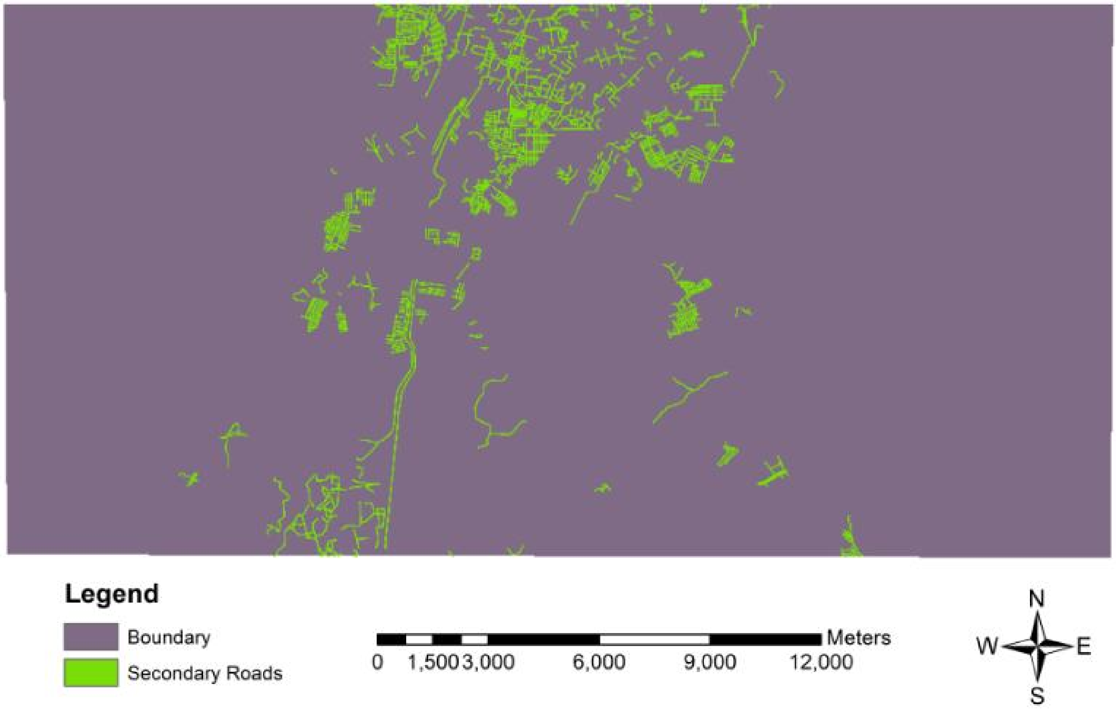
Parks and Playgrounds Zone Buffer (MCC, USA)



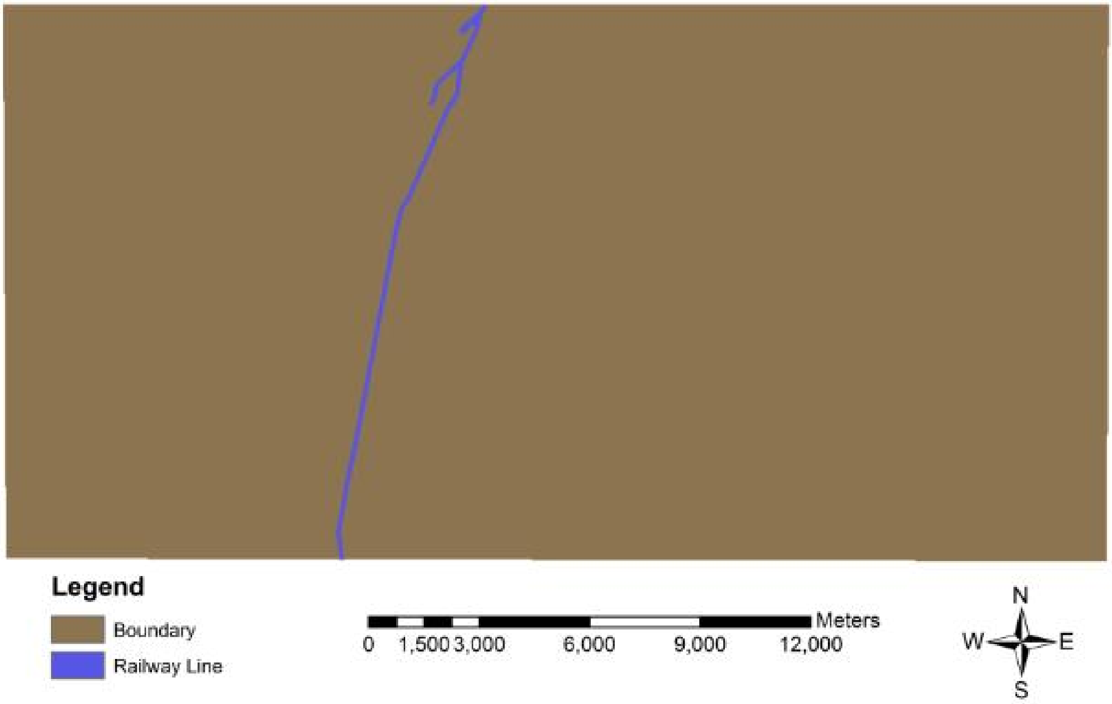
Highway Buffer (MCC, USA)



