POTENTIAL SITE SELECTION FOR OBSOLETE PESTICIDE CHEMICAL WASTE DISPOSAL USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES

A CASE OF ADAMITULU PESTICIDES PROCESSING FACTORY, ETHIOPIA

By: Misganaw Kelemework Tadesse

A Thesis Submitted to the School of Graduate Studies, Addis Ababa University in Partial Fulfillment of Requirements for the Masters of Art (MA) Degree in Environment and Sustainable Development

Addis Ababa University

Advisor: Ermias Teferi Demessie (Ph.D.)

October 2020

Addis Ababa, Ethiopia

DECLARATION

I declare that the research entitled "Potential Site Selection for Obsolete Pesticide Chemical Waste Disposal using Remote Sensing and Geographic Information System Techniques, A Case of Adamitulu Pesticides Processing Factory" is original work of my own, has not been presented for a degree of any other university, and all the sources that I have used or quoted have been indicated and acknowledged using referencing. It is submitted in partial fulfillment of the requirements for the degree of Master of Art (MA) in Environment and Sustainable Development at the Development Studies Department of Addis Ababa University.

Misganaw Kelemework Tadesse

Advisors’ Thesis Submission Approval Sheet

This is to certify that the thesis entitled “Potential Site Selection for Obsolete Pesticide Chemical Waste Disposal using Remote Sensing and Geographic Information System Techniques, A Case of Adamitulu Pesticides Processing Factory, Ethiopia” is submitted in partial fulfillment of the requirements for the degree of Master’s with specialization in Environment and Sustainable Development, the Graduate Program of the Department of Development Studies and has been carried out by Misganaw Kelemework Tadesse, under my supervision.

Therefore, I recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department for defense.

Name of Principal advisor --------------------------------- Signature ------------ Date ---------

Name of co-advisor ------------------------------------- Signature ------------ Date --------------

Addis Ababa University

College of Development Studies

School of Graduate Studies

Environmental& Sustainable Development Chair

Potential Site Selection for Obsolete Pesticide Chemical Waste Disposal using Remote Sensing and Geographic Information System Techniques, a Case of Adamitulu Pesticides Processing Factory, Ethiopia

Misganaw Kelemework

____________________	____________	__________
Dean, School of Graduate Studies	Signature	Date
Dr.Shemelis Damene	____________	______________
Name of the Chairperson	Signature	Date
Dr. Ermias Teferi Demessie	____________	____________
Name of Principal Advisor	Signature	Date
Dr. Desalegn Yayahi	____________	___________
Name of External examiner	Signature	Date
Dr.Shemelis Damene	____________	______________
Name of Internal examiner	Signature	Date

Table of content

Contents **Pages**

List of Tables

Pages

List of Figures

Pages

Dedication

This thesis is dedicated to Ethiopian Chemical Industry Corporation staff who had a restless effort to the betterment of the sector in the process of industrialization and who was a volunteer and polite to provide necessary primary and secondary information during data survey for the success of this research.

Acknowledgments

First and foremost, I thank God, the Almighty, who gives me all the strength, determination, and the ability to accomplish this Master's Thesis. The continuous prayer and ethical support of my parents, and friends have given me the energy to tackle the difficulties during my academic years. Next, I am indebted to my principal advisor, Dr. Ermias Teferi, for his continuous guidance, encouragement, and very friendly approach during all the time of the research and writing this thesis. I would never have finished the work without his commitment. I would also like to thank my teacher, Dr. Engdawork Assefa and Befikadu (Ph.D. candidate), from the College of Development Studies (CDS), for their generous initiation, for reading my draft thesis chapters, and kind me insightful comments and corrections. Their contribution was helpful to shape my thesis. I am also glad to express my thanks to Chemical Industry Corporation for sponsoring to learn and supporting my research financially.

I would like to make bigger my gratitude to my coworker at Addis Ababa head office, Ato Mekonnen Zergaw, Ato Tebable Wudineh, Ato Sin Shaw Altamira, Ato Workagegnehu Mekonnen, Ato Teshome Alemu, and all other colleagues, and at the factory, Ato Simeneh Altay, Dr. Teshome Fetene, Ato Teshome, Ato Gemechu and all other associative for giving me general cooperation and bear my one-year thesis work at field and office. I will never forget their contribution. Their manager general also deserves thanks for the one-month permission they gave me while I was out from our office for finalizing my thesis work.

I would also to like thank my sister`s husband, Priest Engineer Yichalewal Goshime for his good hospitality, reading my draft thesis chapters and kind me keen comments and corrections, and the great care he had given me during the times I wrote the thesis before communicating my principal advisor at Addis Ababa University. He is so kind and a loving father. I would also like to thank my sister, W/o Tiruwork Beshir, had it not been for her encouragement, for her good hospitality, and the great care she had given me during the times I learned and wrote the thesis. She is so kind and a loving sister.

I am grateful to the Ministry of Public Enterprise, Ministry of Industry, Environment, Forest and Climate Change Commission, Ministry of Agriculture, Ministry of Health, Ethiopia Geospatial information Institute, Ethiopia Geological Survey, Chemical and Construction Industrial Input Institute, Chemical Industry Corporation, and Adami-Tulu Pesticide Processing Factory, Adami-Tulu zone Administration office and the study woreda, namely, Adami-Tulu Jido Combolch and Gerbi Keble officials for facilitating my entry to the woredas and kebeles and providing me the necessary data for my research. I am also indebted to all my interviewers and survey participants in the fieldwork. I also am indebted special thanks to my language translators and data collectors in the study woredas.

Last but not least, special thanks are due to my sister-in-law, Eyerusalem Yom, who sacrificed much of her time and energy to manage our home, and resisted the living challenges due to my self-sponsored study. I also acknowledge Ato Shimelis Abebaw and Simenesh Fikadu for their understanding and serve their laptop they had given me during my study. I also extend my earnest gratitude to my brother Wubshet Kelemework who is very kindly to assist our family all the time.

Misganaw Kelemework Tadesse

List of acronyms

ADLI: Agricultural Development-Led Industrialization Strategy.

ADLI: Agricultural-Development-Led Industrialization

AFP: Antifouling Paint

AHP: Analytical Hierarchy Process

ANP: Analytical Network Process

APPF: Adami-Tulu Pesticide Processing Factory

APPF: Adami-Tulu Pesticides Processing Factory

CCII: Chemical and construction Input Institute

CIC: Chemical Industry Corporation

CIC: Chemical Industry Corporation

CSA: Central Statistics Agency

CU: Custom Union

DDT: Dichloro dinitro dipheynyl toluene

DEM: Digital Elevation Model

DW: Depth of Water

EC: Emulsifiable Concentration

EEC: Eurasia Economic Committee

EFCC: Environment, Forest and Climate Change

EGII: Ethiopian Geo-Information Institution

EGS: Ethiopian Geological Survey R&D,

EIDS: Ethiopian Industrial Development Strategy

EMA: Ethiopian Metrological Agency

EPPF: Ethiopian Pesticides Processing Factory ISO

FAO: Food and Agricultural Organization (United Nations agency)

FAOSTAT: Food and Agriculture Organization Corporate Statistical Database

FDRE: Federal Democratic Republic of Ethiopia

FGD: Focus Group Discussion

GCP: Ground Control Points

GDP: Gross Domestic Product

GEF: Global Environmental Facility

GEF: Global Environmental Framework

GII: Geospatial Information Institute

GIS: Geographic Information System

GPS: Geographical Position System

GS: Geological survey

GTP: Growth and Transformation Plan

HIV/AIDS: Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome

ICT: Information Communication Technology

IDW: Inverse Distance Weighted

IPM: Integrated Pest Management (IPM)

ISWMP: Integrated Solid Waste Management Plan

IUPAC: International Union of Pure and Applied Chemistry

IVM: Integrated Vector Management

JPSE: Journal of Pesticide Safety Education

L: Liquid formulation

LC50: Lethal Concentration to 50% of the Test Organisms

LD50: Lethal Dose to 50% of the Test Organisms

LDT: Lowest Dose Tested

LSI: Landfill Suitability Index

MA: Ministry of Agriculture

MAO: Municipal Administration Offices

MDG: Millennium Development Goals

MER: Main Ethiopian Rift

MH: Ministry of Health

MoARD: Ministry of Agriculture and Rural Development

MRL: Maximum Residue Limit

MST: Ministry of Science and Technology

MSW: Municipal Solid Waste

MT: Metric Tones

NGOs: Non Governmental Organizations

NIP: National Implementation Plan

OECD: Organization for Economic Cooperation and Development

OFP: Obsolete Finished Product

Ohm-m: Ohm Meter

ORM: Obsolete Raw Materials

PAN: Pesticide Action Network

PASDEP: Plan for Accelerated and Sustained Development to End Poverty

PCB: Polychlorinated biphenyls

PCM: Pairwise Comparison Matrix

PGA: Peak Ground Acceleration rate

POPs: Persistent Organic Pollutants

RS: Remote Sensing

SAW: Simple Additive Weighting

SC: Soluble Concentration

SDPRP: Sustainable Development and Poverty Reduction Program

SIDS: small islands developing states

SL: Soluble Liquid

SMCA: Spatial multi-criteria approaches

SMCW: Sound Management of Chemical and Waste

SPOT5: Satellite Pour I `Observation de la Terre

SRTM: Shuttle Radar Topography Mission

TEQ: Toxic Equivalent

TIN: Triangulation Irregular Network

TSSS: Temporary Storage Site Selection

TSWCR: Turkish Solid Waste Control Regulations

ULV: Ultra Low Volume

UN: United Nation

UNDP: United Nation Development Program

UNEP: United Nations Environment Program

UPOPs: Unintentionally produced POPs

USEPA: The United States Environmental Protection Agency

USGS: United State Geological Survey

UTM: Universal Transverse Mercator

VOC: Volatile Organic Content

WDG: Water Dispersible Granule formulation

WDP: Wetted Dispersible Powder

WFP: World Food Program

WGS: World Geodetic System

WHO: World Health Organization (UN agency)

WMS: Waste Management System

WOA: Weightage Overlay Analysis

WP: Wettable Powder formulation

WPS: Worker Protection Standard

Abstract

A recent study showed that among the problems of chemical wastes, pesticide chemical wastes disposal system is a serious challenge to human health and the environment as well. Particularly, Ethiopian chemical industries have no optimized disposal techniques and potential sites to avoid obsolete pesticide chemicals safely and environmentally friendly. This research attempts to answer how to dispose of pesticide chemical wastes through potential site selection using GIS and RS with the context of developing countries, particularly in Ethiopian Pesticide Chemical Industries. To dispose of obsolete pesticide chemical wastes safely, this study used a GIS-based multi-criterion as an optimized approach to determine temporary site selection. Based on the explored practices & challenges, and the selected disposal criteria and techniques, a suitable potential site was determined for disposing of pesticide chemical wastes. Geographic Information System (GIS) & Remote Sensing (RS) were used as analysis tools to identify the optimum site for disposing of obsolete chemical wastes. Hence, the researcher believes that GIS and RS with the integration of Multi-Criteria Evaluation (MCE) have the potential for selecting a proper temporary storage site in the process of pesticide chemical waste disposal which can reduce cost and minimize risks.

Keywords*: Chemical Waste Management, Geographic Information System, Remote Sensing, Multi-Criteria Analysis, Waste Disposal techniques.*

CHAPTER: ONE

1. Introduction

Pesticide wastes are becoming gradually observable problems throughout the world. All countries have had to face problems of pesticide waste, although the nature of the problems and therefore the focus of attention are somewhat different between the highly industrialized countries and the developing countries (Bourke et al., 1992). In the United States and Europe, for example, pesticide waste management has focused on the handling of wastewater, disposing and recycling of containers, and remediation of contaminated soils (Bourke et al., 1992). For developing countries, disposal of unused, unwanted, or obsolete pesticide stocks has been a major problem that has also created contaminated soils (Jensen & Christensen, 1986).

Pesticide waste disposing of is an important measurement of the waste management system, which requires much attention to avoid environmental pollution impacts. A disposal site should consider all the socio-economic, environmental, and land-use factors for the community living near the site. Modern site identification and selection tools such as Geographical Information System (GIS) and Remote Sensing (RS) can have the potential to analyze and select suitable site selection for industrial or factory wastes' disposal considering all the criteria (Multi-criteria Analysis) which will help to decide the management of pesticide wastes. The researcher of this study believes that the use of GIS in the selection process will reduce the cost, time and improve the accuracy and quality of the work.

1.1 Background and Justification of the study

Chemical Industry Corporation (CIC) which was established by FDRE Council of Ministers Regulation No. 280/2012 was initially established with only one public enterprise and two chemical industry projects. Later on, CIC integrated three more public chemical industries by FDRE Council of Ministers Regulation No. 416/2017 (2009) and it is mandated to represent government investment in the chemical industry.

CIC has been established as a part of the government investment strategy in the chemical sub-sector where the private sector is unwilling and/or unable to invest due to market failure and the risk associated with the sector. The Corporation in its entry phase has been managing state-owned chemical manufacturing enterprises including Mugher Cement Enterprise, Natural Rubber Plant Development, and Product Project, and Coal-based Urea Fertilizer Complex. Later on three chemical industries, namely, Adami Tulu Pesticide Processing, Batu Caustic Soda and Awsh Melkasa Chemical factory have been integrated in late 2017.

Rationally, chemical industries are crucial to the development of any modern economy. The chemical industry is a sub-sector under the manufacturing industry sector which is involved in the manufacturing of chemicals and chemical products. It is a basic subsector that converts major raw materials such as natural gas and minerals into chemical products that are essential in all areas of life, from food to clothing, housing, communications, transport, right through leisure activities. Its products and services are instrumental in meeting the needs of mankind. In short, there is no single product that can be produced without chemicals and chemical products.

In the Ethiopian chemical industry, the only governmental producer (formulator) of pesticides is Adami-Tulu Pesticides Processing Factory (APPF) which was established in August 1995 in the Oromia region. The Factory is mainly involved in the formulation of insecticides with a very limited variety of herbicides, fungicides, and *acaricides*.

APPF has been producing more than 22 pesticide products that are categorized as a liquid, dust, and wettable powder pesticides (See annex X). The factory has a production capacity of1.5. Million-liter liquid/year, and 1.5 million Kg of dust & wettable powder pesticides. APPF has also a repackaging capacity of 2.72 million liters of Ethio 2,4-D 72% SL (Adama Science and Technology University, 2018).

From the annual plan and achievement report of the factory, the pesticide production trend shows a positive slope from 2011 to 2017 and roughly increased by 23% for powder/dust and 39% for liquid pesticide comparing the year 2011 and 2000(Adama Science and Technology University, 2018). The average amount of pesticides produced by the APPF, were 1,017,510.3 liters/year of liquid while the plan was 1,400,251 liters/year and 1.24 ton for powder (dust and wettable) pesticide (APPF annual plan and reports, 2018). Almost all the pesticide products were used by local consumers except 2307 Kg of insect and herbicides were exported to South Sudan in 2017 (Source: APPF stockholder interviews and central statistics agency (CSA)). Even though the trend shows a positive slope for seven years the company’s average performance is only 72.7 %

for liquid pesticides and 98% for powder pesticides. The low performance, specifically for liquid pesticide, of the company, is mainly due to the shortage of hard currency to import the raw materials. (Adama Science and Technology University, 2018).

Challenges of the APPF to be competitive and cover the need of the pesticide products in the country and to participate in the East African market are:

- Lack of skilled researchers in the field, limited/or no R&D activities, and quality control
  - To understand the market fluctuation due to the dynamic nature of the chemicals and weather condition
  - New product development and expansion
  - To analyze the adverse effects of the chemicals on the environment and propose alternative solutions.
- Lack of technical skills and knowledge to dispose of obsolete pesticides; it's also important to note that disposal cost for outdated chemicals is expensive.
- Limitation of quality packaging infrastructure
- Limited production types; up to date, the factory is formulating only insecticides and few verities of Herbicides, fungicides, and *acaricide*. It has to be able to diversify and increase the number of products based on need assessment.
- Foreign dependency on raw materials and spare parts and also it takes more than four months to import them.
- Lack of skilled machine and electric maintenance personnel.

Therefore, this study focuses on the recent practices and challenges of pesticide chemical waste disposal and the way how to overcome these challenges via scientific solutions. Facts that were missed in the past works about disposal technique were identified as literature gaps which provide solutions on the disposal of obsolete pesticides and to add on the body of knowledge particularly in the Ethiopian context.

1.2 Statement of the Problem

It is well known that due to the accelerated transformation of the country’s economy from agricultural-based to industrial, there will be a significant increment of the industrial establishment. This transformation fosters economic growth, employment opportunity, well-being life of citizens, etc. However, with the expansion of industries, particularly chemical industries, there will be environmental pollution which hurts the health of the community and ecology of the ecosystem.

Past scientific findings showed that developed nations have best practices in utilizing optimized chemical waste disposal system to prevent their environment and citizens from chemical waste pollution and contaminations. However, the trend of developing nations, such as Ethiopia indicates that chemical wastes are not properly identified and disposed of in which some of them keep in the store for a long time, some of them throwing anywhere and everywhere. One of the reasons for these effects is that most Ethiopian chemical industries have no policies and strategies to dispose of chemical wastes and to make them environmentally friendly using an optimized approach. Besides, there has been also a financial shortage, lack of knowledge, and lack of appropriate technology. Due to these shortcomings, particularly in the chemical industry, there have not optimized disposal techniques and potential sites to dispose of expired and obsolete pesticide chemical wastes safely and environmentally friendly. Furthermore, the awareness of the community about the effect of chemical waste is low. The cumulative effect of those above-stated reasons have brought polluted environment, unhealthy community, lower per capita income (lower GDP), poverty and hinder sustainable development. Therefore, this study focuses on the exploration of the recent practice and challenge, the identification of obsolete pesticide chemical wastes disposal methods, the determination of optimized criteria, and selection of temporary storage potential sites to dispose of obsolete pesticide chemical wastes safely and environmentally friendly.

1.3 Research Questions

1. What are the recent practices and challenges of the Adamitulu pesticide Processing factory about waste management?
2. What are the common techniques utilized for disposing of obsolete pesticide chemical wastes?
3. Which criterion is optimum to select appropriate sites to dispose of pesticide chemical wastes?
4. How to select a potential and suitable site for disposing of obsolete pesticide chemical waste?

1.4 Objectives of the study

1.4.1 General objective

The main objective of this study is to develop an implementation framework for disposing of pesticide chemical wastes through potential site selection using GIS and RS in the context of developing countries.

1.4.2 Specific objectives

1. To explore the recent practices and challenges of Adamitulu Pesticide Processing Factory concerning waste management.
2. To identify obsolete pesticide chemical wastes' disposal techniques.
3. To determine optimized criteria in the identification of suitable sites for disposing of obsolete pesticide chemical wastes using multi-criteria analysis.
4. To select optimum temporary storage potential sites for disposing of obsolete pesticide chemical wastes through environmentally friendly approaches.

1.5 Significance of the study

The study is useful from multi-dimensions. As we know, wastes require special handling, because they bring a serious threat to the human and the environment if they are mismanaged. Therefore, the findings of this research would help the factory managers, experts, politicians, and the local governments by showing them clearly how to handle and manage pesticide chemical wastes safely and environmentally friendly.

Now a day, due to the alarming generation of chemical wastes, their management and disposal techniques have been a global challenge. So this study shows how to solve and minimize pesticide waste generation and mismanagement through the integration of GIS &RS technology which is used to locate a suitable pesticide chemical waste disposal site. Furthermore, the outcomes of this study might have a contribution for policymakers, stakeholders, government, and NGOs, and factory and industry managers engaged in chemical production activities and it also provides insightful clues for further researchers in the area of such kind of study.

1.6 Scope of the Study

The study follows a problem-solving approach that investigates obsolete pesticide chemical waste disposal techniques in the pesticide processing factory of Adamitulu. The study is conducted to select appropriate sites for disposing of obsolete pesticide chemical wastes through remote sensing and geographic information system techniques. A multi-criteria evaluation was applied for the selection of optimized obsolete pesticide chemical waste disposal techniques. The roles and harmonization of national chemical institutions (Ministry of Public Enterprise, Ministry of Industry, Ministry of Environment, Forest and Climate Change, Ministry of Agriculture, Ministry of Health, Chemical Industry Corporation, and Adami-Tulu Pesticide Processing Factory) would be included in this scope.

1.7 Limitation of the study

There were many challenges faced by the researcher during the accomplishment of this study. The first impending event to accomplish the task is the time limitation to investigate the study further. In addition to this, financial (budget) limitations to fulfill the expected budget of the study (field survey and data collection cost, material and equipment cost, transportation and telephone cost, documentation cost, facilitation cost, etc.) which limited the researcher to conduct further investigation on the validity and reliability of the research output. Furthermore, the unwillingness of some respondents to give reliable data and information, to be a volunteer for interviewing and focus group discussion were undeniable limitations during the research process.

Primarily, the researcher aimed to conduct the analysis of site suitability at the Woreda level using GIS and RS. However, due to the lack of high capacity computer to process images, the researcher was obliged to select a specific area (Kebele at which the factory is planted) that might have an impact on the accuracy and precision of the output.

1.8 Ethical considerations

As a student who can get access to different documents and personal information, the researcher obeys the ethical values and situations not to disclose any data or information to others. Furthermore; the researcher would use the data and information only for the research. It is only the owner of this study who would have access to the information collected through the interviews, observations, surveys, and document analysis.

1.9 Organizations of the Thesis

This study consists of five chapters. The first chapter deals with the introduction. The second chapter has a detailed survey of the literature review. The third chapter consists of the methodology part of the study. The fourth chapter deals with the result and discussion part of the study and finally, a summary and recommendation will be given.

CHAPTER TWO

Literature Review

2.1 Definition of Terms

The International Code of Conduct on the Distribution and Use of Pesticides defines a pesticide as: "Any substance or mixture of substances intended for preventing, destroying or controlling any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies. The term includes substances intended for use as a plant growth regulator, defoliant, desiccant or agent for thinning fruit or preventing the premature fall of fruit, and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport" (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001)

"**Obsolete Pesticides**" are defined as those pesticides that can no longer be used for their intended purpose or wanted to be used and therefore must be disposed of (Javier M, 2004).

Because of their characteristics "obsolete pesticides" **are hazardous wastes**, and therefore they must be managed as such (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Stockpiles Inventory: - An obsolete pesticide stockpile inventory consists of a list that includes different types of stockpiles, storage site, types of products and wastes present, quantities, storage condition, and risks. The inventory is a management tool that allows obtaining accurate information needed to make a diagnosis of the stockpiles condition, assess the magnitude of the problem, prioritize and draw up action plans (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Active ingredient: - means the biologically active part of the pesticide (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001)

Banned Pesticide:- means a pesticide for which all users have been prohibited by final regulatory action, to protect human health or the environment. The term includes a pesticide that has been refused approval for first-time use or has been withdrawn by industry either from the domestic market or from further consideration in the domestic approval process, and where there is clear evidence that such action has been taken to protect human health or the environment (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001)

Disposal: - means any operation to recycle, neutralize, destructor isolate pesticide wastes, used containers, and contaminated materials (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Formulation: - means the combination of various ingredients designed to render the product useful and effective for the purpose claimed; the form of the pesticide as purchased by users (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Co-formulant means a non-active ingredient component of a formulated product (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Hazard: - means the inherent property of a substance, agent, or situation having the potential to cause undesirable consequences (e.g. properties that can cause adverse effects or damage to health, the environment, or property) (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Exposure to pesticides means any contact between a living organism and one or more pesticides (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Label: -means the written, printed, or graphic matter on, or attached to, the pesticide or the immediate container thereof and also to the outside container or wrapper of the retail package of the pesticide (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Manufacturer: - means a corporation or other entity in the public or private sector or any individual engaged in the business or function (whether directly or through an agent or entity controlled by or under contract with it) of manufacturing a pesticide active ingredient or preparing its formulation or product (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Marketing means - the overall process of product promotion, including advertising, product public relations, and information services as well as the distribution and sale on local or international markets (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Maximum Residue Limit (MRL):- means the maximum concentration of a residue that is legally permitted or recognized as acceptable in or on a food or agricultural commodity or animal feedstuff (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Packaging: - means the container together with the protective wrapping used to carry pesticide products via wholesale or retail distribution to users (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Personal protective equipment: - means any clothes, materials, or devices that protect from pesticide exposure during handling and application. In the context of this Code, it includes both specifically designed protective equipment and clothing reserved for pesticide application and handling (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Pesticide industry: - means all those organizations and individuals engaged in manufacturing, formulating, or marketing pesticides and pesticide products (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Pesticide legislation: - means any laws or regulations introduced to regulate the manufacture, marketing, distribution, labeling, packaging, use, and disposal of pesticides in their qualitative, quantitative, health, and environmental aspects (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Pesticide management means the regulatory and technical control of all aspects of the pesticide life cycle, including production (manufacture and formulation), authorization, import, distribution, sale, supply, transport, storage, handling, application, and disposal of pesticides and their containers to ensure safety and efficacy and to minimize adverse health and environmental effects and human and animal exposure (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Poison: -means a substance that can cause disturbance of structure or function, leading to injury or death when absorbed in relatively small amounts by human beings, plants, or animals.

Poisoning:- means the occurrence of damage or disturbance caused by a poison, and includes intoxication.

Product (or pesticide product): - means the pesticide active ingredient(s) and other components, in the form in which it is packaged and sold.

Registration: - means the process whereby the responsible national government or regional authority approves the sale and use of a pesticide following the evaluation of comprehensive scientific data demonstrating that the product is effective for the intended purposes and does not pose an unacceptable risk to human or animal health or the environment.

Repackaging: -means the authorized transfer of a pesticide from any commercial package into any other, usually smaller, a container for subsequent sale (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Residue: -means any specified substances in or on food, agricultural commodities, or animal feed resulting from the use of a pesticide. The term includes any derivatives of a pesticide, such as conversion products, metabolites, reaction products, and impurities considered to be of toxicological significance. The term "pesticide residue" includes residues from unknown or unavoidable sources (e.g. environmental) as well as known uses of the chemical (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Responsible authority: - means the government agency or agencies responsible for regulating the manufacture, distribution, or use of pesticides and more generally for implementing pesticide legislation.

Toxicity: - means a physiological or biological property that determines the capacity of a chemical to do harm or produce injury to a living organism by other than mechanical means (FAO-UN, 2002)

Chemical: Any basic substance that is used in or produced by a reaction involving changes to atoms or molecules.

Potential Site: A specific project site that has the potential capacity, and containment for chemical waste storage but requires more data acquisition and further evaluation to be defined as a qualified Site (Albany, et.al, 2017; Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Qualified Site: A project site that has to meet all required technical and non-technical criteria for chemical waste storage and is ready to permit(Albany, et.al, 2017; Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Selected Area: A project area that shows sufficient capacity, and containment for chemical waste storage but is currently poorly defined and requires more data acquisition and further evaluation to define Potential Sites (Albany, et.al, 2017; Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Site Characterization: The process of evaluating Potential Sites to identify one or more Qualified Sites, which are viable for storage and ready to permit. Technical and non-technical data is used and data sampling/analysis is site-specific(Albany, et.al, 2017; Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Site Characterization involves two stages: (1) Initial Characterization involves an analysis of available site-specific information and (2) Detailed Characterization involves site-specific field acquisition and analysis of new data (Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Site Screening: The process of evaluating Sub-Regions within basins or other large geographic regions and identifying Selected Areas within those regions that warrant additional investigation for storage. Available technical and non-technical data is used and data sampling/analysis is coarse(Albany, et.al, 2017; Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

Site Selection: The process of evaluating Selected Areas and identifying Potential Sites within those areas, which warrant additional investigation for storage. Available technical and non-technical data are used, and data sampling/analysis is necessary and sufficient to identify individual sites(Albany, et.al, 2017; Javier M, 2004; Bourke et al., 1992; Blackman Jr, 2001).

2.2 Strategy & Policy Review of Ethiopia

The Federal Democratic Republic of Ethiopia (FDRE) has put remarkable effort to achieve broad-based, accelerated, and sustained economic growth to eradicate poverty during the past two decades. To this effect, three major national policies /strategies /national plans are designed and implemented. These are:

- Agricultural Development-Led Industrialization Strategy (ADLI). Within the framework of ADLI, the "Ethiopian Industrial Development Strategy'' (EIDS) was launched in 2004 and implemented to accelerate the industrial development of the country.
- Plan for Accelerated and Sustained Development to End Poverty (PASDEP) was implemented (MoFED, 2009).
- The First Growth and Transformation Plan (GTP I) gives due emphasis to promoting the manufacturing sector and the role of chemical industries becomes highly significant (MoFED, 2013).

Ethiopia's development strategy up to the end of GTP I was Agricultural-Development-Led Industrialization (ADLI). In this long-term strategy, agriculture has played a leading role in the growth of the country's economy. Its broad objectives were to modernize agriculture and improve its efficiency and productivity, ensure food security, create employment opportunities and enhance the country's foreign exchange earnings to promote the development of a vibrant industrial sector and accelerate overall economic growth. ADLI is supplemented by sector-specific strategies in areas such as health, education, ICT, population, industry, etc.

In the framework of ADLI, Ethiopia has been implementing two sets of macro-economic programs since 2002/3 which are designed to accelerate the reduction of poverty in a sustainable manner. The central objectives of these programs were to address the human development needs and achieving the Millennium Development Goals(National Planning Commission and the United Nations in Ethiopia,2015). These programs were:

(1) The "Sustainable Development and Poverty Reduction Program (SDPRP)" that lasted from 1995 to 2004/05 and

(2) “Plan for Accelerated and Sustained Development to End Poverty (PASDEP)” from 2005/6 to 2009/10.

SDPRP focused on accelerating progress mainly in education and health, expanding the infrastructure, opening the economy, building institutions, and further delegation of governance to the district level. Ethiopia’s vision is to transform Ethiopia into a middle-income country by 2025. This is stated in the 2009/10 Green Paper by the Ministry of Science and Technology: "to see Ethiopia become a country where a democratic rule, good governance and social justice reign upon the involvement and free-will of its peoples, and once extricating itself from poverty becomes a middle-income economy" (as recognized by a per capita income of 1000 USD by 2025).

The GTP I has formulated national strategic pillars that boost industrial development. These are:

- ✓ Sustainable rapid economic growth
- ✓ Maintaining agriculture as a major source of economic growth
- ✓ Creating favorable conditions for industry to play its role in the industry
- ✓ Enhancing expansion and ensuring the quality of infrastructural development
- ✓ Expansion of social development and generating their quality
- ✓ Strengthening good governance and capacity building; and
- ✓ Empowering women and youth and ensuring their benefits

In the GTP I, one major focus areas for industrial development was the development of Medium and Large Scale Manufacturing Industries by identifying the following prioritized sub-sectors. These are:

- ✓ Textile and Garment Industries
- ✓ Leather and Leather Products Manufacturing Industries
- ✓ Agro-Processing including Sugar Industries
- ✓ Chemical / including Cement /and Pharmaceutical Industries
- ✓ Metal and Metal Engineering Industries

By the end of GTP I, the government has implemented different development interventions to speed up the industrialization process of the country and improve the living standard of the population at large. The country's economic growth and development strategy in the GTP II focus primarily on the promotion of Industry-Led Economic Development where the manufacturing sector plays a dominant role in the overall industrialization process.

2.3 Global Analysis of Chemical Industry

Chemicals are an integral part of modern daily life. Scientific findings showed that there is hardly any industry where chemical substances are not used and there is no single economic sector where chemicals do not play an important role. Thus, chemicals are used in a wide variety of products and processes and are the major contributors to national and world economies. Consequently, the chemical industry is one of the key industries with great contribution to the world economic output. The industry is one of the largest employers and contributes to welfare and employment on a global scale.

Chemical industries are heterogeneous with many sectors such as organic, inorganic, dyes, paints, pesticides, and specialty chemicals. They are produced in selected countries, which have advanced technology and production skills.

The chemical industry is generally categorized into the following three broad segments:

1. **Basic chemicals**, also known as commodity chemicals, include organic and inorganic chemicals, bulk petrochemicals, other chemical intermediates, plastic resins, synthetic rubber, man-made fibers, dyes, and pigments, printing inks (Kemf, 2013; UN, 2011; Feunang et al., 2016).
2. **Agricultural chemicals** are another group of chemicals that include fertilizers and crop protection chemicals such as pesticides (Kemf, 2013; UN, 2011; Feunang et al., 2016).
3. **Specialty chemicals** are low volume but high-value compounds, and are also known as performance chemicals. These chemicals are derived from basic chemicals and are sold based on their function. For example, paint, adhesives, electronic chemicals, water management chemicals, oilfield chemicals, flavors and fragrances, rubber processing additives, paper additives, industrial cleaners, and fine chemicals. Sealants, coatings, catalysts also come under this category (Kemf, 2013; UN, 2011; Feunang et al., 2016).

2.4 Global Production, Trade, Use and Disposal of Chemicals and their Health and Environmental Effects

There have been increasing chemical intensification of the economy both the continuous growth trends and the changes in global production, trade, and use of chemicals point toward an increasing chemical intensification of the economy. This trend affects all countries but will particularly exert an added chemicals management requirement on developing countries and countries with economies in transition that often have limited capacities to deal with such complex challenges.

This chemical intensification of the economy derives largely from three factors:

1. The increased volume and a shift of production and use from highly industrialized countries to developing countries and countries in economic transition;
2. The penetration of chemical-intensive products into national economies through the globalization of sales and use;
3. The increased chemical emissions resulting from major economic development sectors (Kemf, 2013; UN, 2011; Feunang et al., 2016).

2.5 Production, Imports, Shifts, and Uses of chemicals from Highly Industrialized to Developed Countries

Studies, projecting trends to 2050, forecast that global chemical sales will grow about 3% per year to 2050. However as chemical production, trade, use, and disposal continue to expand worldwide, this expansion is not evenly distributed geographically. Chemical manufacturing and processing activities, once largely located in highly industrialized countries, are now steadily expanding into developing countries and countries with economies in transition. Chemical use in developing countries is influenced both by countries' needs for additional production domestically and by production-related to trade (Kemf, 2013; UN, 2011; Feunang et al., 2016).

2.5.1 Penetration of Chemical Intensive Products into National Economies

Many countries are primarily importers of chemicals and are not significant producers. Agricultural chemicals and pesticides used in farming were among the first synthetic chemicals to be actively exported to developing countries. Today, as consumption of a wide range of products increases over time, these products themselves become a significant vehicle increasing the presence of chemicals in developing and transition economies. These include liquid chemical personal care products for sale directly to consumers; paints, adhesives, and lubricants; as well as chemically complex articles ranging from textiles and electronics to building materials and toys.

In some instances, the most significant human and environmental exposures occur through product use and disposal and are added to those occurring during manufacturing (Kemf, 2013; UN, 2011; Feunang et al., 2016).

2.5.2 Increased Chemical Emissions Resulting from Major Economic Development Sectors

Total pesticide expenditures in South Africa rose 59% over the period 1999 to 2009, and are projected to rise another 55% in the period 2009 to 2019. Individual industries that are users of chemicals or that emit a significant amount of chemicals as unintentional by-products also contribute to the chemical intensification of national economies. As developing countries and those in economic transition increase their economic production, the related chemical release has raised concern over adverse human and environmental effects (Kemf, 2013).

Chemical contaminations and wastes associated with industrial sectors of importance in developing countries include pesticides from agricultural runoff; heavy metals associated with cement production; dioxin associated with electronics recycling; mercury and other heavy metals associated with mining and coal combustion; butyl tins, heavy metals, and asbestos released during ship breaking; heavy metals associated with tanneries; mutagenic dyes, heavy metals and other pollutants associated with textile production; and toxic metals, solvents, polymers, and flame retardants used in electronics manufacturing. An added concern includes the direct exposure resulting from the long-range transport of many chemicals through environmental media that deliver chemical pollutants that originate from sources thousands of kilometers away (Kemf, 2013; UN, 2011; Feunang et al., 2016).

2.5.3 Health and Environmental Effects of Chemical Exposures: An Increasingly Complex Challenge

The release of chemicals continues to affect all aspects of natural resources including the atmosphere, water, soil, and wildlife. Chemicals released into the air can act as air pollutants as well as greenhouse gases and ozone depletes and contributes to acid rain formation. Chemicals can contaminate water resources through direct discharges to bodies of water, or via deposition of air contaminants to water. This contamination can have adverse effects on aquatic organisms, including fish, and on the availability of water resources for drinking, bathing, and other activities (Kemf, 2013; UN, 2011; Feunang et al., 2016). It is common for soil pollution to be a direct result of atmospheric deposition, dumping of waste, spills from industrial or waste facilities, mining activities, contaminated water, or pesticides (Kemf, 2013; UN, 2011; Feunang et al., 2016).

Environmental effects of the chemical intensification of the national economies are furthermore compounded by the trans boundary movement of chemicals through the air or water. Throughout the globe, atmospheric air currents deliver chemical pollutants that originate from sources some thousands of kilometers away (Kemf, 2013; UN, 2011; Feunang et al., 2016).

In conclusion, chemicals will be produced and used in ways that minimize significant adverse impacts on the environment and human health will require a more concerted effort by international agencies, national and local governments, business and civil society organizations. Corporations will need to assume more responsibility for safe chemical production and sound management all along the value chain. Governments will need to adopt and more effectively implement instruments and approaches, define responsibilities and improve administrative and strategic coordination. This also requires providing developing countries and countries with economies in transition with technical assistance, technology transfer, institutional capacity building, and training on the new methods and tools that are being used today by developed countries, the private sector, and civil society (Kemf, 2013; UN, 2011; Feunang et al., 2016).

The absence of effective chemical management by governments, corporations, and international bodies leads to market uncertainties in developing countries and countries with economies in transition. It inhibits risk-aware financial institutions in the investment and banking sectors from making an investment that supports strong economic development. Additional financing for chemical management may come from economic instruments for cost integration and recovery within countries. Such funding has to be triggered and complemented by international financing from national and international development assistance programs. To be effective and sufficiently funded and sustainably maintained, sound chemical management must be comprehensively mainstreamed into national, social, and economic planning and be coordinated internationally (Jacobs, Massye Rachel, and Molly, 2013).

Sound chemicals management is a vital element that underpins each aspect of a green economy and should be integrated not only by investments in natural capital in the realm of agriculture, fisheries, forest, and water, but also in the investment in energy and resource efficiency, manufacturing, waste management, building, and urban design, tourism and transportation. Sound chemicals management must become a national and international environmental, public health, and economic and business development priority (Kemf, 2013; UN, 2011; Feunang et al., 2016).

2.6 Waste and Waste management issues

The concepts of waste and waste management were raised by many scholars since the emergence of industrialization. Ebistu & Minale (2013) defined that waste is a material that is discharged and discarded from each stage of daily human life activities, which leads to adverse impacts on human health and the environment. Wastes are substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law(UNEP, 1989). The business dictionary defines waste management as the collection, transportation, and disposal of garbage, sewage, and other waste products (www.businessdictionary.com).

Waste management or Waste disposal is all the activities and actions required to manage waste from its inception to its final disposal. This includes amongst other things, collection, transport, treatment, and disposal of waste together with monitoring and regulation. It also encompasses the legal and regulatory framework that relates to waste management encompassing guidance on recycling etc. As stated by (Banar et al., 2009) solid waste management is a complex and multidisciplinary problem that should be considered from technical, economic, and social aspects on a sustainability basis. For a healthy environment, both municipal and industrial wastes should be managed according to the solid waste management hierarchy.

As described by (Alavi et al., 2013), chemical waste is a waste that is made from harmful chemicals (mostly produced by large factories).

Chemical waste may or may not be classed as hazardous waste. Alavi et al.(2013)also categorized chemical hazardous wastes as solid, liquid, or gaseous material that displays either a "Hazardous Characteristic" or is specifically "listed" by name as a hazardous waste. The four characteristics of chemical wastes that are considered hazardous include Ignitability, Corrosivity, Reactivity, and Toxicity Alavi et al.(2013). According to Guerrero, Maas, & Hogland (2013), disposal of wastes through landfill is an inevitable element of all solid waste management systems. Even if all activities for reduction, reuse, and recycling are implemented, there will always be a need for land disposal of a residual proportion of the waste produced originally(Alavi et al., 2013).

According to UNDP, an approved site or facility means a site or facility for the disposal of hazardous wastes or other wastes that is authorized or permitted to operate for this purpose by a relevant authority of the state where the site or facility is located(UNEP, 1989). Environmentally sound management of hazardous wastes or other wastes means taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner that will protect human health and the environment against the adverse effects which may result from such wastes (UNEP, 1989).

2.7 Pesticide, obsolete pesticide and related case studies

2.7.1 Pesticide and formulation technology

A pesticide product consists of two parts: active and inert ingredients. Active ingredients are chemicals that control the pest. Inert ingredients are primarily solvents and carriers\ that help deliver the active ingredients to the target pest; they serve to enhance the utility of the product.

Inert ingredients may be liquids into which the active ingredient is dissolved, chemicals that keep the product from separating or settling, and even compounds that help secure the pesticide to its target after application. The combination of an active ingredient with compatible inert ingredients is referred to as a formulation. Pesticides are formulated for many reasons. A pesticide active ingredient in a relatively pure form, ready for manufacturers' use, rarely is suitable for field application. An active ingredient usually must be formulated in a manner that: -

- Increases pesticide effectiveness in the field;
- Improves safety features;
- Enhances handling qualities.

The formulation gives the product its unique physical form and specific characteristics, enabling it to fill a market niche. There are approximately 900 pesticide active ingredients formulated into 20,000 pesticide products sold and used in the United States today(Martin et al., 2011).