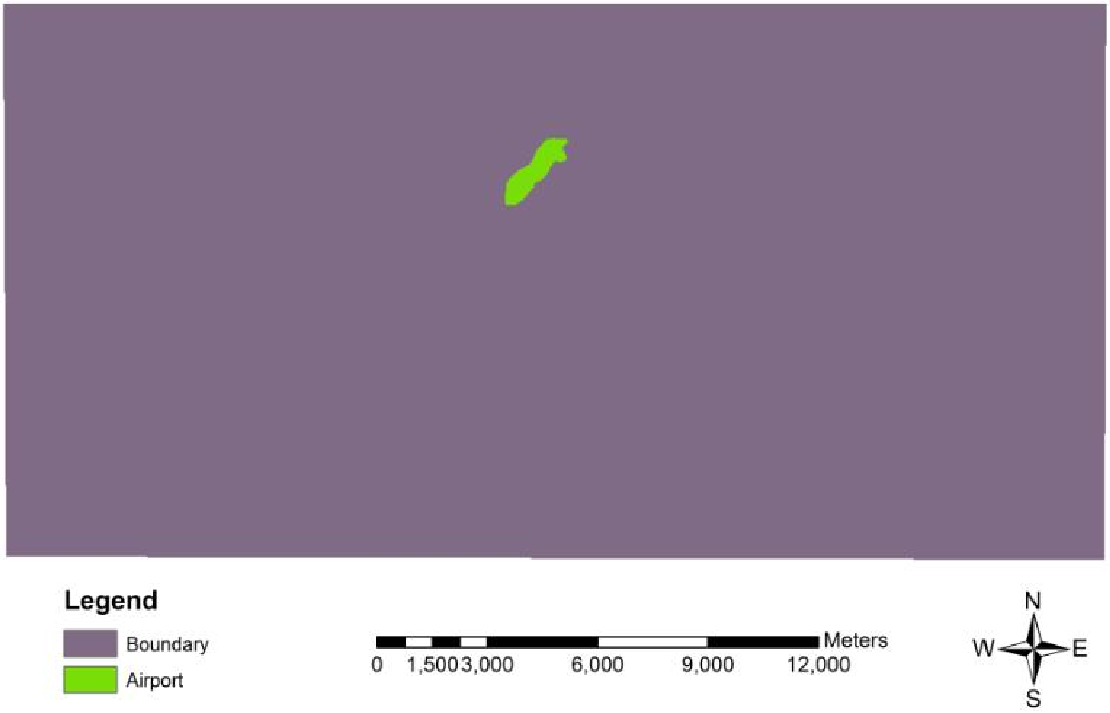
Primary Roads Buffer (MCC, USA)