2.7.2 Reducing the human and environmental risks of obsolete pesticides

According to Lagnaoui, Dasgupta, Meisner, & Blankespoor, (2010), before 2000, Ethiopia was found to have stockpiled more than 2,500 tons of obsolete pesticides. The key reasons included unregulated imports, selling, and donations over 50 years. Most of these obsolete stocks are of poor quality and are improperly packed and labeled. The country was also found to have 1,000 tons of contaminated soils at more than 900 sites. A national inventory conducted by FAO in 1999 found more than 1,500 tons of obsolete stocks at 256 sites. A major disposal project conducted from 2000–2003 under the leadership of FAO, in collaboration with Ethiopia's Ministry of Agriculture, collected and moved these obsolete stocks to ten in-country storage sites before transporting them to Finland for high-temperature incineration. A total of US$4.4 million was required, with funds from the Netherlands ($2.2 million), Sweden ($1.2 million), and the United States ($1 million) (Haylamicheal and Dalvie 2009). A second project phase, initiated in 2006, is to dispose of the country's remaining obsolete stocks at incineration facilities in the UK and Germany. This phase also focuses on container management, regulatory and policy reform, promotion of Integrated Pest Management (IPM) and Integrated Vector Management (IVM), and pesticide awareness-raising activities. The total cost of disposal and post-disposal activities is about $US8.13 million, with funds provided by Belgium ($3.89 million), Finland ($1.11

million), Japan ($1.14 million), the ASP ($1.30 million), CLI ($0.40 million), and Ethiopia ($0.29 million). A US$2.62 million GEF grant signed in 2007 supports disposal and prevention activities (Lagnaoui et al., 2017).

2.8 Recent Case Studies Related to Pesticide Chemical Wastes Management

2.8.1 Practices of Georgia

During 1976-1985, around 3,000 tons of obsolete pesticides (including POPs) were dumped at the country's main pesticide dumpsite Lagluja, 80 km from the capital Tbilisi. The most hazardous ones – including DDT – were stored in concrete waste cells while less toxic pesticides were dumped in open trenches and covered with soil. A GEF/UNDP project was approved in 2011 to help the Ministry of Environmental Protection & Natural Resources safely dispose of up to 250 tons of POPs pesticides at Lagluja (Arora, 2015). Working with the Marneuli municipality, the site was fenced off and warning signs installed. Drainage ditches were restored to minimize run-off and soil/water pollution. Drilling and sampling/assessment located the buried pesticides and showed the concrete waste cells had collapsed, leading to mixing of pesticides with other materials including soil. 230 tons of POPs pesticides and contaminated soil (including 118 tons of DDT) were excavated, repackaged, and transported to certified disposal facilities in Belgium and France(Arora, 2015). Formulation and adoption of national technical guidelines for the handling, transport, storage, and disposal of POPs pesticides followed. Determination of the number of pesticides left in the landfill and finalization of a long-term cleanup and remediation plan will be the last activity. The project has safeguarded the health of 137,000 people and their livestock, while national capacity developed for dumpsite investigation, risk assessment, and export of hazardous waste will ensure that the Government can effectively manage its hazardous wastes in the future (Arora, 2015).

2.8.2 Practices of Viet Nam

Viet Nam has a ban on the import and use of POPs pesticides. However, lack of funding and access to technologies led to the accumulation of unused pesticide stockpiles in sheds or buried underground. With no safeguards in place, the high concentration of buried pesticides led to severe pollution of water, soil, and food. Communities constructed housing or relied on polluted water sources leading in certain locations to severe health impacts including deaths and birth abnormalities (Arora, 2015). Since 2009, a GEF/UNDP/FAO project has assisted the Government to clean up priority sites and destroys 1,140 tons of POPs pesticides. 1,153 potentially contaminated sites have been reviewed, 335 assessed in detail, and the top 100 included in the National Target Program on Pollution Management and Environmental Improvement (Arora, 2015).

2.8.3 Practices of Mauritius

The safe disposal of hazardous waste is a challenge for many small island developing states (SIDS) as land is limited and bad waste practices can quickly result in ecosystem damage and health impacts(Arora, 2015). This is the case in Mauritius whose pristine environment is a major tourist attraction. Of particular concern were a large quantity of DDT (150 tones, of which 0.6 tones used each year for malaria control), 5 tons of PCB-containing oil, and 100 kg of other POPs pesticides. Most were stored in unsafe conditions causing severe soil and water contamination (Arora, 2015). Disposing of obsolete POP chemicals, cleaning-up POPs contaminated areas, and developing alternative strategies for vector management to reduce the country's reliance on DDT were the main objectives of this GEF/UNDP project t(Arora, 2015). The project has so far disposed of 139 tons of DDT, 5 tons of PCB contaminated waste, and 300 m3 of excavated POPs contaminated soil (from three hot spots which were also remediated). To reduce dependence on DDT to control malaria, project staff worked with the Ministry of Health and Quality of Life to develop an Integrated Vector Management (IVM) strategy which included identification, testing, and selection of effective and safe alternatives to DDT (such as pyrethroids), surveillance of mosquito breeding places, and bed nets(Arora, 2015).

2.8.4 Practices of Kazakhstan

CBS poses significant environmental and health hazards in Kazakhstan, which ranks second among CEIT countries with an estimated 980 tons of PCB contaminated soils and 255,000 tons of PCB contaminated soils(Arora, 2015). The main aim of the GEF/UNDP PCB Management Plan for Kazakhstan was to demonstrate sound management of PCBs in all its life cycle phases. Project results included the adoption of a regulatory framework for PCB management;

training of 1,100 people, 2 national hazardous waste companies, and 10 laboratories on PCB management and analysis; identification of an additional 571 PCB-containing capacitors and 48 PCB-containing transformers; and stakeholder awareness. Six different land-based export routes for PCB wastes were explored - none were feasible due to PCB transboundary movement bans. 80 tons of contaminated soil was then sent by plane to France for disposal – the first time for a GEF project(Arora, 2015). An additional 150 tons of repacked capacitors (~1,400) are awaiting similar export procedures in 2015(Arora, 2015).

2.8.5 Practices of Jordan

Jordan's NIP indicated important barriers for the sound management of PCBs, including the absence of a centralized data system, lack of regulations on the handling of PCBs, inadequate capacity of laboratories and storage facilities, and low awareness of risks (Arora, 2015). The GEF/UNDP project addressed these challenges by supporting the accreditation of the national laboratory and testing 14,062 pieces of electrical equipment. Those showing a concentration of 50 ppm and higher were again analyzed by gas chromatography. All equipment was labeled and registered in a PCB database (Arora, 2015).

Workers were trained on PCB identification, proper handling, storage, drainage, transport, and disposal. The resulting regulation - in combination with training and awareness-creation - has helped safeguard workers by minimizing further cross-contamination and minimizing exposure to PCB-contaminated equipment, waste, and soil. The project also drained, packed, and labeled 65 tons of PCBs (19 transformers and 68 capacitors), which are currently safely stored and awaiting transport to an approved disposal facility in Europe (Arora, 2015).

2.8.6 Practices of Nigeria

This GEF/UNDP project has helped reduce releases and exposure to UPOPs from the open burning of municipal and agricultural wastes by introducing alternative approaches through training and practical demonstration. Support was provided for the development of a National Policy on Municipal and Agricultural Waste Management, and training of 1,500 project stakeholders and beneficiaries on BAT/BEP in the same areas. One key result was upgrading of an aggregate of 35 ha of dumpsites to controlled dumpsites in the two pilot states to reduce open burning (Arora, 2015).

In Anambra State, community-based waste sorting, collection, and composting were established. Three color-coded waste sorting receptacles were provided to 560 households to sort their waste. Recyclable and compostable waste was taken to the compost plant for processing into organic fertilizer and plastic crumbs and then sold to farmers and horticulturists for soil replenishment and to industry for recycling (Arora, 2015).

2.8.7 Practices of Honduras

The UNDP/GEF project "Strengthening national management capacities and reduction releases of POPs in Honduras" shows how a small country, through a holistic chemicals management approach, can successfully address various POPs and chemicals management challenges. This multi-POPs project is on course to dispose of 60 tons of POPs pesticides, 112 tons of PCB containing wastes, and reduce UPOPs releases from open burning of municipal and health-care waste by 80 g-TEQ. The national chemicals management regime is being strengthened through the adoption of the National Policy for Environmentally Sound Management of Chemicals, the creation of a National Commission on Chemicals Management, and regulations for the management of PCBs and contaminated sites (Arora, 2015).

The city dump was closed and a new landfill was developed. Now 30,000 tons of waste is properly disposed of yearly and not being burned. Public and private health care facilities were trained in proper healthcare waste management and a special area at the landfill now receives healthcare waste (Arora, 2015).

2.8.8 Practices of China

China started producing DDT in the 1950s. At its production peak, it had 11 facilities producing 21,000 tonnes. In 1983, China stopped large-scale production and agricultural application of DDT, and since 1995 production has averaged 5,000–6,000 tones/yr. To minimize the release and potential risk of DDT, China worked with UNDP to develop two GEF projects to phase-out all remaining uses of DDT and then shut down all DDT production facilities (UNDP, 2015). The first project "Improvement of DDT-based Production of Dicofol and Introduction of Alternatives

Technologies including IPM for Leaf Mites Control in China", completed in 2013, eliminated 2,800 tons of DDT used each year for the production of Dicofol(Arora, 2015).

The second project "Alternatives to DDT Usage in the Production of Antifouling Paint (AFP)", completed in 2014 eliminated 250 tons of annual DDT use in AFP production used to coat the bottom of ships to prevent the adhesion of organisms such as sea-mussels and algae. The AFP manufacturing industry was converted to non-toxic and environmentally friendly alternatives, end-users were convinced to accept the new AFPs, and environmental management at shipyards was improved. Economic incentives resulted in cost benefits for end-users – in particular, smaller fishing vessel owners who were most vulnerable to AFP price increases (Arora, 2015).

2.9 Criteria and Value for Solid Waste Disposal Sites Selection

Adeli & Khorshiddoust (2011) showed in their study suitable distance from main roads to solid waste dumping site as a criterion for solid waste dumping site selection. According to their thought, solid waste dumping sites must be located at a suitable distance from the roads network to facilitate transportation and consequently to reduce relative costs. They preferred a buffer of 2000 m distance from main roads by referring to different sources. The summary of their classification was shown in the table below.

Table2. 1: Distance in meter versus road suitability level

Sn. No.	Distance in meter	Description
1	Less than 500m	Unsuitable road
2	500m to 1000m	Low suitable road
3	1000m to 1500m	Moderate suitable road
4	1500 to 2000m	Highly suitable road

Shahabi et al. (2014), supports the above criteria and they described that locating landfills near main roads has aesthetic problems for passengers. This criterion was determined based on radial distances from main roads (highways and main roads).

According to Sener et al. (2006), the landfill must neither be located within 500 m of a railway line nor be placed on a site close to historic/cultural/scenic sites(Issa, S.M, Shehhi, 2012) Shahabi et al.(2014), investigated that locating landfills near main roads has aesthetic problems for passengers.

As reviewed and suggested by Ebistu & Minale (2013), a landfill must not be located near any surface streams, lakes, rivers, wells, or wetlands. Proximity to wells was an important criterion for accessing the landfill site. Landfills create noxious gases and leachate that make them unsuitable to be in proximity to water wells (THOSO & A, 2007). As reported by Ebistu & Minal (2013), the landfill must not be located within 500 m of a railway line(Sener et al., 2006). A weighting of 10 is applied if <500 m from the railway line and 0 if >500 m away (Ebistu & Minale, 2013). As investigated by Ebistu & Minale (2013), a landfill site should not be placed on a site close to historic/cultural/scenic sites Ebistu & Minale (2013). Ebistu & Minale (2013) said that a landfill must not be located within 100 m of irrigational canals. A weighting of 0 is then applied if <100 m away and 10 for >100 m away.

Regarding land uses, Shahabi et al. (2014) pointed out that the selected lands for landfill must be based on zoning restrictions. They grouped land uses into residential, agricultural, industrial, and unused lands. Shahabi et al. (2014), explained that land cover is a critical criterion in landfill siting because landfill operations, such as drilling, lead to the destruction of land cover. Landfills cannot be located in wetlands and forest areas. Dry farming lands, rangelands, and barren lands were considered optimal for landfill siting.

(Babalola & Busu, 2011), raised the issue of suitable distance from protected areas as a criterion for solid waste dumping site selection. The protected area in this study includes churches, mosques, parks, and others. According to their argument, the landfill should not be located near sensitive areas listed above to a limit of 3,000 m buffer surrounding.

Babalola & Busu (2011), also raised the suitability of settlement as another criterion for waste dumping site selection. They determined the safe distances from settlements for urban centers and rural villages as 7000m and 3000m respectively. Like other criteria, settlement areas were classified according to their suitability. They grouped the reclassified distances from unsuitable to the most suitable as shown in the table below.

Table2. 2: Distance from damping sites and their suitability for Urban Centers and Rural Villages (source: (Babalola & Busu, 2011) &(Alavi et al., 2013) and organized by the researcher)

Sn.No	For Urban Centers		For Rural Villages	
	Distance range	Suitability level	Distance range	Suitability level
1	0 to 2500m	Unsuitable	0 to 500m	Unsuitable
2	2500 to 4500m	Less suitable	500 to 1000m	Less Suitable
3	4500 to 5500m	Suitable	1000 to 1500m	Suitable
4	5500 to 7000m	Most Suitable	1500m to 2000m	Most Suitable

The above study showed that the unsuitable area covered the highest share (45% of the total area) as compared to other levels of suitability. The class values were given based on the level of suitability from the lowest to the most suitable area used at the time of the weighted overlay. In their study, the location of solid waste sites for rural and urban areas was in the opposite direction and required additional information to determine the site (Babalola & Busu, 2011). The other important criterion for determining a solid waste dumping site is slope suitability. As mentioned by(Nishant.T, Prakash M.N, 2010) &(Adeli & Khorshiddoust, 2011), the suitability of slope is a criterion for a solid waste dumping site. In their study, they indicated that the lower the slope, the more highly suitable site than the land with a higher slope. Different researches showed that areas with high slopes will have a high risk of pollution and they are not potentially a good site for dumping. The majority of their study area falls under the slope class of 0-10%, which covers 90.7% of the total study area. Sener et al. (2011) confirmed the work of Nishant.T, Prakash M.N, (2010), by describing that the land with a slope of less than 10% is highly suitable for solid waste dumping.

Kontos, Komilis, & Halvadakis (2005), described the slope of the damping site as one of the criteria to determine appropriate landfill. They have illustrated that the slope of the land surface is a crucial factor for constructing and operating a landfill site. According to their thought, very steep slopes will lead to higher excavation costs, whereas flat areas are more suitable for landfill construction. Therefore, the flatter area gets a higher score. The grouping is done as shown below.

Table2. 3: Grading of damping site sloppiness (Extracted from Kontos et al., 2005 and organized by the researcher)

Sn. No.	Nature of the slop	Sloppiness in %	Grade
1	Very steep areas	>45%	0
2	Steep areas	25-45%	2
3	Moderately steep areas	20-25%	4
4	Inclined planes	10-20%	8
5	Slightly sloping areas	<10%	10

Issa, S.M, Shehhi (2012), have suggested that the appropriate slope for constructing a landfill is about 8–12% because too steep of a slope would make it difficult to construct and maintain, and too flat of a slope would affect the runoff drainage. Slopes above 12% created high runoff rates for precipitation. With a higher runoff rate and decreased infiltration, contaminants can travel greater distances from the containment area (Alavi et al., 2013; Ebistu & Minale, 2013, and Kim et al., 2013), proposed that aspect is simply the measure of the direction of the slope. It begins with 0° at the north, and then in a clockwise direction ends at 360° again at the north. Aspect is often classified into four major directions namely; north, east, south, and west or into eight major directions; north, northeast, east, southeast, south, southwest, west, and northwest. They described the directional values as shown in the table below.

Table2. 4: Classification of aspects based on the direction and their respective values in degrees. (Source: M. Kim et al., (2013))

Sn. No.	Aspects	Value in degrees
1	North	0 – 22.5^{o} and 337.5 – 360^{o}
2	North East	22.5^{o} – 67.5^{o}
3	East	67.5^{o} – 112.5^{o}
4	South East	112.5^{o} – 157.5^{o}
5	South	157.5^{o} – 202.5^{o}
6	South West	202.5^{o} – 247.5^{o}
7	West	247.5^{o} – 292.5^{o}
8	North West	337.5^{o} – 360^{o}

All evaluation criteria discussed earlier were all considered in the raster format and were combined in a grid that bears all the grade values obtained from the individual grid (M. Kim et al., 2013). Y. Kim et al., (2013) have also shown that as the distance from residential areas increases, the issues of public opposition to siting of waste disposal facility diminishes. Consequently, the suitability of the site increases as public opposition diminishes. Waste disposal sites should not be located in populated urban or rural areas. Hence the land suitability for landfills increases with the increase in distance from the residential areas (M. Kim et al., 2013).
Shahabi et al. (2014), reported that education is one important infrastructure of society. Waste disposal near the school makes the environment very polluted. For that reason, it is a very essential criterion to choose the perfect buffer for the waste disposal site selection. Shahabi et al. (2014) discussed that classification of land type is based on the manual of the water and soil research institute of Iran (Mahler 2012 manual). According to this guideline, the land is divided into different units based on geology, morphology, and soil characteristic. The mainland type in the study area was river alluvial plains (Mahler, 1970; (Shahabi et al., 2014). The classification of land type is shown in the table below.

Table2. 5: Classification of the land type according to Mahler 2012 Manual (Extracted from Mahler 2012 Manual and Shahabi et al., 2014; and organized by the researcher)

Sn. No.	**Land Units**	**Land Type**	**Description**	**Score**
1	5.1	River Alluvial Plains	Deep soil with a moderate-to-heavy texture has low salt and is permeable, making it suitable for cultivation.	2
2	5.6	Barren land	Very deep and heavy soil with high alkalinity and salt has low porosity and low water permeability.	10
3	5.8	soil	Deep and heavy soil with moderate-to-high alkalinity and salt. Its permeability to water was moderate.	5
4	6.2	Barren land	Deep and heavy soil with moderate to- high alkalinity and salt. Sometimes it is used as temporary rangeland. Its permeability to water is moderate-to-low.	8

Shahabi et al. (2014), also showed that distance from generation point’s proximity to waste production centers is an important factor in the economic feasibility of a candidate landfill site. This point was considered as a benchmark and the distance of all candidate landfill sites to the transfer station was evaluated as shown in the table below.

Table2. 6: Scoring Grades based on the distance from generation points to waste production center (Extracted from Shahabi et al., 2014 and organized by the researcher)

Sn. No.	Distance from generation points to waste production center	Scoring Grade
1	2000 m	10
2	2000 – 3000 m	8
3	3000 – 5000 m	5
4	5000 – 10,000 m	2
5	>10,000 m	1

According to the review of Shahabi et al. (2014), distance from generation points was considered as a benchmark and the distance of all candidate landfill sites to the transfer station was evaluated. As produced by Kim et al. (2013), the elevation of the study area generally ranges between 0 and 30 meters. The elevation is an important parameter in the identification of the landfill site.

Shahabi, Keihanfard, Ahmad, & Amiri (2014) have divided the main factors that are important in the selection of solid waste management landfills into three categories: environmental, socio-culture, and techno-economic factors. They also defined some criteria and sub-criteria for each of these factors according to the standards and regulations for landfill siting of the case country and based on the literature (Chang et al., 2008; Kontos et al., 2005; Moeinaddini et al., 2010; Nas et al., 2010; Sener et al., 2010, 2011; Wang et al., 2009; Shahabi et al., 2014).

Many factors must be incorporated into landfill siting decisions, and Geographic Information Systems (GIS) are ideal for preliminary studies due to the capacity to manage large volumes of spatial data from a variety of sources (Sener and others 2006;(Zelenović Vasiljević et al., 2012).

According to Vasiljević et al. (2012), seventeen factors that play an important role in selecting a regional landfill site were identified, and according to their nature and role in the decision making process, factors were treated as criteria, restrictions, and dual factors /criterion and restriction/ (Zelenović Vasiljević et al., 2012). Vasiljević et al. (2012) described that the seventeen factors influencing landfill site selection were divided into three types according to nature and role in the decision-making process: criteria, restrictions, and dual factors. All factors were clustered according to their domain of influence into geo-natural, environmental, social, and techno-economic factors. Appropriate factors were identified from the consultation of technical experts in the field of waste management, project design processes, and construction (Zelenović Vasiljević et al., 2012). Vasiljević et al. (2012) summarized that each of the 17 criteria/sub-criteria was assigned a different rating on the scale: 1 (unsuitable for landfill sitting) to 7 (the most suitable for landfill sitting) according to legislation restrictions, experts' experience, and international references. All identified factors were clustered into four major factor groups: geo-natural, environmental, social, and techno-economic factor groups as shown below.

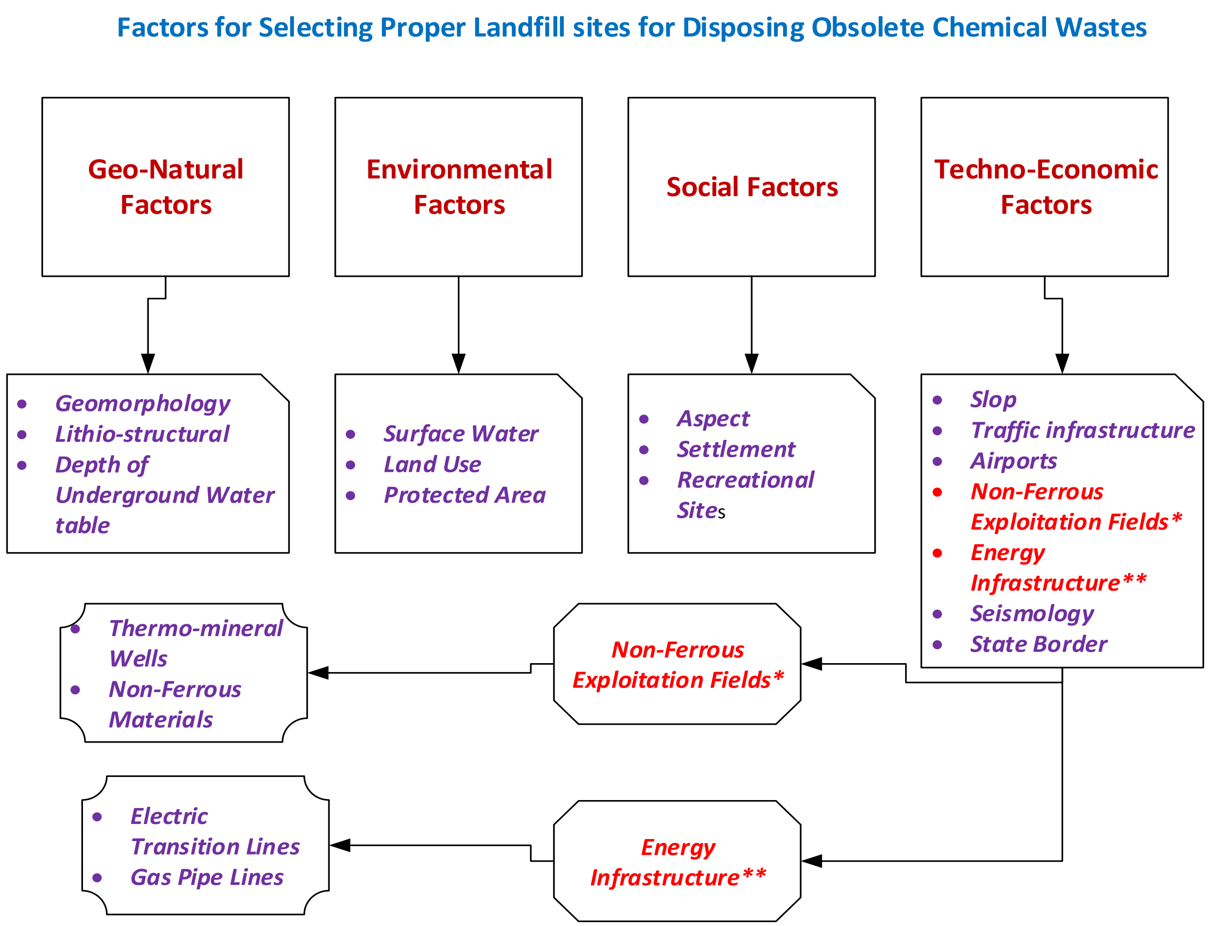


Figure2. 1: Factors for selecting proper landfill sites for disposing of obsolete chemical waste (Zelenović Vasiljević et al., 2012)organized by the researcher.

As indicated by Shahabi et al. (2014), a disposal site must consider all the socio-economic, environmental, and land use factors within the city as well as people safety. GIS can analyze the suitable site selection for urban waste disposal considering all the criteria (Multi-criteria Analysis) which will help the local governing body as a part of e-governance. The use of GIS in the selection process will reduce the time and enhance accuracy. As described by Shahabi et al. (2014), environmental factors consisting of surface water, groundwater quality, land cover, and ecological character, disposal site management and public health, safety, and nuisance. Economic factors consisting of land use and social value consisting of the distance from human settlements, industry, and proximity to protected places, and impacts on housing and/or other development. The technical-operational criteria consisting of the altitude, the design of the site, i.e. hydrological evaluation, and grading of the surfaces/protection of the slopes, access roads, and the distance from the main source of waste consumption.

2.10 Determination of relative importance weights of criteria

Shahabi et al.(2014) proposed that the relative importance of criteria to each other should be calculated. One of the most common methods that have been used in recent years is AHP. It is a multi-attributed accepted decision-making technique that has been incorporated into the GIS-based land-use suitability procedures (Kontos et al., 2005; Moeinaddini et al., 2010; Saaty, 1980; Sener et al., 2006, 2010, 2011; Sharifi et al., 2009; Yesilnacar and Cetin, 2005). Following the above stage, the pairwise comparison matrix (PCM) formed in which a_{ii} = 1 and a_{ij} = 1/ai. Next, to this, the relative importance of the criterion's weights was calculated by the geometric mean of each row of the PCM (Saaty, 1980). The obtained geometric means were then normalized and the relative importance weights were extracted(Shahabi et al., 2014)

2.11 Evaluation of land suitability

Shahabi et al.(2014), reviewed that the Landfill Suitability Index (LSI) of every point is calculated by the Simple Additive Weighting (SAW) method, a widely utilized method for the calculation of final grading values in multiple criteria problems owing to its easiness and proportional linear transformation of raw data (Malczewski, 2004). The LSI for each point was calculated using the following equation:

$$(Ai) = \sum_{j=1}^{n} \text{wj } x \; Xij$$

Where,

- ✓ $\mathbf{A_i}$ = the suitability index for each point i,
- ✓ $\mathbf{W_j}$ = the relative importance weight of criterion j,
- ✓ $\mathbf{X_{ij}}$ = the grading value of each point “i” under criterion “j” and
- ✓ **n** = the total number of criteria (Shahabi et al., 2014).

The relative importance of each criterion determined by AHP showed that the ***most important*** ones were ***sensitive ecosystems*** and ***surface water***, while the ***least important*** criterion was ***the slope***. The suitability index of each point was calculated by the SAW method (Shahabi et al., 2014).

As Vasiljević et al. (2012) illustrated that landfill siting was done using Arc GIS 9.3.1 with the AHP extension for Arc GIS ext_ahp.dll (Marinoni 2009). The multi-criteria evaluation was used for its capability to simultaneously evaluate several possible choices in the siting process while taking into account various relevant criteria, as well as frequently conflicting objectives. (Vasiljević et al., 2012).

2.12 Methodology to select landfills site using GIS & RS

The method employed by Ebistu & Minale (2013) to select appropriate landfills is from secondary sources those include a SPOT5 image of the town with a spatial resolution of 5 m, the master plan of the town, and a topographical map of the town. Pre-processing operations such as radiometric image restoration and rectification were applied to enhance the analysis of the SPOT5 image. The study used a spatial multi-criteria analysis technique to identify the most suitable solid waste site. Higgs (2006) described that Spatial multi-criteria approaches(SMCA) have the potential to reduce the costs and time involved in siting facilities by narrowing down the potential choices based on predefined criteria and weights and permitting sensitivity analysis of the results from these procedures. Linear distances were derived for each factor at maximum size for classification. Classifications were done on various layers and the values were assigned ranging from most suitable to unsuitable. Whereas, reclassification of layers was done into the 1's, 2's, 3's, and 4's scoring system, where 1 represented unsuitably, 2 less suitable, 3 moderate suitable, and 4 highly suitable. The pair-wise comparison of criteria was performed and results were put into a comparison matrix. The matrix is populated with values from 1 to 9 and fractions from 1/9 to ½ representing the importance of one factor against another in the pair (Ebistu & Minale, 2013).

Nas, Cay, Iscan, & Berktay (2010), explained that a vector-based GIS software package i.e., ArcGIS 9.0 and its extensions, were used as the GIS tools in siting those can perform suitability analysis using multi-criteria evaluation analysis.

Methodologies used by (Nas et al., 2010) are normally based on a composite suitability analysis using map overlays and their extension to include statistical analysis.

According to Babalola & Busu (2011), a GIS-based constraint mapping is employed to eliminate the environmentally unsuitable site and to narrow down the number of sites for further considerations. Overlay of generated buffer maps was done to identify sites where the constraints parameter will be employed (Babalola & Busu, 2011).

For the analysis of optimized site selection, the major data suggested by Babalola & Busu (2011)**,** are satellite data, topographic maps, rainfall, and soil depth, geospatial data (latitude and longitude), wind speed, and direction. The acquired data are entered into the GIS and then processed which then paved the way for the actual processing segment. They also showed that the data were processed using the Arc GIS software. The initial part bears vector maps, which form the layers of land use, rainfall, soil, slope, aspect, etc. All these layers were then entered into the model builder and thereafter converted to raster (grid) format from where buffering of all the constraint mapping was carried out. After this, classification was done and the union of all the buffered layers.

The methodology of Suman Paul (2012) also covered some sequential steps. Among those steps, spatial feature extraction or classification is one of the GIS capabilities for searching suitable sites. According to Paul (2012), the ultimate aim of GIS is to support spatial decision making which has been structured into three major phases: Intelligence, Design, and Choice. Multi-Criteria Analysis (MCA) is a decision support technique where a decision is a choice between alternatives (Suman Paul, 2012).

2.13 The role of GIS in solid waste management

As reviewed by Nas et al. (2010), the functions of GIS include its ability to:

- ✓ Capture, store, and manage spatially referenced data;
- ✓ Provide massive amounts of spatially referenced input data and perform analysis of the data;
- ✓ Perform sensitivity and optimization analysis easily; and
- ✓ Communicate model results (Vatalis and Manoliadis, 2002).

(Glanville & Chang, 2015), examined that the first step to locate landfill site is identification and consideration of criteria and standards, followed by parameters determination to define to digital layers for use in Arc GIS software and finally doing necessary actions to find optimized places(Glanville & Chang, 2015).

Many of the attributes involved in the process of selection of sanitary landfill sites have a spatial representation, which in the last few years has motivated the predominance of geographical approaches that allow for the integration of multiple attributes using geographic information systems (Kontos et al., 2003; Sarptas et al., 2005; Sener et al., 2006; Gomez-Delgado and Tarantola, 2006; Delgado et al., 2008; Chang et al. 2000; Nas et al., 2010).

Alavi et al. (2013) also described that the combination of GIS and AHP is a powerful tool to solve the landfill site selection problem because GIS provides efficient manipulation and presentation of the data, and AHP supplies consistent ranking of the potential landfill areas based on a variety of criteria (Sener et al., 2006). A decision modeling procedure was developed, based on the AHP, to locate nuisance facilities (Erkut and Moran, 1991; Alavi et al., 2013)

2.14 What is Multi-Criteria Evaluation (MCE)?

As stated by Suman Paul (2012), multi-criteria analysis is a sequence of processes in which several decisions have to take for problem recognition and ends with recommendations. Multi-criteria evaluation in GIS is concerned with the allocation of land to suit a specific objective based on a variety of attributes that the selected areas should possess (Eastman & Longley, 2005). Nas et al. (2010) described that Multi-criteria evaluation (MCE) is used to deal with the difficulties that decision-makers encounter in handling large amounts of complex information.

As reviewed by Vasiljević et al. (2012), GIS and multi-criteria decision analyses complement one another and allow building consensus and ensuring the sustainability of decision alternatives.

As stated by S. Paul (2012), a suitable disposal site must follow environmental safety criteria and attributes that will enable the wastes to be isolated so that there is no unacceptable risk to people or the environment. Criteria for site selection include natural physical characteristics as well as socio-economic, ecological, and land-use factors. The Geographical Information System (GIS) can provide an opportunity to integrate field parameters with population and other relevant data or other associated features, which will help in the selection of suitable disposal sites (S. Paul, 2012). Any sort of decision making is depending on three basic phases:

1. Intelligence Phase: - involves searching or scanning the decision environment for conditions calling for decisions. The data acquisition, storage, retrieval, and management functions convert the real-world situation into a GIS database during this phase. This involves assumptions or views of the world underlying a particular decision problem. The assumptions are concerned with the following questions:

a. Which of the real-world entities should be observed, selected, filtered, classified, and recorded as data items?

b. Which items are relevant to subsequent spatial decision problems?

Coordination must be given to the usefulness, accuracy, reliability, and flexibility of data.

2. Design phase: - involves inventing and analyzing a set of possible solutions to the problem identified in the intelligence phase. Here, in the case of site suitability analysis for urban development, what are the spatial decision criteria or decision rules we have to consider in locating those suitable sites? So the design phase represents the decision situation by structuring and formalizing the available data and information about the decision problem. Spatial decision alternatives are derived by manipulation and analysis of the data and information stored in the GIS. The design phase will help us in creating rule-based decision trees or knowledge base in the Expert Classifier shell of the software.

3. Choice Phase: - decision rules for locating suitable sites for solid waste disposal has been prepared based on expert knowledge and a multi-criteria analysis process. In the decision process, at this phase, each alternative is evaluated and analyzed with others in terms of specific decision rules. The rule is used to rank the alternatives under consideration. The ranking depends upon the decision-maker is a preference. In general, GIS does not provide a mechanism for representing choice and priority in the context of evaluating conflicting criteria and objectives. Under these circumstances, the ultimate success of GIS in decision making depends on how well the system can succeed as a spatial decision support system in the decision-making process(Suman Paul, 2012).

2.15 Transportation Mechanisms

As described by Suman Paul (2012), in a typical MSW, collection and transportation system consists of Household waste containers, Waste collecting equipped trucks, Workers with the protective suite.

In big cities, however, a transfer station may be needed due to the large amount of waste and the long distance to the MSW facilities. Due to the unavailable waste collection services in outside municipality areas, open dumping and burning are typical disposal methods for MSW in such areas(S. Paul, 2012).

2.16 Estimation of Waste storage

A moving average is defined as an average of a fixed number of items in the time series which move through the series by dropping the top items of the previous averaged group and adding the next in each successive average (Molugaram & Rao, 2017). The moving average method is an improvement over the semi-average method and short-term fluctuations are eliminated by it. The following steps are involved in the method:

Step 1: In the first step, a group of beginning years (periods), which constitute cycle is chosen for calculating the average. This average is placed in front of the mid-year of the group.

Step 2: Now delete the first-year value from the group and add a succeeding year value in the group. Find the average of the reconstituted group and place it in front of this group.

Step 3: If the number of years in a group is odd, the middle year is located without any problem. But if the number of years in the group is even, the average of the averages in pairs is calculated and placed against the mid-year of the two.

Step 4: Repeat Step 2 till all years of the data are exhausted.

Step 5: The moving averages calculated are considered as an artificially constructed time series.

Step 6: Plot the moving averages on a graph paper taking years along the X-axis and moving averages along the Y-axis by choosing a proper scale.

Step 7: Join the plotted point in the sequence of periods.

2.17 Summary of Literature Review

As we have discussed so far, wastes are substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law(UNEP, 1989). Chemical wastes such as pesticide wastes are one of the main harmful residues which have negative impacts on the environment, both for living things and non-living things. They are toxic, persistent, inflammable, reactive, corrosive, and volatile as well. Unless they are treated critically or are disposed of using appropriate techniques, they will pollute the environment and will expose human life to a hazardous situation. There are different approaches to dispose of hazardous chemical wastes. Some of the disposing techniques include biological, chemical, and physical.

Temporary storage site selection is one of the physical disposing techniques which are used to damp obsolete chemical wastes temporarily until the further degrading process is carried out and converted into a usable form. The selection process is accomplished using GIS and RS which can capture, store, and manage spatially referenced data; provide massive amounts of spatially referenced input data and perform analysis of the data; perform sensitivity and optimization analysis easily; and communicate model results (Vatalis and Manoliadis, 2002).
The criteria to select sites for disposing of solid wastes were raised by many scholars considering existing scenarios. Generally, the selection criteria can be grouped into geo-natural, environmental, social, and techno-economic factors. Considering the site to be selected using

these criteria, GIS and RS can determine optimized places that are relatively free from risk and cost-effective.

2.18 Gaps Identified from the Literature

The main objective of reviewing past scientific papers is to explore the recent practices, challenges, and measures to overcome the challenges of the case under investigation. Besides, the new concepts which are missed by those papers will be added to the body of knowledge to fill the existing gap. In this review, the researcher tried to investigate the recent practices and challenges of chemical wastes disposing of techniques in general site selection bottlenecks in particular.

In the previous related works, scholars miss the following points.

1. Almost all past related research works, focused on solid waste disposal, excluded or didn't consider chemical wastes disposing of as a serious issue. However, pesticide chemical wastes are hazardous substances that damage living things.
2. Only a few researchers tried to indicate hazardous wastes disposing of. But they were focused only on the strategic level by missing the operational level.
3. The criteria to determine landfills site are different from scholars to scholars and there are no holistic and integrated criteria which have been used as standard or benchmark to select optimized hazardous waste disposing sites.
4. The science of disposing of hazardous wastes using GIS and RS is at infant stages, especially in developing countries.

2.19 Conceptual Framework Development

In this research, there are seven phases to implement an optimized pesticide chemical waste disposing of by selecting proper temporary storage using GIS and RS. The first phase tells about waste characterization. The characterization stage involves waste identification, waste inventory, determining major characteristics of wastes, and waste categorization. This phase gives basic knowledge for the implementer to understand the waste type, amount, characteristics, and their impact on the surroundings. Benchmarking these phenomena, the implementer will transfer to the determination of waste disposing techniques which includes chemical, biological, and physical (Temporary Storage Site Selection). After selecting the technique, criteria will be set depending on the geological, environmental, and other characteristics of the selected site. The criteria include geo-natural, environmental, social, and techno-economic factors. The fourth phase is conducting of site suitability analysis using GIS and RS. In this stage, the site for disposing of pesticide chemical wastes will be selected. In the fifth phase, the temporary storage site will be constructed which requires knowledge and skill of civil engineering, mechanical engineering, and others. After the construction is completed, the six-phase deal with the pre-treatment process using chemical, biological and physical approaches. The next phase is the transportation of wastes to the constructed temporary storage site. The means for transporting can be via canals, pipelines, or vehicles. The last but not the least phase is the degradation and conversion of obsolete pesticide chemical wastes into a usable form using chemical, biological or physical methods. If the above phases are properly implemented, the researcher believes that risk will be minimized, the disposing cost will be reduced and through time the wastes will be converted into a usable form. Consequently, the framework will be environmentally sound, socially acceptable, and economically viable which will have a great contribution to sustainable development.

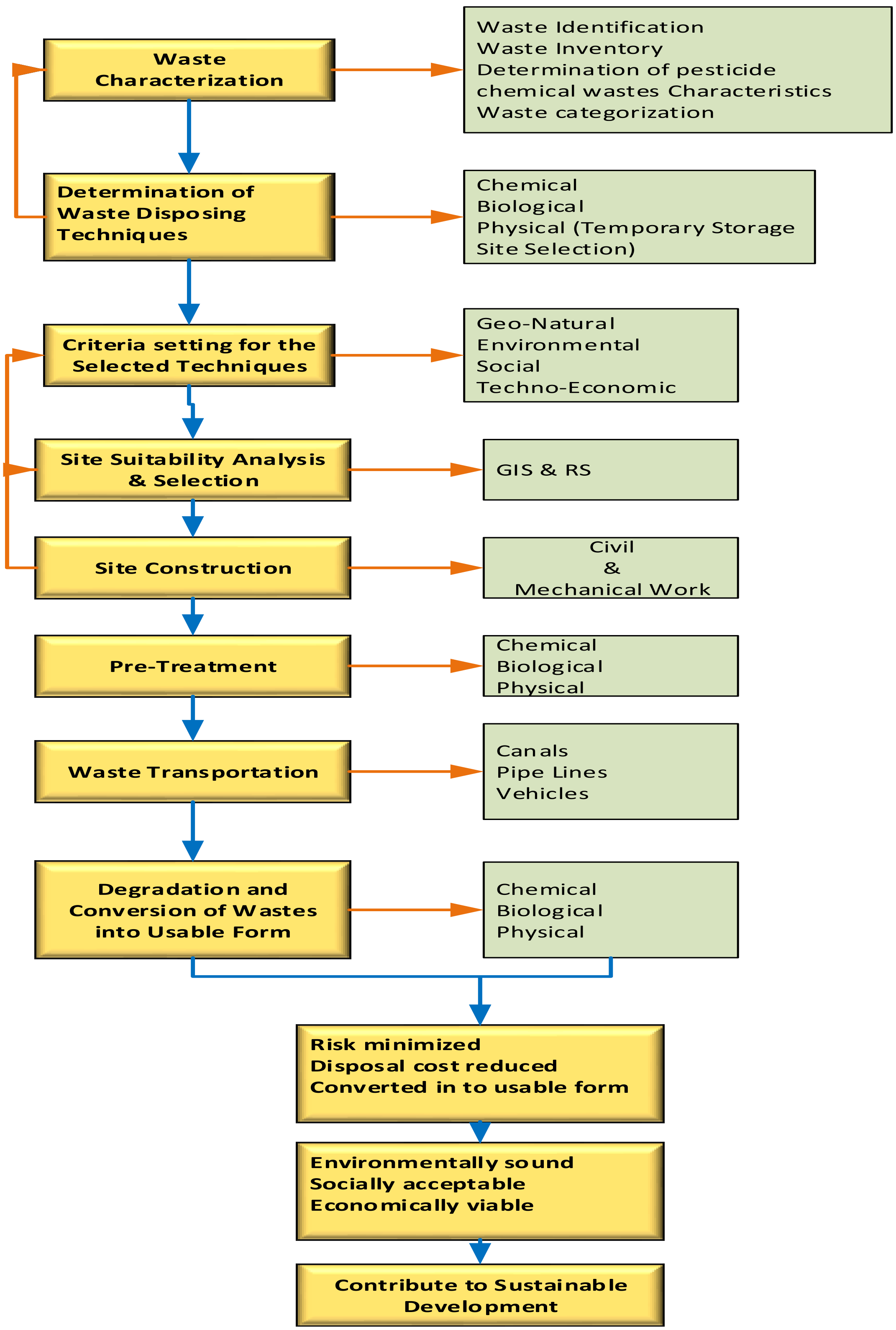


Figure2. 2: Conceptual Framework of Obsolete Pesticide Chemical Wastes Disposal.