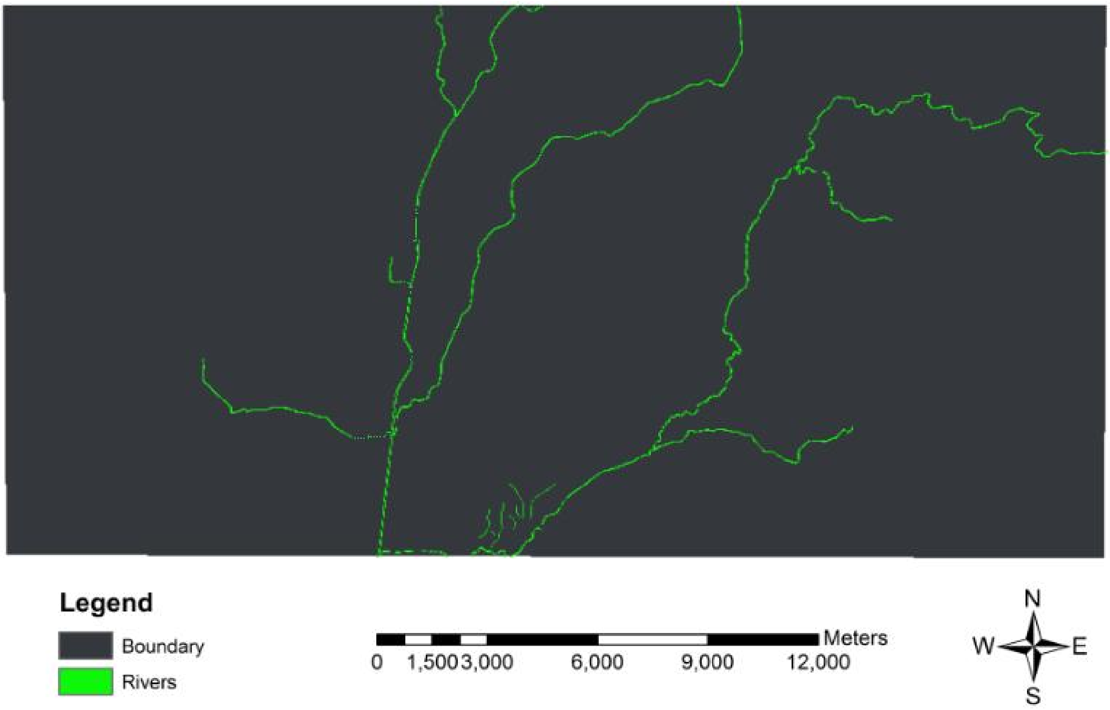
Secondary Roads Buffer (MCC, USA)



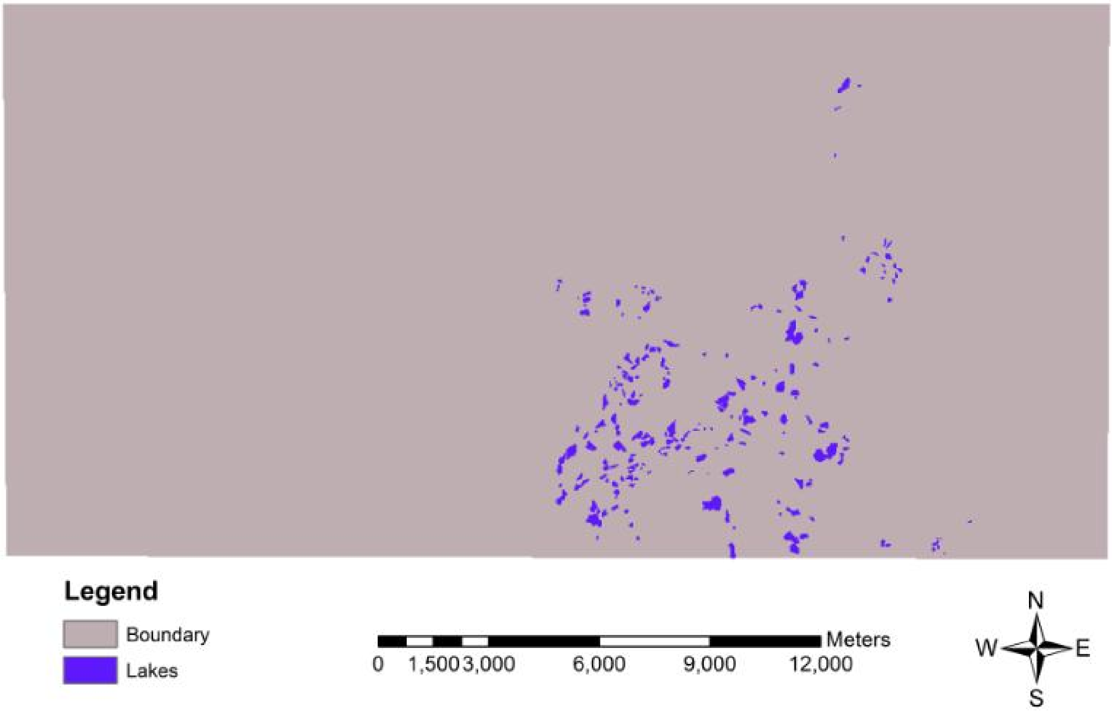
Railway Line Buffer (MCC, USA)