CHAPTER: THREE

Research Methods

3.1 Study Area

3.1.1 Location

Adami Tulu Jido Kombolcha is one of the woredas in the Oromia Region of Ethiopia. Part of the Misraq Shewa Zone located in the Great Rift Valley, Adami Tullu and Jido Kombolcha with the area of 109,450.57ha is bordered on the south by Mirab Arsi Zone with which it shares the shores of Lakes Abijatta and Langano, on the west by the Southern Nations, Nationalities and Peoples Region, on the north by Dugda Bora, on the northeast by Lake Zway, and on the east by the Arsi Zone. The main town of the woreda is Adami Tullu; other towns include Abosa, Bulbulla, and Jido.

Most areas of this woreda range in altitude from 1500 to 2300 meters above sea level; Mount Aluto is the highest point. Rivers include the Bulbula, Jido, Hora Kalio, and Gogessa. A past survey of the land in the woreda showed that 27.2% is arable or cultivable, 21.6% pasture, 9.9% forest, 15.7% swampy, and the remaining 25.6% is considered as degraded or otherwise unusable.

There are two state-owned industries in the woreda (one producing Soda ash, the other Caustic soda), 44 private small industries employing 299 people, and 1,670 registered businesses including 321 wholesalers, 1034 retailers, and 315 service providers. Zway State Farm is a major on-going government project in this woreda. There were 37 Farmers Associations with 17,144 members and 12 Farmers Service Cooperatives with 8740 members. Adami Tulu and Jido Kombolcha have 95 kilometers of dry-weather and 85 all-weather roads, for an average road density of 141 kilometers per 1000 square kilometers. About 84% of the rural, 88% of the urban and 85% of the total population have access to drinking water. In October 2009, woreda authorities announced that 4,300 hectares of land were being developed for irrigation, involving over 2,000 farmers who would plant the land in various fruits and vegetables, which could then be harvested more than twice a year.

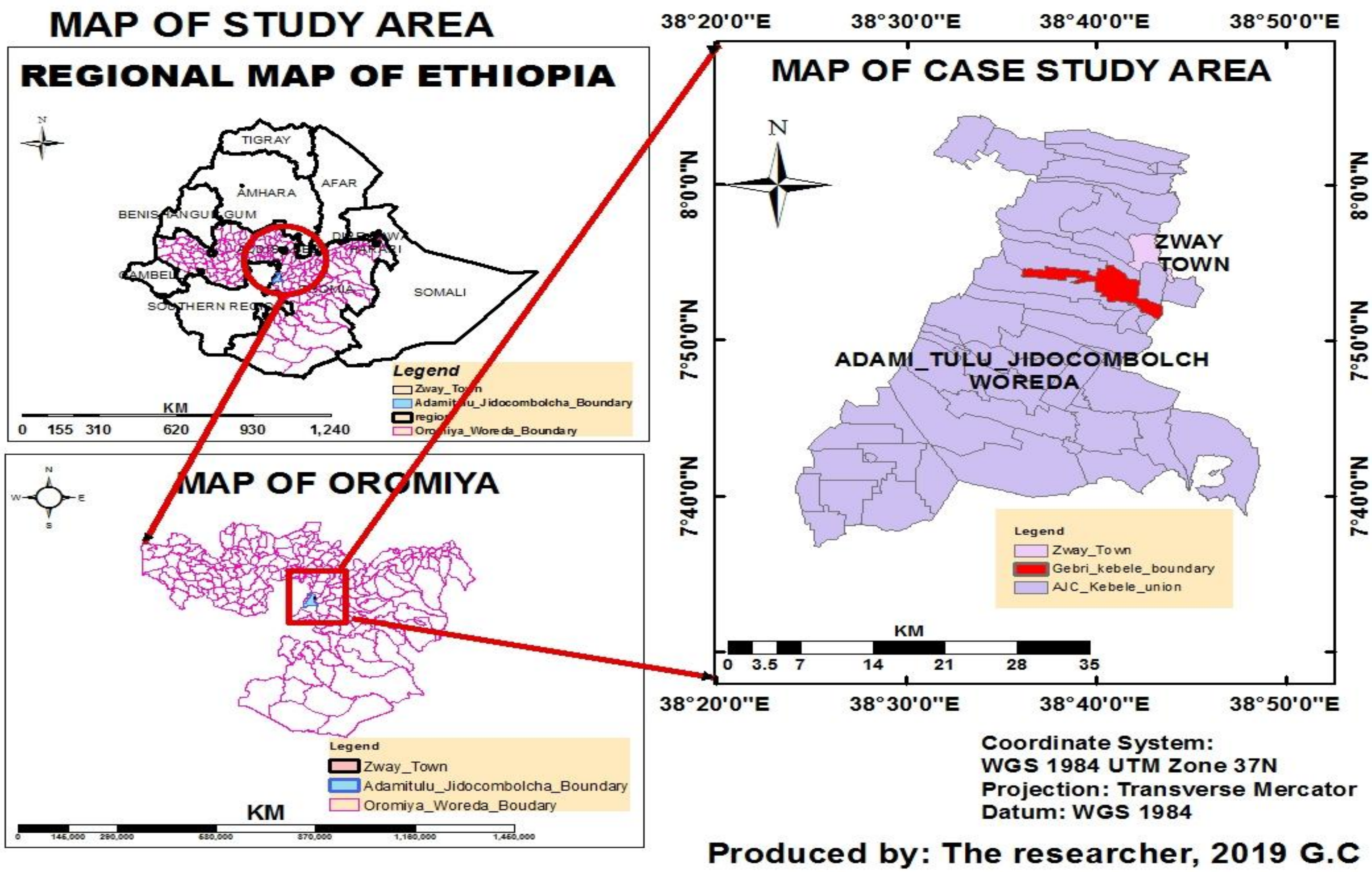


Figure3. 1: Map of study area (Source: own)

3.1.2 Demographics

The 2007 national census reported a total population for this woreda was 141,405, of whom 71,167 were men and 70,238 were women; 20,923 or 14.8% of its population were urban dwellers. The majority of the inhabitants were Muslim. They constitute 82.65% of the population while 11.61% of the population was Ethiopian Orthodox Tewahdo Christianity, and 5.09% of the population was Protestant. According to woreda profile data, the 2018 G.C census reported a total population for this woreda reached 201,125, of whom 98551 were men and 102,574 were women.

3.1.3 The climate

Ecologically, the district is generally termed as the main lowland with unreliable rainfall conditions, which is bimodal and erratic. Its distribution pattern is variable and the areas remain dry for most months of the year. All parts of the Adami Tulu district come with the sub-tropical climate zone. Average annual temperature &rainfall are 15-20^{0}c & 800mm respectively.

The high rate of evapotranspiration as a result of dry conditions coupled with low rainfall availability is limiting the practice of rained (both crop production and animal rearing). The district is generally moisture stressed and people depend on Lake Zway for all uses (Human, irrigation, and livestock). Moreover, the underground water of the area is full of concentrated fluoride and it is not favorable for domestic and agricultural use. As a result of these and other factors, the district is food insecure and mostly categorized as drought-prone in the zone where many people depend on relief food assistance and productive safety-net program.

3.1.4 Soil

Clay soil & sandy soil are the two types of soils found in the district. Both of the soils are used for the production of crops like Maize, Teff, Sorghum, etc.

3.1.5 Vegetation

The major natural vegetation found in the district belongs to woodland and savannah. Natural and man-made forests protected by the community are 9,348 & 3,252 respectively. Historically, the district is known for its dense cover of acacia trees with typically savanna grassland.

However, recently, due to unwise utilization of forest resource by the local community for charcoal making, cultivation, and overgrazing, those natural species like acacia *albida, acacia tortoise, ficusvasta* has been destroyed tremendously.

3.2 Method and Material

3.2.1 Research Design

An explore survey study design that focuses on a particular unit of a site or a factory was used in the study. The study uses a mixed-method strategy, i.e. concurrent triangulation strategy, which is used to develop a more complete understanding of the topic and to get cross-validate findings. The case study method allows the investigator to retain the holistic and meaningful characteristics such as production and managerial processes, and the economic growth of the factory. As described by different kinds of literature, the research design is the process of arranging conditions for collection and analysis of the raw data which is observational including descriptive and analytical methods. The study was a focus on the potential site selection for disposing of obsolete pesticide chemicals which will be solved the problems related to chemical waste management.

The study was carried out from September to October (make it at least fourteen months) in Ethiopia, Oromia Regional State with special inference to Adami Tulu and Jido Kombolcha (formerly Zway) which needs both quantitative and qualitative data. The analysis about the management of obsolete pesticide chemical waste mainly includes:- exploring the recent practices and challenges of obsolete pesticide chemical waste management, identifying and prioritizing disposal techniques, determination of optimized waste disposal criteria, and selection of appropriate temporary storage potential site for disposing of obsolete pesticide chemical wastes. The sample design that deals with the method of selecting items were observed for the conducted study. As far as primary data is concerned, field surveys, observation, interviews, and focus group discussions were used. For secondary data, manual of industries, strategic and annual plan of the factory, as well as the sector, report documents, and electronic secondary databases, were reviewed.

To be specific, the required primary and secondary data were collected in the form of field survey, semi-structured interview and focus group discussion of the case factory and the district where the factory is planted on one hand; and document review from Ethiopian authorized and responsible governmental organizations (Ministry of Public Enterprise, Ministry of Industry, Environment, Forest and Climate Change Commission, Ministry of Agriculture, Ministry of Health, Ethiopia Geospatial information Institute, Ethiopia Geological Survey, Chemical, and Construction Industrial Input Institute, Chemical Industry Corporation and the case factory on the other. The site observation was used as a means to triangulate the results of a semi-structured interview and focused-group discussion as well as the gaps identified from the literature.

3.2.2 Research Approach

In this study, the researcher used both quantitative and qualitative approaches or mixed approach. The reason why this method is used to improve the accuracy of the result by triangulating the quantitative with qualitative and vice versa. Moreover, it improves readers' understanding of how the mixed approach is employed and how can verify uncertainty in the data collection approach. So, using the mixed approach, the researcher can answer the raised research questions that quantitative or qualitative methods couldn't answer solely and address complex problems that have to be solved using variable approaches and to minimize bias as well.

The quantitative approach involves the generation of data in a quantitative form which can be subjected to careful quantitative analysis to investigate the trend of pesticide production, the amount of obsolete raw material and production, criteria determination for site selection, concerning disposing of obsolete pesticide waste based on the collected data while qualitative approach concerns with subjective assessment of attitudes, opinions and casual relationships in case of site selection, disposal system, causes, problems and engaged volunteer participants of obsolete pesticide waste management practices. The mixed approach generates results either in non-quantitative form or in the form which are not subjected to rigorous quantitative analysis. Field observation, semi-structured interview, and focus group discussion were used that have to be analyzed qualitatively.

3.2.3 Method of Data Collection

To obtain relevant data from different sources, multiple data gathering techniques were employed. Therefore, a field survey using hand-held GPS &RS, focus group discussion, semi-structured interview, and personal observations were employed at the data-gathering stage (which includes both quantitative and qualitative data). Quantitative data includes closed-ended information such as estimation of obsolete pesticide waste storage, lab test data (recorded by the factory), trends of obsolete pesticide waste data, site investigation, site selection criteria setting and determination, optimizing disposal methods, a ranking of sites, and final site selection analysis. Some quantitative information is found in primary& secondary documents (e.g. seismic risk, soil permeability, geological layer resistivity, slope, land cover, and others). In contrast, qualitative data consists of open-ended information that the researcher gathers through interviews with the respondent (e.g. the recent challenges, disposing techniques, factory work procedure, the impact of obsolete pesticide waste and remedial measures, production & environmental quality management, and evaluation method, final model development, and others). An interview and focus group discussion had been administered and collected data from factory experts, process owners, concerned stakeholders, operators of the factory, and managers at their office.

3.2.4 Source of Data

Primary data: Field observation, interviews, and focus group discussion were used as primary data techniques. In addition to this, photographing capturing, topo-sheet, satellite image, and maps were also used to investigate the current situation of the case area. The secondary data employed in this study was obtained from the factory office; headquarter office and the above-mentioned stockholders. Studies conducted by governmental institutions engaged in volunteers' participant office, international journals, guiding manuals, official reports, dictionary books, and websites were used accordingly.

3.2.5 Population and Sampling Procedure

Population: - According to the 2018 G.C census report of woreda profile data, the total population for Adamitulu Jido Kombolcha woreda is 201,125, and at the factory level, as reported by Ethiopian chemical industry corporation human resource data, the population is 297.

Sampling procedure: -Getting representative samples were done by adopting a purposive sampling method. The main reason behind this selection is that until 2016 G.C, there was only one industry that can formulate pesticide chemicals. However, recently, there is one new private factory that produces pesticides (Zera Engineering and manufacturing PLC). But the researcher didn't consider this newly established private company since it doesn't have much accumulated obsolete pesticide within the past two years, and it cannot indicate the trend of impact in such cases. Hence, the selection of the sampling technique was purposive. The numbers and types of factory employees (interviewees) from the different departments were purposively determined to get representatives of each department and assessed the overall investigating obsolete and disposal trends of pesticide chemical wastes. The case company under study is the sample unit and the sample size was determined from the total population using a purposive sampling approach. In addition to this, the researcher can manage the variation within the sample by splitting the population into strata. Thus the 4 strata with their representative sampling frame were arranged (See Annex IV: I-III). Finally, approximately 16% of the respondents from the total strata were selected proportionally as sample size. Hence the total sample size in this study was estimated as forty-seven. The overall research framework of the study is illustrated in figure 3.2

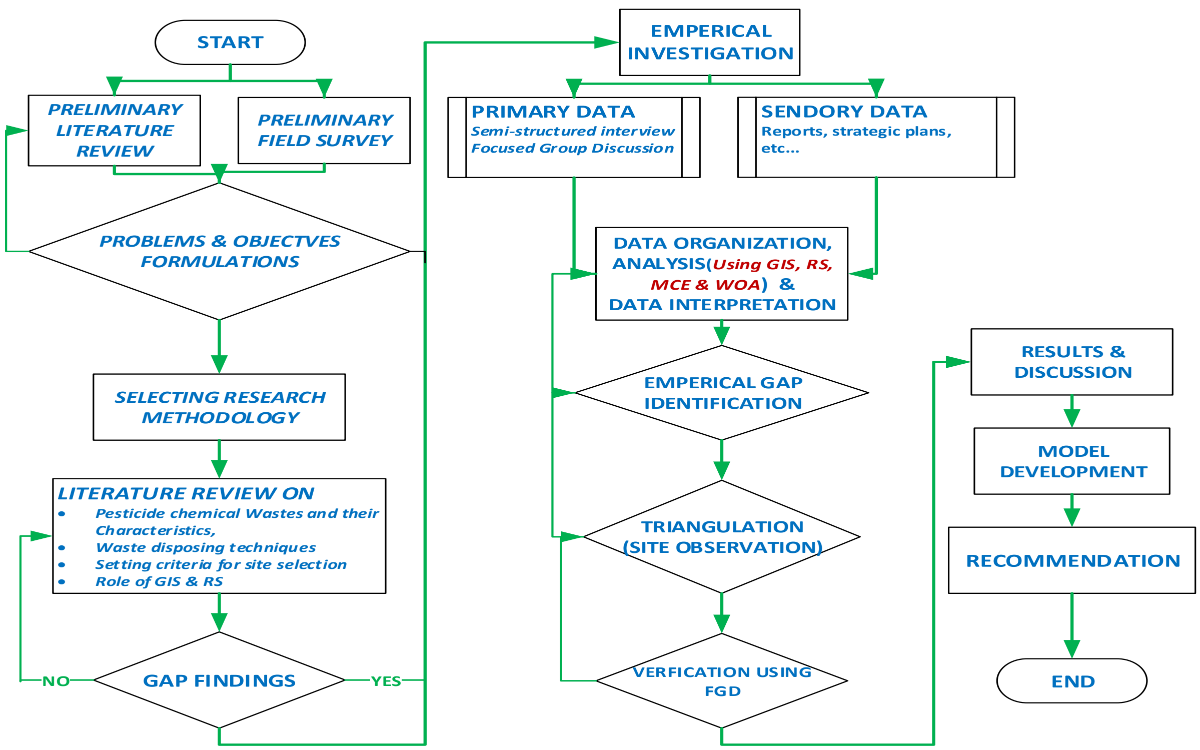


Figure 3. 2: Research Framework of the study (Source: Own, 2019)

3.2.6 Data Analysis

Part one

The first part of the analysis was conducted based on the evidence obtained from the interview, FGD, and field observation. The integrity of data analysis can be compromised by the environment or context in which data was collected i.e., face-to-face interviews, focused group, and field survey. Since the data collection process could be influenced by the environment/context, researchers should take this into account when conducting data analysis.. The analysis was conducted analytically using tables, graphs, and figures. The details are discussed below.

A. Semi-structured Interview

Experts, operational managers, and higher-level officials were involved in the interview. From a total of 47 respondents, all of them gave responses with a response rate of 100%. Concerning the sex status, **78.72** % of the respondents (35.14% from federal, 35.14 woreda &24.32% from kebele) were male and the remaining 21.28% were female (10% from federal, 40% from woreda, and 50% from kebele). The majority of the respondents were from woreda (36.17%) and (29.79%) both from federal and kebele (See appendix V; A).

B. Focused-group Discussion

The samples for FGD were selected from departments of the factory which have an impact on the success of the analysis. The variety of participants includes factory experts from different departments, process owners, concerned stakeholders, and factory managers.

C. Site Observation

The researcher visited the factory two times. During the first visit, a preliminary observation was conducted at each department and a discussion was also made with the principals of each division. In the second visit, detail and critical observation were done in line with checklists prepared for this purpose. The main objective of this field observation is to triangulate the results of a semi-structured interview and focused-group discussion whether they are matched or not.

Part two

The second part of the analysis was conducted based on the pieces of evidence obtained from RS, Satellite images, field survey data by GPS, Cartographic, Seismic, and Geological information data. The integrity of data analysis can be conducted by using RS, GIS, and MCE approach in which the decision was made. I.e., criteria setting and selection procedure vs input data analysis and bio-geophysical parameters measurement. The methodological framework of site selection analysis is illustrated in Figure 3.3.

A. Input Data, Criteria Selection, and Processing Method

I. Input Data

The preliminary data that were collected to analyze the site selection using GIS and RS include Topographic map (Survey of Ethiopia), Aerial photographs (EGII, SPOT 5 image), Soil map of Ethiopia, Geological Map (Ethiopian Geological survey), Groundwater map of Ethiopia, Seismic Data adopted from (Wilks, Ayele, Kendall, & Wookey, 2016). Rainfall, Floods (EMA), and Metrological Data (EMA). Ground controls points were identified using GPS.

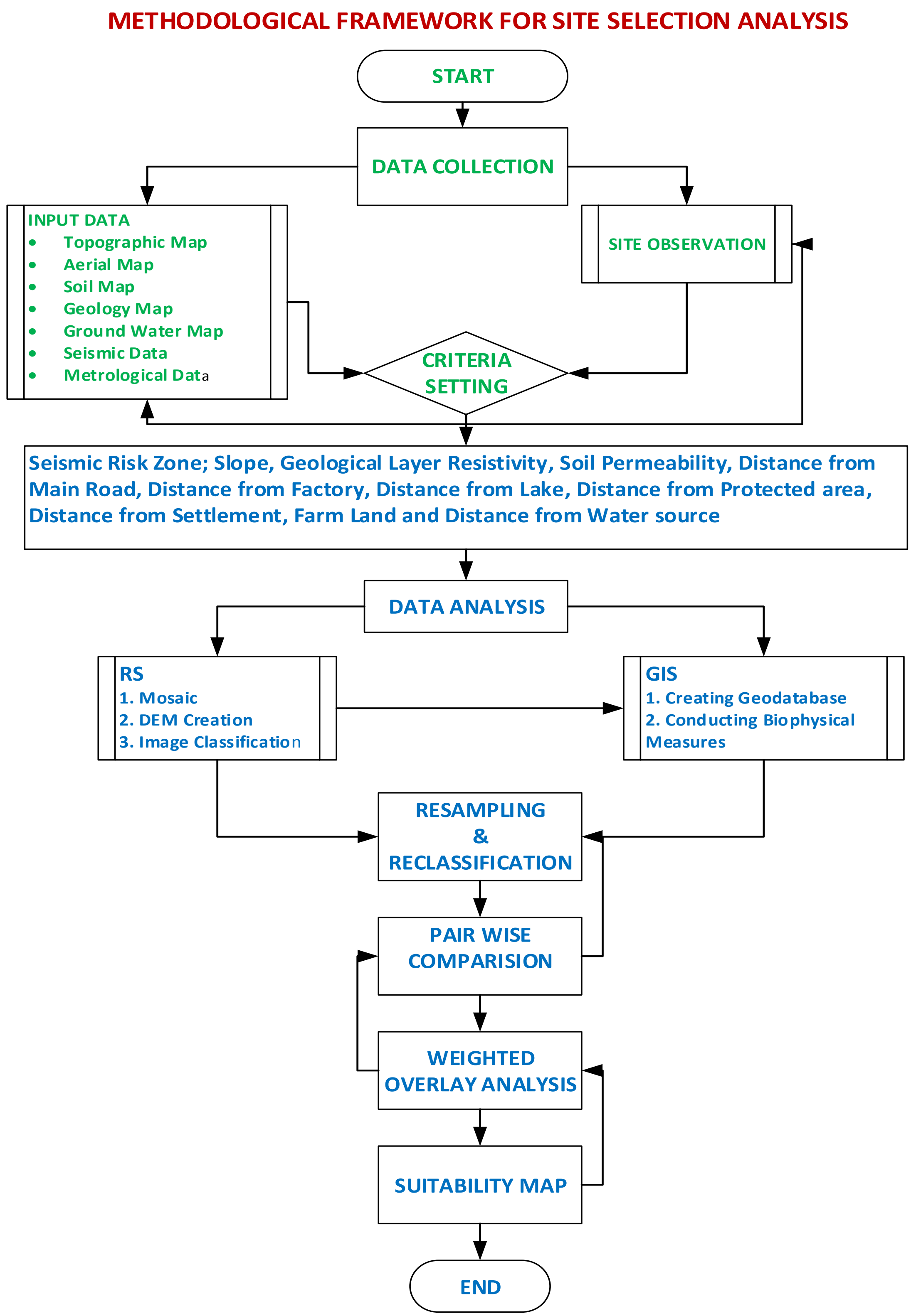


Figure3. 3: Methodological Framework of Site Selection Analysis

II Criteria Setting and Selection Procedures Optimization

Selection of temporary storage site using GIS and RS needs criteria which tell about the overall situation of the candidate sites. There are techniques to evaluate all criteria and to select the most appropriate ones which have a high impact on the waste disposing process. One of the techniques used to evaluate candidates is Multi-Criteria Evaluation. Multi-criteria evaluation in advanced spatial analysis is concerned with the allocation of land to suit a specific objective based on a variety of attributes that the selected areas should possess(Eastman & Longley, 2005).

To select criteria for site characterization, the geographical background of the factory is vital. Hence, the background information about the factory land was used as inputs to weigh and select the criteria. The factory is found in Oromia Regional State, Southern Shoa, Zway town. It is bordered from north direction by bushlands and farmlands; northeast direction by lake Zway and Zway town, east direction by farmlands and settlements; south direction by grasslands, bushlands and farmlands, Adami Tulu town, forest lands, and the main roads; southeast direction by floriculture (flower production); west direction by grasslands, farmlands, bushlands, and scattered settlements; northwest direction by grasslands, farmlands, bushlands, and scattered settlements; and southwest direction by farmlands, bushlands, grasslands, scattered settlements, Adami Tulu town and floriculture (Observed by the researcher). The range of the slope for the factory and its surrounding varies from 0^o (flat area) to 79^o (very steep). The aspects used in this analysis were adopted from the work of Krishna and Babu (1999) (See appendix VI; Table 4.13)

A. Steps for selecting sites in field survey

Adopting from the work of Krishna & Babu (1999), the methods used for selecting the temporary storage site are summarized in Figure 3.4.

The site sensitivity index for each attribute was adopted from Kharat, Kamble, Raut, Kamble, & Dhume (2016). The overall selection process was carried out using attribute measurements. The attribute score is found by multiplying the weightage sensitivity index. (See appendix X; Table 4.16). Based on the above author's classification and geographical background of the factory site, the researcher selected the following criteria using MCE, and weight was given for each criterion to select the better ones.

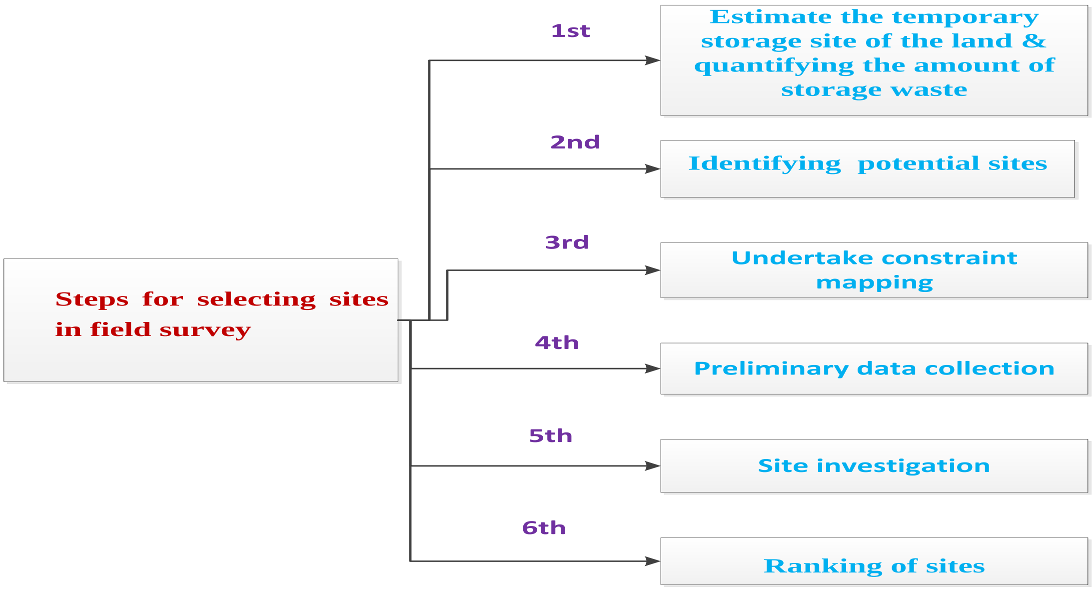


Figure3. 4: Site Selection Procedures

Table3. 1: Selected criteria's and their weighted influence for site selection

Sr.No	Name of Criteria	Zones	Scale Value	Suitability	Influence (%)
1	Seismic Risk zone (Wilks, Ayele, Kendall, Wookey, 2017)	0.0-0.5 PGA(m/s^2)	10	High suitable	20
		0.5-0.75 PGA(m/s^2)	7	Suitable	
		0.75-1.0 PGA(m/s^2)	4	Low Suitable	
		>1 PGA(m/s^2)	0	Unsuitable	
2	Slope (kontes et al., 2005)	>45%	0	Unsuitable	9.2
		20 -45%	4	Low Suitable	
		10 – 20%	7	Suitable	
		<10%	10	HighSuitable	
3	Distance from the main road (Adeli and Khorshiddouts, 2011)	<1000	0	Unsuitable	7.9
		1000 – 1500m	4	Low suitable	
		1500 – 2000m	7	Suitable	
		>2000m	10	High Suitable	
4	Distance from lake (Decided by the researcher considering the existing location)	< 1500m	0	Unsuitable	8
		1500 – 2000m	4	Low Suitable	
		2000 – 3000m	7	Suitable	
		>3000m	10	High Suitable	
5	Distance from the settlement (Babalora & Busu, 2010)	< 500m	0	Unsuitable	10.8
		500-1500m	4	Low Suitable	
		1500 -2000m	7	Suitable	
		>2000m	10	High Suitable	
6	Distance from the	<2000m	0	Unsuitable	9.1

Sr.No	Name of Criteria	Zones	Scale Value	Suitability	Influence (%)
	protected area (Decided by the researcher considering the existing location)	2000 – 3000m	4	Low Suitable	
		3000 – 5000m	7	Suitable	
		>5000m	10	High Suitable	
7	Distance from the water source (Decided by the researcher considering the existing location)	< 1000m	0	Unsuitable	9.4
		1000 – 1500m	4	Low Suitable	
		1500 – 2500m	7	Suitable	
		>2500m	10	High Suitable	
8	Geological layer resistivity (Decided by the researcher considering the existing location)	1-1000 ohm-m	0	Unsuitable	10.4
		10 - <1000 ohm-m	4	Low Suitable	
		10-1000 ohm-m	7	Suitable	
		1000-10000 ohm-m	10	High Suitable	
9	Distance from factory (Decided by the researcher considering the existing location)	<1000m	0	Unsuitable	8.2
		1000-5000m	4	Low Suitable	
		5000-10000m	7	Suitable	
		>10000m	10	High Suitable	
10	Farmland (Decided by the researcher considering the existing location)	<500	0	Unsuitable	7.1
		500-1500	4	Low Suitable	
		1500-3000	7	Suitable	
		>3000	10	High Suitable	

III. Processing Method

A. Crating File Geodatabase

It is well known that geodatabase provides a generic framework for geographic information. This framework can be used to define and work with a wide variety of different user- or application-specific models. The geodatabase of this research consists of folder geodatabase, personal geodatabase, datasets classes, and attributes.

B. Generating DEM from RS data (SPOT-5 Satellite)

SPOT-5 Satellite Sensors (2.5m/5m)

SPOT-5 Satellite sensor was decommissioned on March 31, 2015. The improved version of SPOT-5 can make 5m and 2.5m resolution and has a wide imaging swath that covers 60 x 60 km or 60 km x 120 km in twin-instrument mode. The SPOT-5 satellite also provides an ideal balance between high resolution and wide-area coverage. Compared to its predecessors, the SPOT-5 satellite offered greatly enhanced capabilities, which provided additional cost-effective imaging solutions. The coverage offered by SPOT-5 was a key asset for applications such as medium-scale mapping (at 1:25 000 and 1:10 000 locally), urban and rural planning, oil and gas exploration, and natural disaster management (Astrium, 2019).

DEM

Digital Elevation Model (DEM) is defined as any digital representation of the continuous variation of relief over space," (Burrough, 1986), where relief refers to the height of the earth's surface concerning the datum considered. DEM is also considered as the digital representation of the land surface elevation concerning any reference datum (Koroleva & Nikitin, 2014).

DEM can be generated from stereo pair of satellite images, such as optical remote sensing images which acquired spot 5 satellites. The spot 5 satellite is conventionally used in generating DEMs by using the photogrammetric techniques, i.e., it is the art, science, and technology of obtaining reliable spatial information about physical objects and the environment through the process of recording, measuring, and interpreting image data(Mboin et al., 2012)

In this study, the SPOT5 image of the district is the main data used for image processing to develop the site selection characterization model and MCE is used for selecting suitable pesticide chemical waste temporary storage site. Based on the DEM data, the topography of Gebri kebele is low in the northeast and high in other parts with an elevation range from1038m to 1542m.

C. Making Mosaic from SPOT 5 Satellite Image

Mosaic is a data model within the geodatabase used to manage a collection of raster datasets (images) stored as a catalog and viewed as a mosaicked image. Mosaic datasets have advanced raster querying capabilities and processing functions and can also be used as a source for serving image services(Mboin et al., 2012). In this study, mosaics were made the seven grid cell SPOT 5 image of the district combined into one mosaic dataset those are used to manage, display, serve, and distribute raster data. They are created, edited, and managed with the tools in the Mosaic Dataset toolset in the Data Management toolbox.

D. Image Processing

Pre-processing

In this study, pre-processing was carried out to correct for any distortion due to the characteristics of the imaging system and imaging conditions. Under this process, the radiometric correction was applied to correct for uneven sensor response over the whole image and geometric correction to correct for geometric distortion due to Earth's rotation and other imaging conditions (such as oblique viewing) In addition to this, the image would be transformed to conform into a specific map projection system (WGS_1984_UTM_zone_37N) and ground control points (GCP's) are used to register the image to a precise map (geo-referencing).

Image Classification

The image classification procedure used in this study is unsupervised classification, in which the computer program automatically groups the pixels in the image into separate clusters, depending on their spectral features. Each cluster will then be assigned a land cover type by the researcher. The following image shows a Gebri site thematic map. This map was derived from the multispectral SPOT 5 image of the research area.

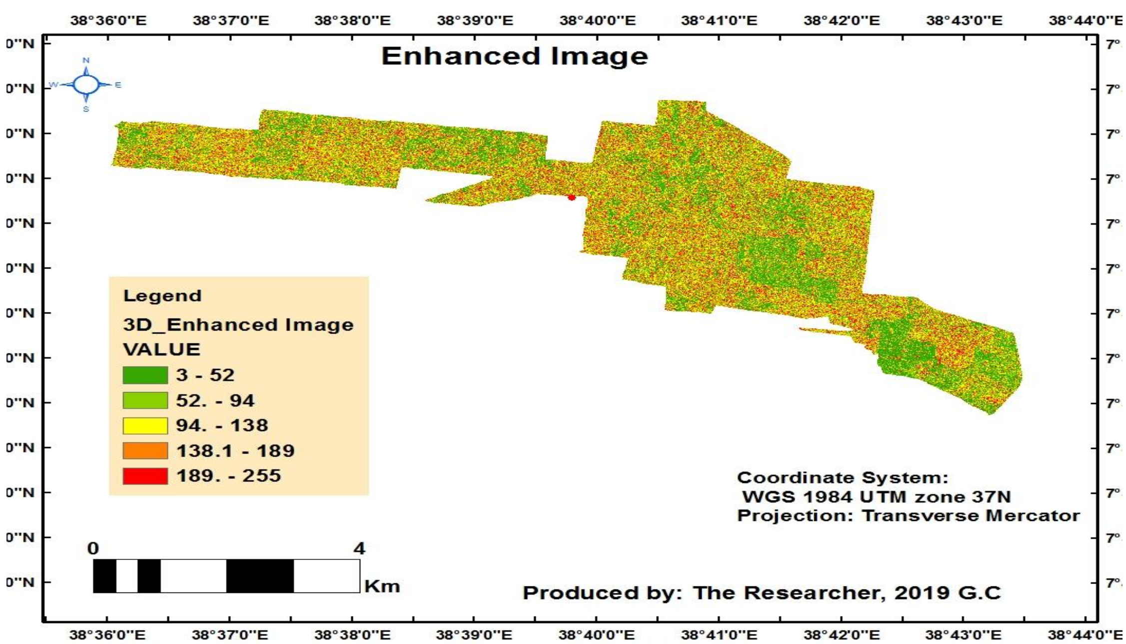


Figure3. 5: Thematic Map of Gebri Site Derived from the SPOT 5 Image Using an Unsupervised Classification Algorithm (Source: Own, 2019)

Note that the accuracy of the thematic map derived from remote sensing images should be verified by the researcher during field observation.

Spatial Feature Extraction

From SPOT 5m spatial resolution imagery, details such as buildings and roads can be seen. In addition to this, road markings, individual trees, lakes, and drainage lines can be seen clearly. The result of applying the extraction of the factory site is shown in the following image.

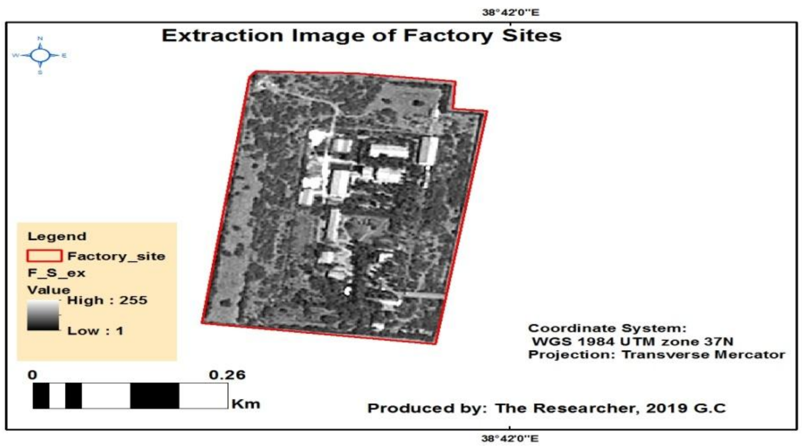


Figure3. 6: Extraction Image of Factory Site (Source: Own, 2019).

Measurement of Bio-geophysical Parameters

In this study, the satellites can be used to make measurements of the bio-geophysical parameters of the earth, such as soil permeability, geographical layer resistance, water source, seismic risk zone, distance from different land features, etc., by using Arc GIS 10.3.1 software.

Generally, the analysis of the quantitative & qualitative data was carried out using a mixing of data: i.e. merging or converging the two data sets by actually bringing them together, connecting the two data sets by having built on the other, or embedding one data set within the other so that one type of data provides a supportive role for the other dataset. Concerning primary data, the interviews and observed data analysis will be carried using Microsoft Excel graphs and charts. Descriptive statistics such as percentage, graph, pie chart, and ratio were used.

Field survey, field observation, satellite image, and map data was analyzed with the help of GPS, RS, and GIS software, multi-criteria analysis, and weightage overlay analysis. Weighting by pairwise comparison is a method used for determining weights for those different factors. It stems from the Analytic Hierarchy Process (AHP), a famous decision-making framework developed by the American professor of mathematics (Saaty, 2008). (See appendix XIII).

In the analysis process, the following three steps led to the result:

Step 1: Completion of the pair-wise comparison matrix: - two criteria were evaluated at a time in terms of their relative importance. Index values from 1 to 9 were used.

Step 2: Calculating the criteria weights: – the weights of the individual criteria were calculated. In this analysis, first, a normalized comparison matrix was created: each value in the matrix was divided by the sum of its column. To get the weights of the individual criteria, the mean of each row of the second matrix was determined. These weights were already normalized; their sum is 1.

Step 3: Calculating the consistency matrix: – a statistically reliable estimate of the consistency of the resulting weights was made.

The RCI value is used to calculate the AHP's CR value that evaluates how consistently importance ratings were applied in the pairwise comparison decision matrix. If the CR is less than 10%, importance ratings were applied consistently, and weights (i.e., principle eigenvectors) calculated in the decision matrix are acceptable to use in suitability analysis (Saaty, T.L, 2001).

The AHP Consistency Ratio (CR) was then used to evaluate how consistently the importance ratings were applied in comparing each criterion's importance over other criteria (Trianta phyllo & Mann, 1995). The pairwise comparisons are deemed consistent if the CR is less than 10%, (Triantaphyllou & Mann, 1995). The CR is calculated as follows: Consistency Index (CI) / Random Consistency Index (RCI). The CI is found by the following equation:

$CI = (\lambda max - n)/n - 1$; $\lambda max = \Sigma$ of products between principal eigenvectors and column totals (Σ), and n = number of criterion being compared (Estoque & Murayama, 2012). (See appendix XV; H).