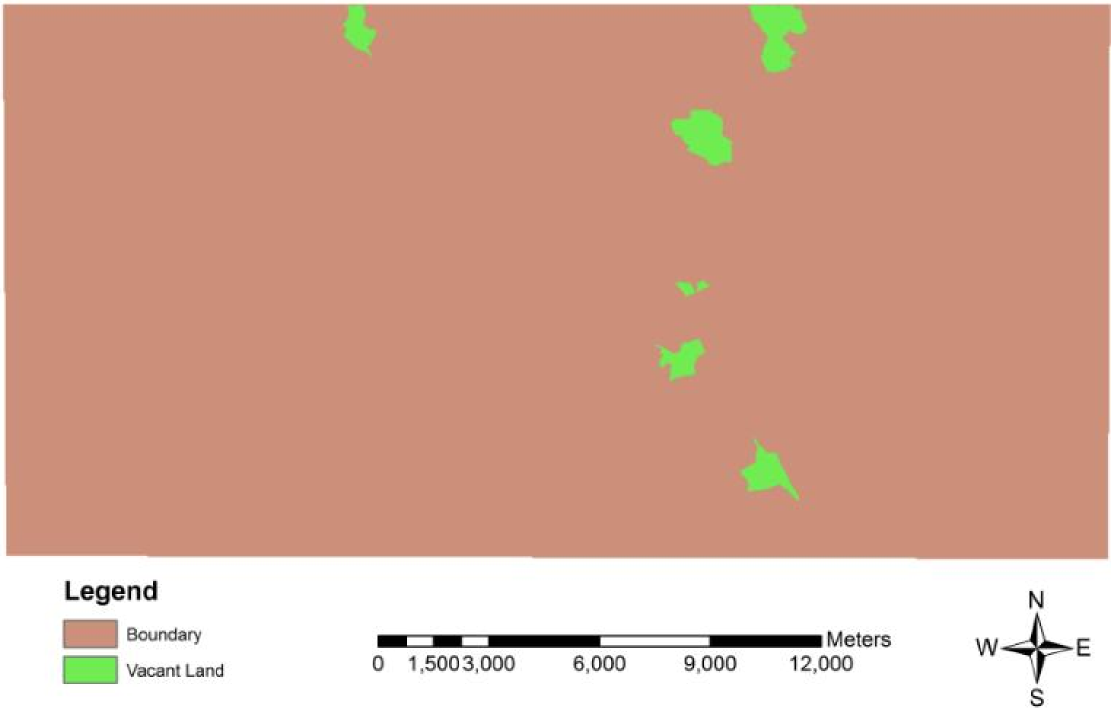
Airport Buffer (MCC, USA)