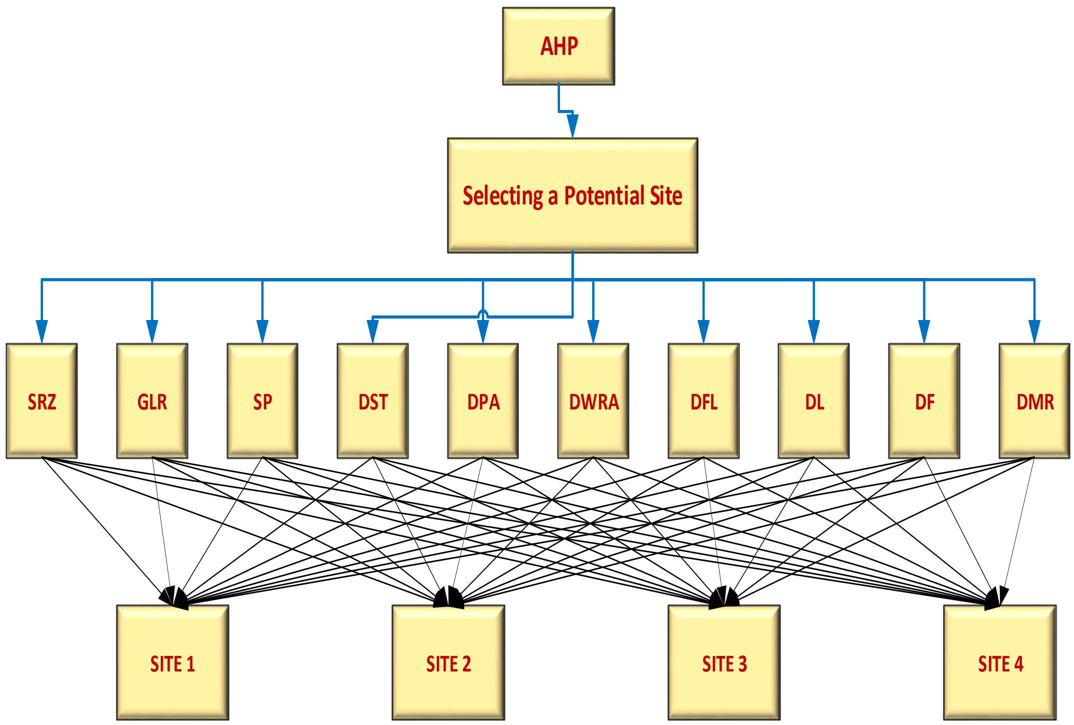


Figure3. 7: Development of AHP structure with a goal at the top level, the attribute/criteria at the second level, and alternatives at the third level.

Weighted overlay analysis

It is a process of assigning a numerical weighting factor to each thematic layer according to its relative importance compared to all other layers. In principle, the weighted overlay is possible with raster and vectors just like a Boolean overlay. In this case, the weighted linear summation models are used as an approach and follow the following steps:

1. Selecting the criteria: the first step is to choose criteria that characterize the area;
2. Standardization: the different measurement scales of the input data need to be matched.
3. Distribution of weights: each information layer receives a weight. The weight reflects the relative importance of each layer respective to the other.
4. Application of the algorithm: the algorithm of the weighted linear summation multiplies all grid cells of a layer by their weight. Then, the layers are added together. In the resulting suitability layer, suitable cells have high values while not suitable cells have low values

Furthermore, the practically collected data was analyzed using descriptive statistical methods. Major site characterization and site selection criteria had been described. The analysis would also focus on attempting to identify relationships between the site selection criteria and pesticide chemical waste disposal techniques.

CHAPTER: FOUR

Result and Discussions

4.1 Introduction

This chapter deals with the results obtained from the analysis using primary and secondary data. Some data such as site observation and previous related works were used as means to triangulate the results of the analysis. The details of the obtained results are discussed below.

4.2 Recent Practices and Challenges in Obsolete Chemical Wastes Disposal

Chemical waste management is a challenge for the pesticide chemical factories in developing countries mainly due to the increasing generation of wastes (Guerrero et al., 2013). Unless wastes are managed critically, they will be harmful both to human beings and to the environment at large. The collected secondary data shows that the factory understudy has produced more than 22 types of pesticide chemicals. There are wastes some of which are formed during and after the process and others are due to obsolete chemicals. During the focused group discussion, the researcher verified that factory professionals know pesticide chemicals' use, characteristics, and type. They have also aware of the negative impact of obsolete chemical wastes on human health and to the environment as well when they are improperly stored or disposed of. However, they lack knowledge, skills, and commitment concerning the management and disposing techniques of chemical wastes.

The main causes for the formation and accumulation of pesticide chemical wastes are: inaccurate forecasting and poor production planning, importing chemicals from abroad for technology transfer which couldn't considered the existing demand of consumers, problem of registration due to lack of quality assurance institution which has certified testing laboratories to assure the transferred product for registration within the country, absence of R&D, unplanned production orders from practitioners, unbalance inventory of recipe and formulation during production, improper handling of tracing material and product wastes due to quality problems.

As far as the negative impacts of obsolete pesticide chemical wastes are concerned, the disposing of wastes on the community and the environment results in disease symptom on the factory employees due to improper use of safety materials and due to the harmful nature of chemicals during the process. In addition to this, during the rainy season, the slag storage will be full of liquid wastes and will be flooded the surrounding area which pollutes the community living in the surrounding. Moreover, containers, pills, packing materials, and other irrelevant materials are incinerated which brings air pollution.

Concerning the positive impact, the trends of the factory show that they treat containers that are durable and usable for other activities by washing those using chemicals that avoid their harmfulness. Next to washing, they prepare the containers for the market which generate income for the factory and its employees. In addition to this, it also gives job opportunities for the surrounding community which has its share of unemployment reduction. However, the treating process is not standardizing and doesn't follow scientific procedures to wash and clean containers through chemicals.

Major challenges observed in the factory include; lack of knowledge in pesticide chemicals production engineering and management, improper organizational structure, absence of world-class accreditation institute at national level which gives recognition through critical investigation, the lack of attention to the sector in general and the factory in particular, a limited number of researchers who raised about obsolete pesticide chemicals issues and no one tries to solve the disposal problems at the firm level. There was one trend about chemical waste disposal during the 1990s. With the financial support of the United Nation and FAO, obsolete pesticide chemical wastes were sent to Netherland for disposal. Recently, with the support of WFP, DDT inventory is started using the project which is carried out at the national level. However, there is no scientific disposing technique within the factory.

4.3 Trends in Generating Wastes

Globally, with the advent of the green revolution (1940-2015), the production and consumption of pesticides have been increasing rapidly (Mengistie, 2016; M.I. et al., 2013). According to the data obtained from UNDP (2011), worldwide, total expenditures on pesticides increased by 61% between 1999 and 2009, from $1.1 billion to $1.9 billion. Consequently, the global pesticide market was reached around $44 billion in 2011 and projected to increase by 2.9% per year to $48 billion in 2014(Benoît-Norris et al., 2011; Group, 2016).

Coming to the developing scenario, the consumption of chemicals in developing countries is growing remarkably faster than in developed countries and is predicted to account for a third of global consumption by 2020 ((Honkonen, Tuula, A.Khan, 2017; UNEP 2012b).

On current trends, developing countries are expected to account for 37 percent of the production of high volume industrial chemicals by 2030. Wastes from products containing chemicals that are hazardous to human and environmental health are an increasing source of concern in many developing countries, where regulatory frameworks for environmentally sound waste management are often weak, non-existent, or poorly enforced (UNEP 2012a). Besides, economic growth, urbanization, and industrialization result in increasing volumes and varieties of both solid and hazardous wastes. In addition to this, globalization can aggravate waste problems through growing trade, with developing countries often at the receiving end (Banuri, 2010).

Concerning Ethiopia's case, although the chemical pesticide used in Ethiopia was historically low, recent developments in food production and expansion in the floriculture industry have resulted in higher consumption of chemical pesticides (Amera & Abate, 2008). Recently, Ethiopia has been considered as having the largest accumulations of obsolete pesticides in the horn of Africa. According to the report of the Ministry of Agriculture and Rural Development, there were 402 stores at 250 sites containing 1, 500 tons of obsolete pesticides (MOARD, 2007). It has been reported (MOARD, 2007) that a significant portion of the obsolete pesticides has been removed since then. However, it should be noted that as the obsolete pesticides are removed, new pesticides are imported and are possibly contributing to further accumulation (Amera & Abate, 2008). The following figures show the trends of obsolete raw materials, finished products, and their average in Ethiopian PPF from 2012 to 2018.

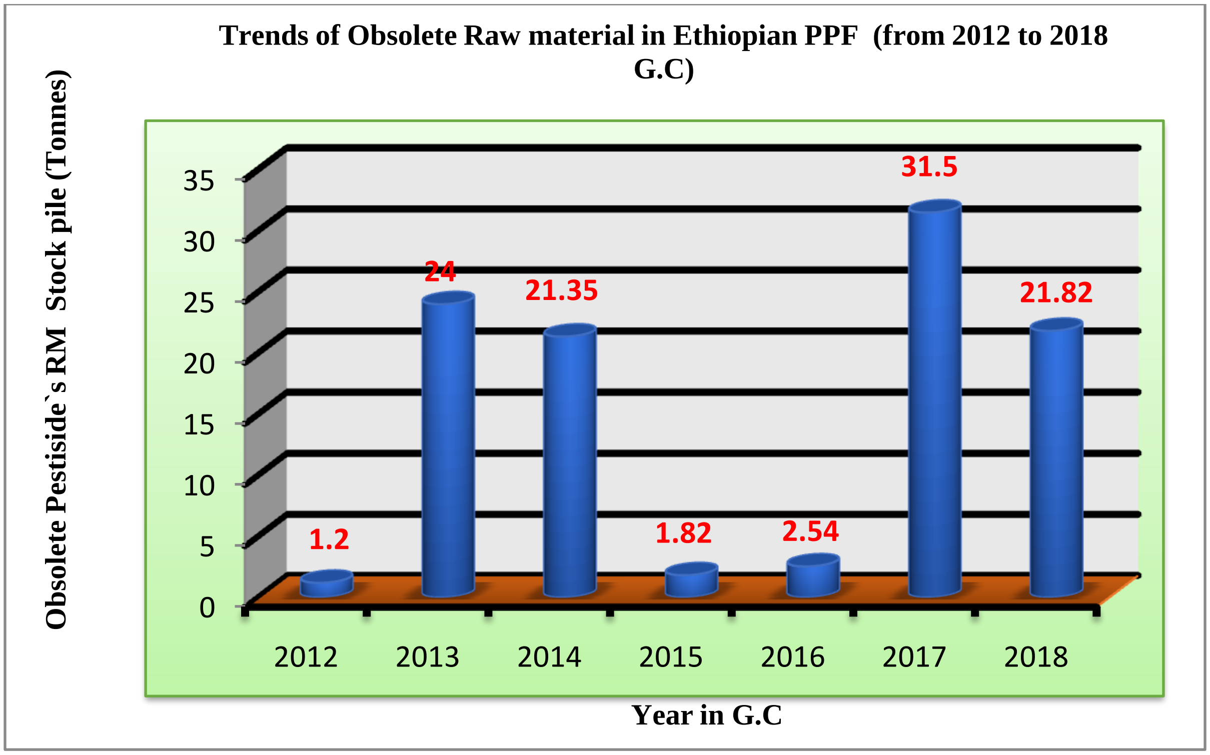


Figure4. 1: Trends of Obsolete Raw Materials in Ethiopian PPF (Source: APPF, 2019)

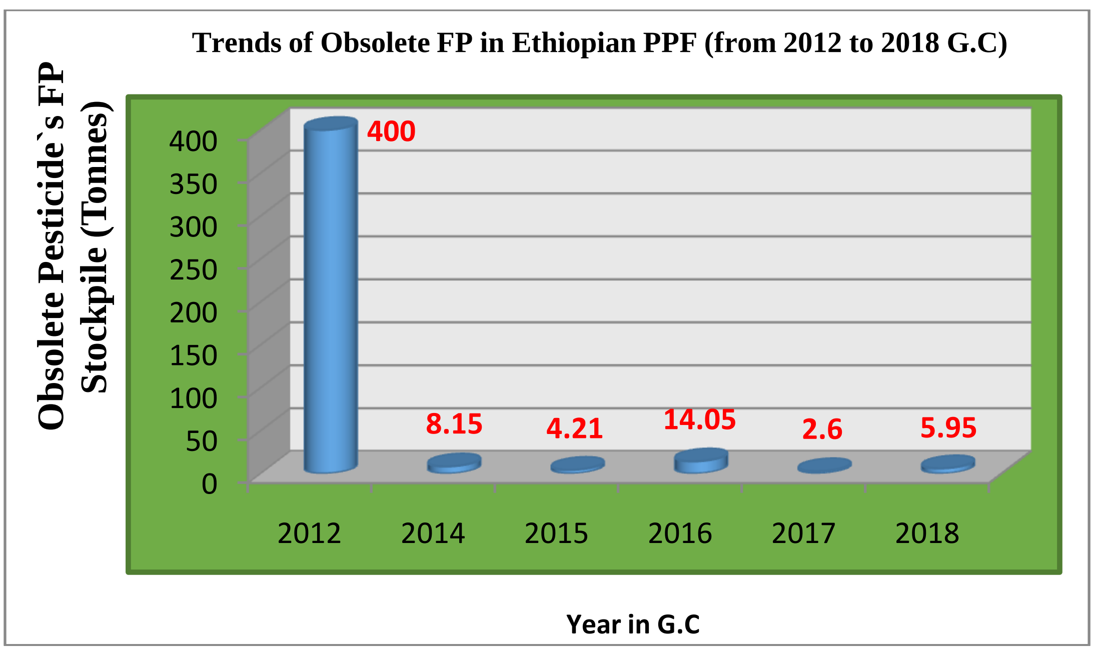


Figure4. 2: Trends of Obsolete Finished Products in Ethiopian PPF (Source: APPF, 2019)

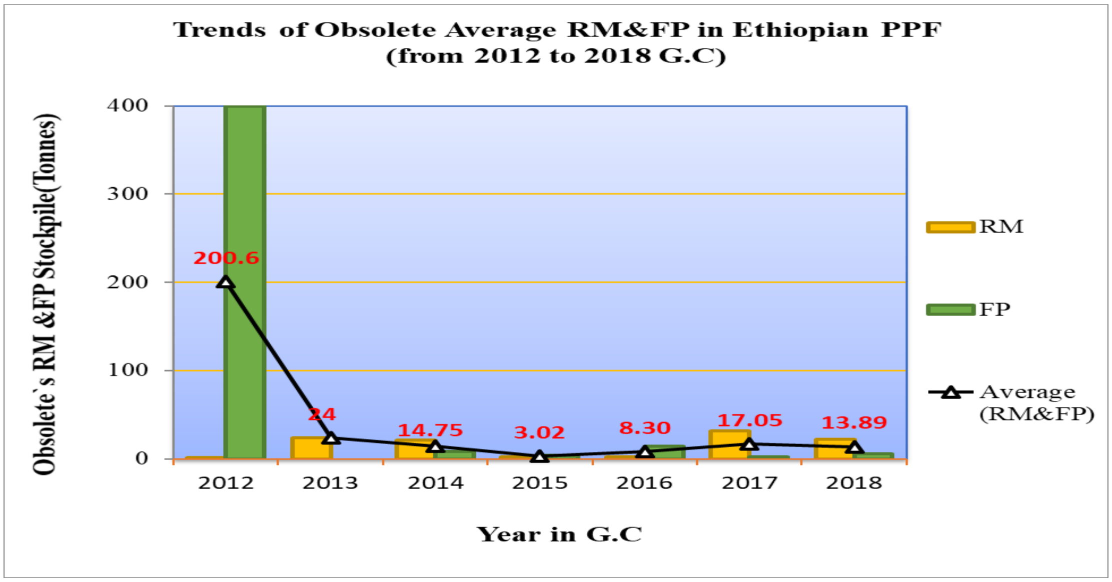


Figure4. 3: Trends of Obsolete Average Raw Materials and FP in Ethiopian PPF (Source: APPF, 2019)

4.4 Estimation of Waste storage

Based on the factory data, the amount of obsolete pesticide waste storage is estimated by using a 7-year moving average method. The moving average method is an improvement over the semi-average method and short-term fluctuations are eliminated by it.

The resulting graph provides the trend.

Table4. 1: Actual Obsolete Raw Material value (Source: APPF, 2019)

ORM &OFP Actual value			
Year(G.C)	ORM Value (Tone)	OFP Value (Tone)	Average of ORM & OFP Value (Tone)
2012	1.2	400	200.60
2013	24	0	12.00
2014	21.35	8.15	14.75
2015	1.82	4.21	3.02
2016	2.54	14.05	8.30
2017	31.5	2.6	17.05
2018	21.82	5.95	13.89

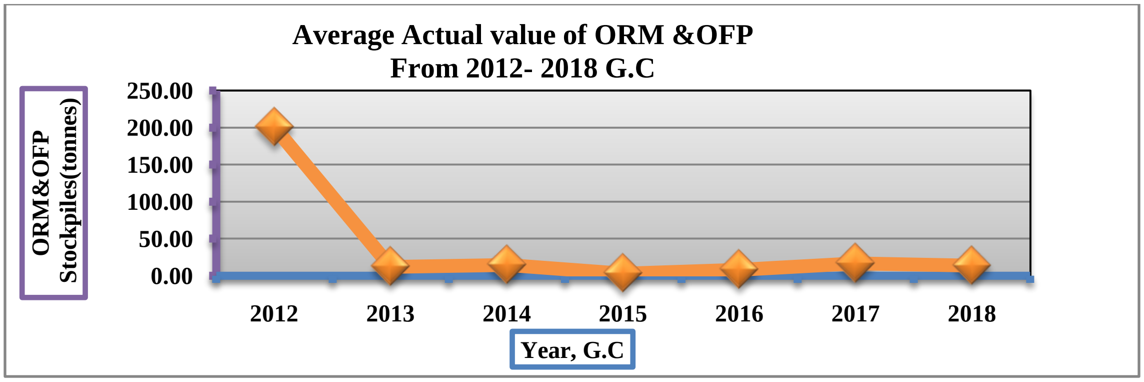


Figure4. 4: Average Actual Value of ORM and OFP

Table4. 2: Estimation of ORM &OFP trend value for 25 years

ORM &OFP Estimation of trend value for 25 years			
Year(G.C)	Estimation of ORM Value (Tone) for the next 25 years	Estimation of OFP Value (Tone) for the next 25 years	Average estimation of ORM & OFP Value (Tones)
2019	14.89	62.14	38.51
2020	17.17	5.83	11.50
2021	15.81	6.99	11.40
2022	14.42	6.70	10.56
2023	18.62	7.53	13.08
2024	26.66	4.28	15.47
2025	21.82	5.95	13.89
2026	18.48	14.20	16.34
2027	19.00	7.35	13.18
2028	19.27	7.41	13.34
2029	19.79	7.31	13.55
2030	20.64	7.23	13.94
2031	21.18	7.00	14.09
2032	20.83	7.11	13.97
2033	20.83	7.11	13.97
2034	21.17	6.10	13.64
2035	21.48	6.06	13.77
2036	21.79	6.00	13.90
2037	22.05	5.95	14.00
2038	22.11	5.92	14.01
2039	21.94	5.98	13.96
2040	21.94	5.98	13.96
2041	22.10	5.81	13.96
2042	22.23	5.79	14.01
2043	22.32	5.78	14.05

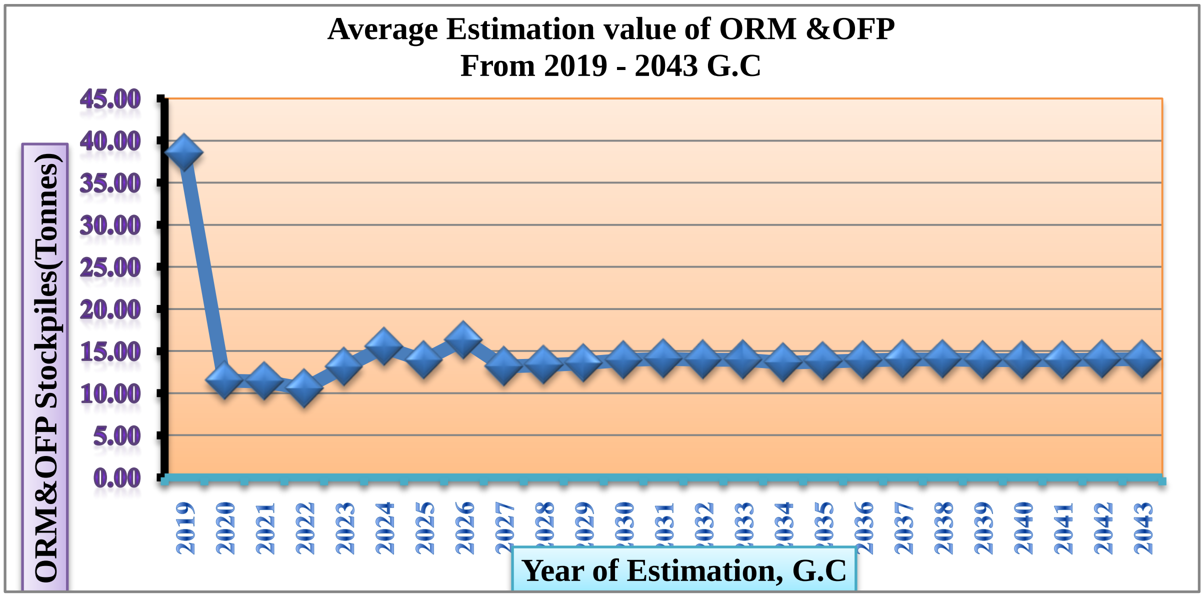


Figure4. 5: Average estimation value of ORM &OFP

4.5 Optimization of Techniques for Disposing of Obsolete Pesticide Chemical Wastes for Developing Countries

Different wastes are disposing of techniques which are used to dispose of obsolete wastes. Some of the techniques have the potential to convert the wastes into usable form while others are used as temporary storage. Generally, scholars grouped the waste disposing techniques into chemical, biological and physical (site selection). The main reason behind selecting the appropriate disposing techniques lies with driving factors that affect the selection process. Cost, technology, knowledge, and risk are among the factors which affect the selection process especially from the technological and socio-economic conditions of developing countries in general and Ethiopia case in particular. Since we are grouped under low-developing countries, we have the very limited financial capacity, lack updated knowledge, and technology and we are exposed to environmental risks. From the three disposing techniques, chemical and biological methods need high capital, updated technology, and high-level professionals. Therefore, this study focused on the physical approach, i.e., temporary storage site selection, which needs relatively low cost, technology, and semi-skilled professionals.