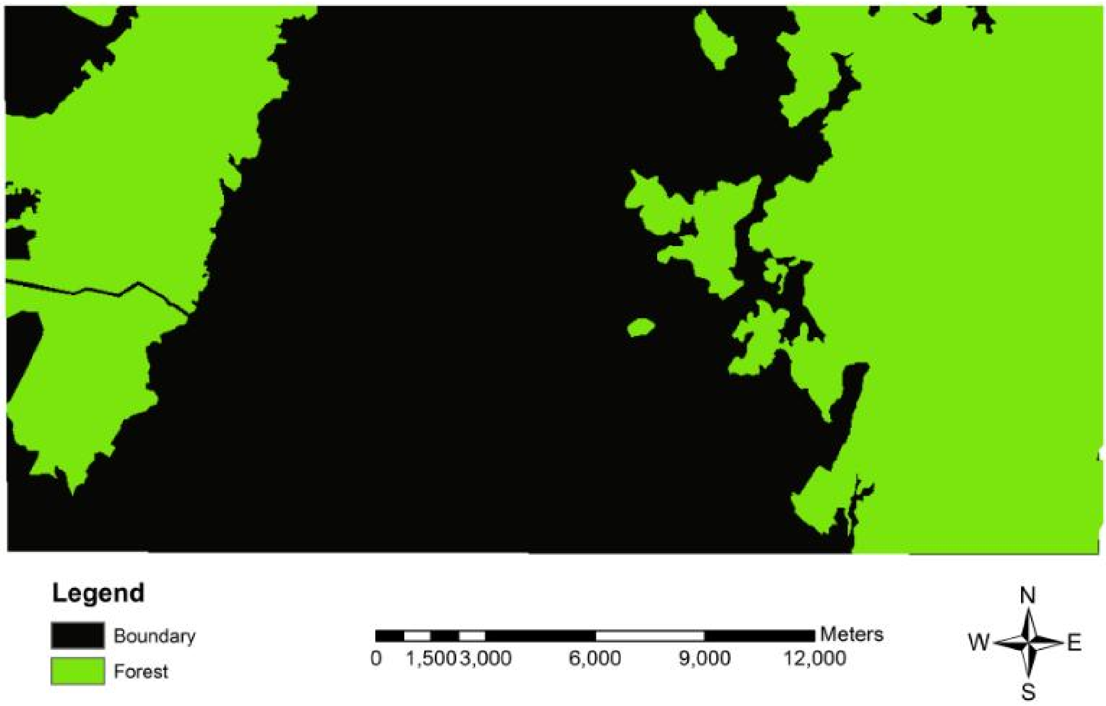
Rivers Buffer (MCC, USA)



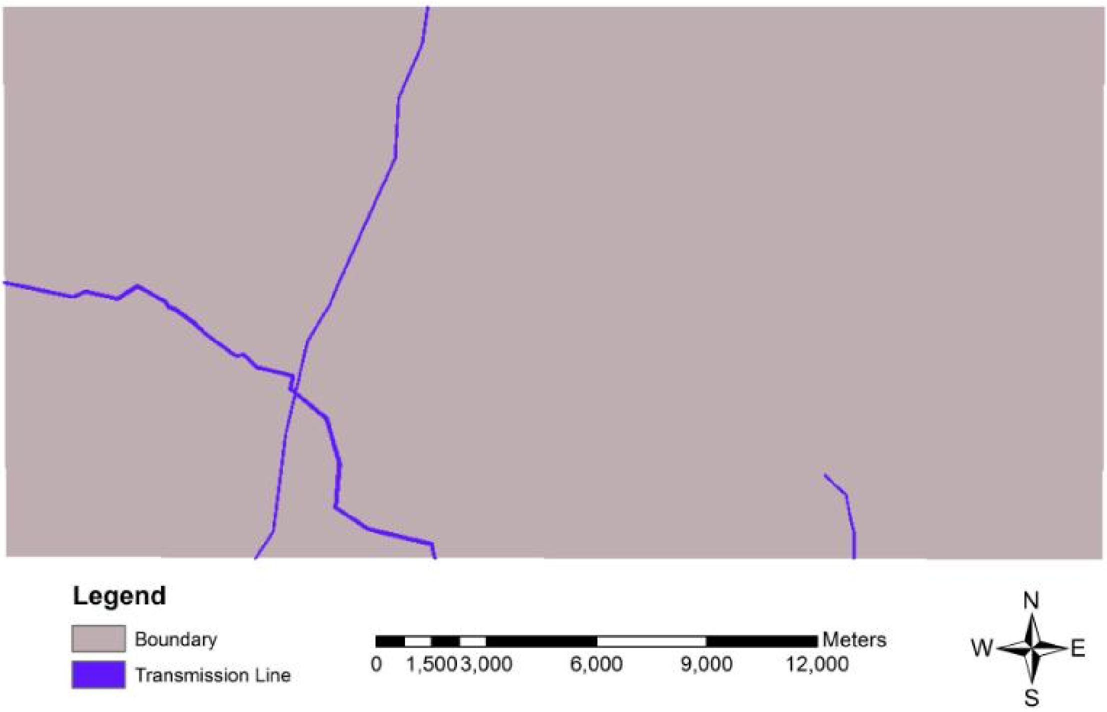
Lakes Buffer (MCC, USA)



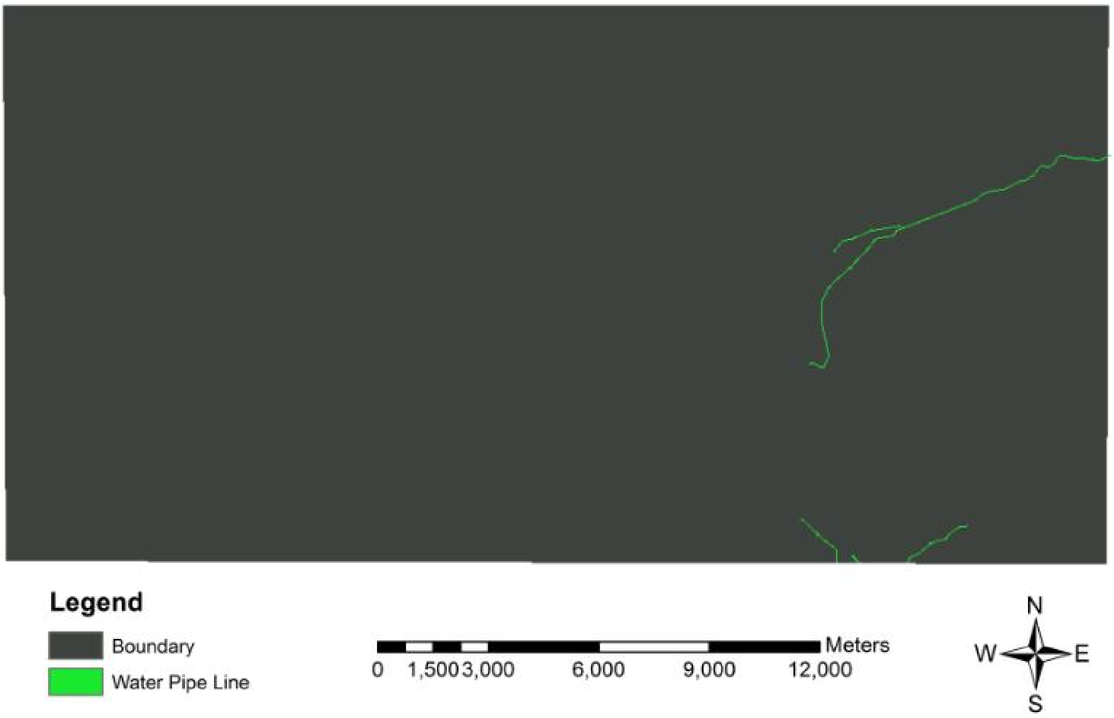
Vacant Land availability in Study Area



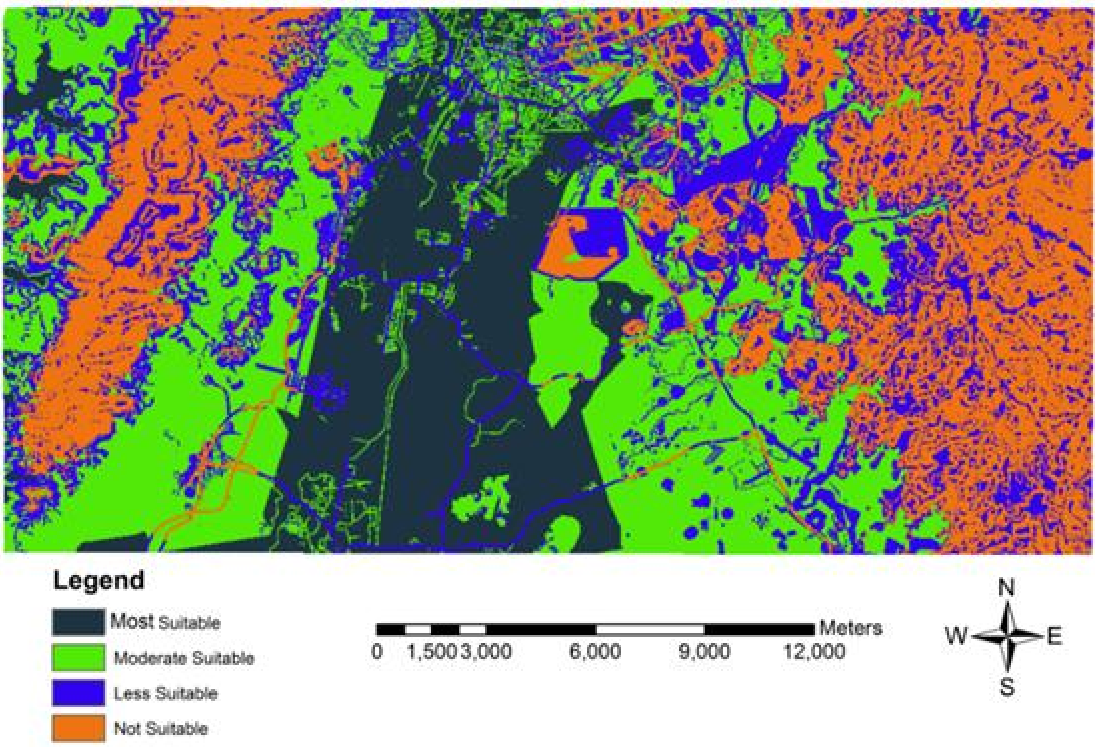
Forest Buffer (MCC, USA)



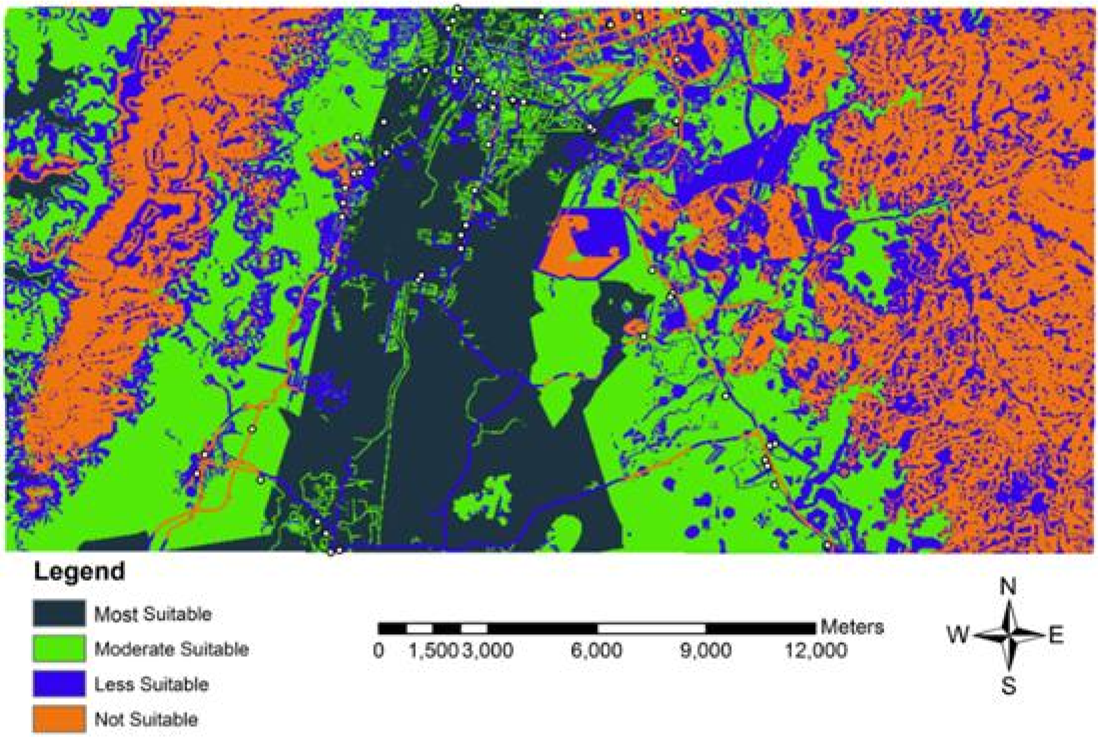
High Voltage Transmission Line Buffer (MCC, USA)



Water Pipes Buffer (MCC, USA)



Final Land Suitability Map for PFS rendering to MCC, USA



Land Suitability Map rendering to MCC, USA with Existing PFS