4.5.1 Pair wise Comparison

Pesticide chemical wastes can be disposed of chemically, biologically, or physically. From the perspectives of developing countries, the criteria which were compared with each other to select the appropriate techniques in descending order of importance are cost, technology, knowledge, and risk. Based on the focused group discussion, expert knowledge, and stakeholder preferences the weight of importance given are 0.5, 0.25, 0.15, and 0.1 respectively.

Criteria: Cost, Technology, Knowledge, and Risk

Alternatives: Physical, Biological, and Chemical

The pair wise comparison and normalized pair wise matrix for each criterion and alternatives were interpreted and the results were shown in the appendix. (See appendix XII; Table 5.5.2-5.5.5).

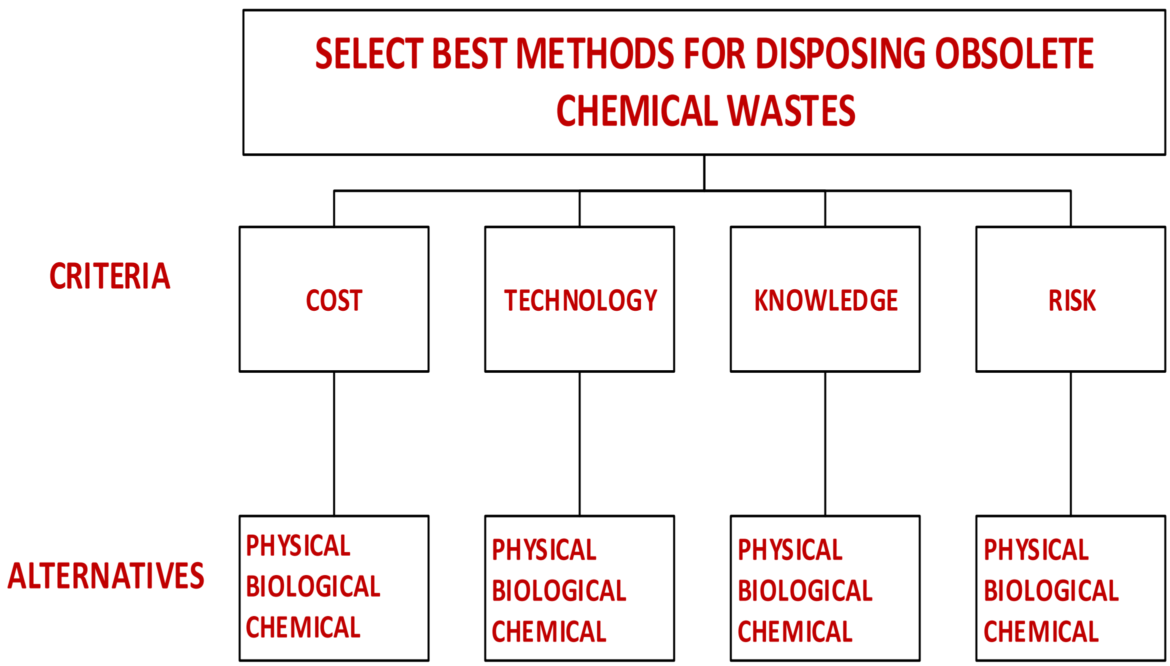


Figure4. 6: Criteria and alternative comparison for selecting methods

The comparison results that the highest weight is given to cost (47.69%) and the least is to risk (3.93%). Next to criteria comparison, each alternative/attributes were compared with each other, i.e., physical to biological, biological to the chemical method, and physical to chemical methods for cost, knowledge, technology, and risk.

A. Cost Influential factors such as transportation, labor, and the availability of land, often involved in the site selection decision. A relative Priorities for Costs are:

- Physical Method = 8.0277 (78.71%)
- Biological Method = 2.0254 (19.86%)
- Chemical Method = 0.1460 (1.43%)

This means that concerning Cost, the Physical Method is preferred first (78.71%), then Biological Method (19.86%), and then Chemical Method (1.43%). (See appendix XII; A-E).

B. Technology Simplicity: Complex technological processes are not automatically better than simple ones. The principles of the simplicity of design and operation for site selection are particularly important in the chemical industry. A relative Priorities for Technology Simplicity are:

- Physical M. = 5.0278 (67.27%)
- Biological M. = 1.7454(23.35%)
- Chemical M. = 0.7014 (9.38%)

This means that concerning Technology simplicity, the Physical Method is preferred first (67.27%), then Biological Method (23.35%), then Chemical Method (9.38%). (See appendix XII; F-G).

C. Knowledge Simplicity: simply easy to understand, explain and practice. A relative Priorities for Knowledge Simplicity are:

- Physical M. = 2.7889(62.3%)
- Biological M. = 1.2855 (28.71%)
- Chemical M. = 0.4023 (8.99%)

This means that concerning Knowledge simplicity, the Physical Method is preferred first (62.3%), then Biological Method (28.71%), then Chemical Method (8.99%). (See appendix XII; H-I).

D. Risk Reduction: loss mitigation, disaster risk prevention, the feasibility of the site. A relative Priorities for Risk Reduction are:

- Chemical M. = 1.7786 (45.4%)
- Biological M. = 1.3105 (33.65%)
- Physical M. = 0.8077 (20.95%)

This means that concerning Risk Reduction, Chemical Method is preferred first (45.4%), then Biological Method (33.65%), then Physical Method (20.95%). (See appendix XII; J-K).

Finally, to select the best method, add the average value of each attribute and take the average concerning the alternative methods as shown below.

Table4. 3: Best method of disposing techniques comparisons result table

Candidate Methods	Attributes/factors						
	Avg. Cost	Avg. Technology	Avg. Knowledge	Avg. Risk	Total	Total avg.	Rank
Physical	**8.0277**	**5.0278**	**2.7889**	**0.8077**	**15.8433**	**3.96**	**1**
Biological	2.0254	1.7454	1.2855	1.3105	6.3578	1.59	**2**
chemical	0.146	0.7014	0.4023	1.7786	3.0283	0.76	3
Total	10.1991	7.4746	4.4767	3.8968			
Total Avg.	3.4	2.5	1.5	1.3			

4.6 Determination of optimized criteria for the identification of potential site selection

Integrated disposal siting is a difficult, complex, and tedious process requiring evaluation of various criteria. Optimized siting decisions have gained considerable importance in ensuring minimum damage to the different environmental components. The overall criteria identification process was done using field survey data & attribute measurements. The attribute score is found by multiplying the weightage sensitivity index as discussed in chapter 4. The result is shown in the figure below.

Optimized Criteria in the identification of suitable site selection for disposing obsolete pesticide waste

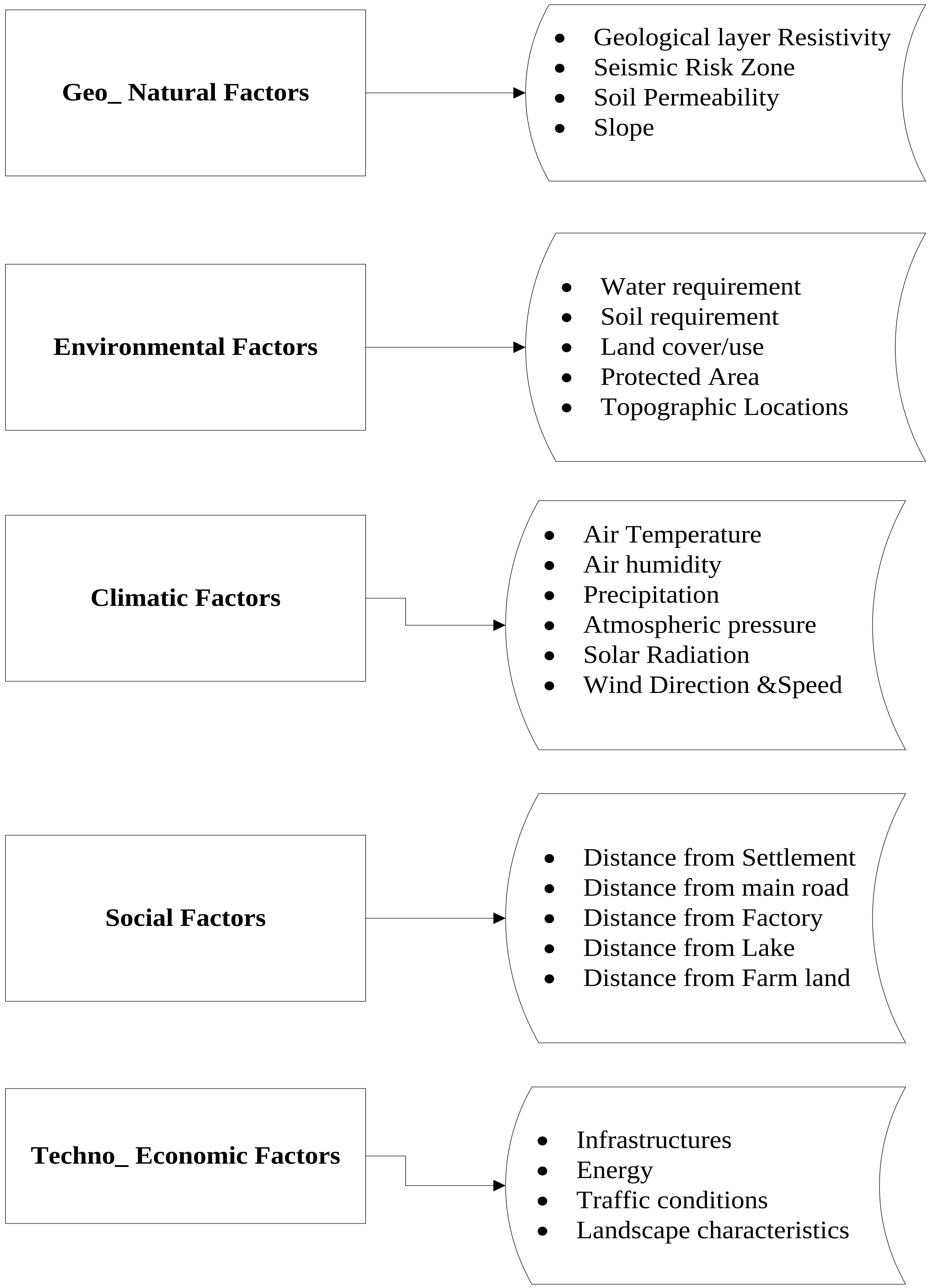


Figure4. 7: Optimized criteria in the identification of suitable site selection for disposing obsolete pesticide waste.

4.7 Evaluation of Site Selection Criteria

Selection of temporary storage site using GIS and RS needs criteria which tell about the overall situation of the candidate site. There are techniques to evaluate all criteria and to select the most appropriate ones which have a high impact on the selection process. One of the techniques used to evaluate candidates is Multi-Criteria Evaluation. Multi-criteria evaluation in advanced spatial analysis is concerned with the allocation of land to suit a specific objective based on a variety of attributes that the selected areas should possess.

As it is already discussed in chapter four, considering the case factory and its surrounding spatial location, the ten factors/attributes/criteria are used to select the potential temporary storage site. The analysis was done using Arc GIS Software (Arc GIS 10.3.1).

4.8 Selection of suitable potential site

The site selection for pesticide chemical waste disposal site involves comparisons of several options based on the environmental, socioeconomic, receptor, accessibility, waste management, and geological related impacts. Different weights that were derived from the practice and have an impact on the environment were assigned to all the factors. The higher the weight, the more significant is the decisive factor in the overall effectiveness. The weights were developed by providing a series of pairwise comparisons of the relative consequence of factors to the suitability of pixels for the activity being evaluated.

4.8.1 Site selection

During Site Selection, identified selected areas are evaluated using previous studies and additional existing data to determine if a potential storage site can be identified. The purpose of Site Selection is to further evaluate Selected Areas and to develop a shortlist of Potential Sites suitable for Site Characterization (Adopted from Albany, et.al, 2017).

Accordingly, technical information to be considered includes data from existing digital data core samples, available seismic survey data, and other available geological data (some of which must be purchased, e.g. Image data &topographic map). After this stage, the researcher will have a list of the most promising potential sites to be evaluated during initial site characterization.

Finally, initial site characterization, the researcher continues the evaluation of one or more of the higher-ranked potential sites. During this stage, a researcher performs an initial site-specific assessment of the selected significant criteria/factors/ environmental, accessibility, receptor, socio-economic, waste management, climatologically, and geological issues for the designated potential sites. While the analysis in Site Selection relies primarily on existing data, Site Characterization will likely involve the acquisition of new, site-specific data (e.g., seismic data).

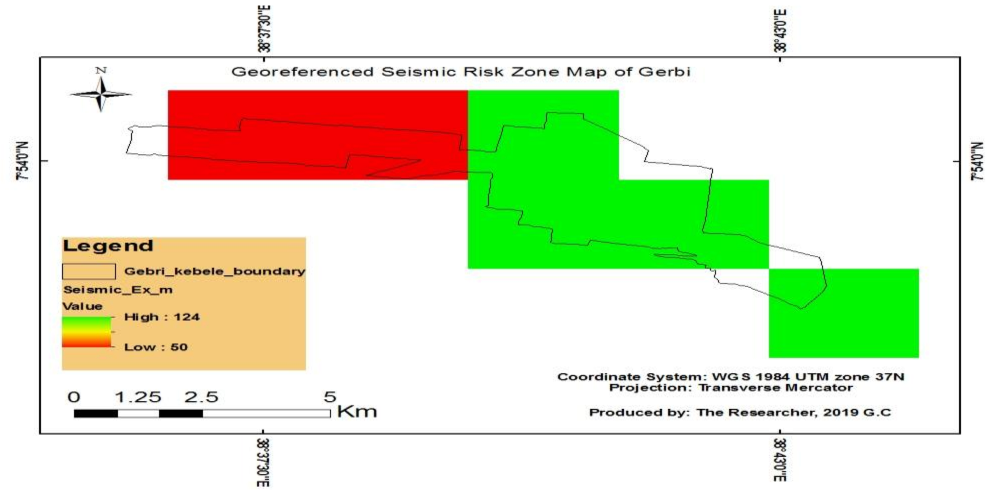
GIS has a key role in solving environmental problems. Environmental problems related to physical, chemical, and biological factors and all the related factors impacting behaviors are challenging to measure without using GIS. The thematic information derived from the RS images is often combined with other auxiliary data to form the basis for a Geographic Information System (GIS). AGIS is a database of different layers, where each layer contains information about a specific aspect of the same area which is used for analysis by the resource scientists. Based on such kind of functionalities of GIS, the researcher measures the selected biophysical parameters as indicated below.

A. Seismic Risk zone

As indicated above, the case study was conducted in Zway town in which the district is part of the rift valley. In addition to this, the situation in rift valley is complicated by the fact that it is filled with thick sedimentary layers, which amplify amplitudes of seismic waves. The shape of the valley affects the propagation of seismic waves significantly(Wilks, Wilks, Ayele, Kendall, & Wookey, 2016). Therefore, the researcher has considered seismic zone as the main factor to select suitable temporary storage site for disposing of obsolete pesticide chemical wastes.

The PGA is contoured in 0.25 m/s^2increments. Earthquakes since 1900 of $M > 4$ are white circles and sized by magnitude (International Seismological Centre, 2016). The six listed significant earthquakes in the Main Ethiopian Rift (MER) are grey. Thick dashed black lines mark the boundaries of the rift segments. National borders are dashed red lines and the capital city of Ethiopia (Addis Ababa) is the blue star. Seismic layer data used in this study was adopted from (Wilks, Ayele, Kendall, & Wookey, 2016). The seismic hazard map which shows the existing situation of the case under study is shown in the following figure.

The researcher made georeferencing, ranking, and the result was summarized as shown below.



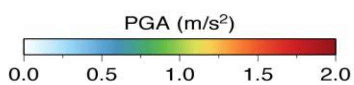


Figure4. 8: Georeferenced Seismic Risk map of Gerbi site (Source: Own, 2019)

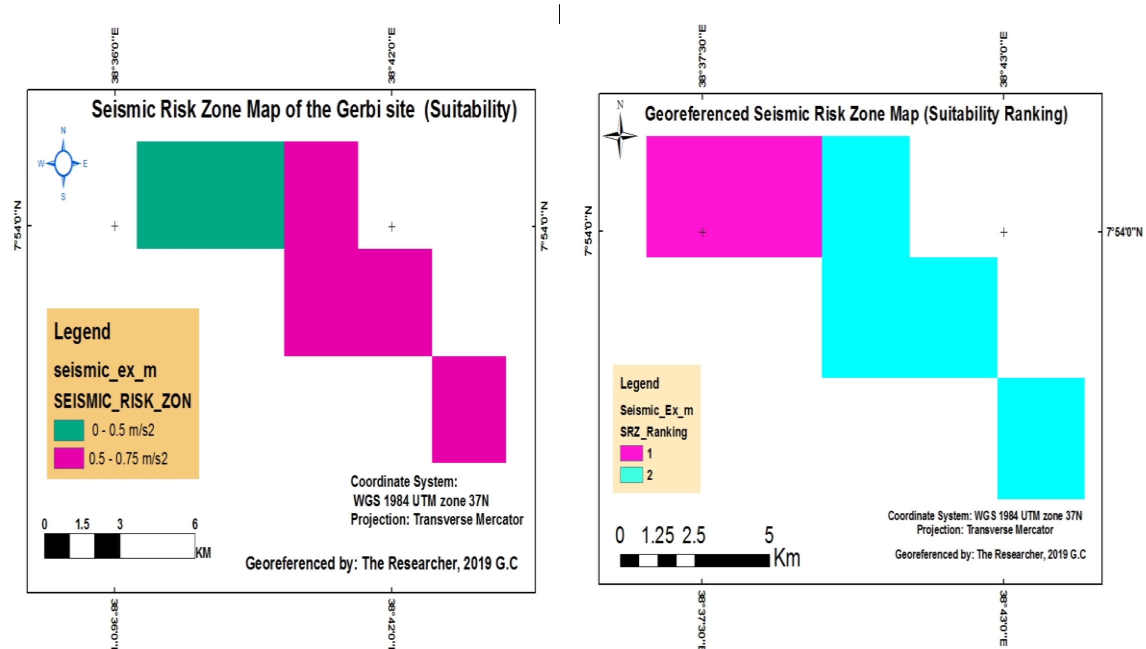


Figure4. 9: Georeferenced and ranked Seismic Risk Zone map

B. Soil permeability

Soil permeability is the property of the soil to transmit water and air which is one of the most important qualities to consider for site selection. The soil data used in this study was adopted from, 2019 which was taken from (www.fao.org/tempref/FI/CDrom/FAO_Training/FAO). According to FAO, 2019 soil permeability is classified into seven classes. (See Appendix XI).

The other permeability measurement is using variation according to soil texture since soil permeability relates to soil texture and structure. Usually, the finer the soil texture, the slower the permeability (See Appendix XI; B-C).

The size of the soil pores is of great importance concerning the rate of infiltration (movement of water into the soil) and the rate of percolation (movement of water through the soil). Pore size and the number of pores closely relate to soil texture and structure and also influence soil permeability.
Considering that the above information and made georeferencing of the case site soil type and permeability are shown below:

Table4. 4: Soil type and permeability of Gerbi site

S.No	Soil texture type	Permeability rate in cm/hr
1	Vertisols~ Clay	*0.05*
2	Andosols ~ Clay Loam	**0.8**
3	Gypsisols~ sand	**5**
4	Leptosols ~ sandy loam	**2.5**

C. Geological layer resistivity

Resistivity is the resistance per unit volume. It is defined as the voltage measured across a unit cube's length (Volts per meter, or V/m) divided by the current flowing through the unit cube's cross-sectional area (Amps per meter squared, or A/m2). This results in units of Ohm-m2/m or Ohm-m. The Greek symbol rhoρ is often used to represent resistivity(Naivasha, 2010)

The next figure is a representative chart (adapted from Minsley, Wellman, Walvoord, & Revil, 2015) illustrating very generally how the resistivity of important rock groups compare to each other. This type of figure is given in most texts on applied geophysics.

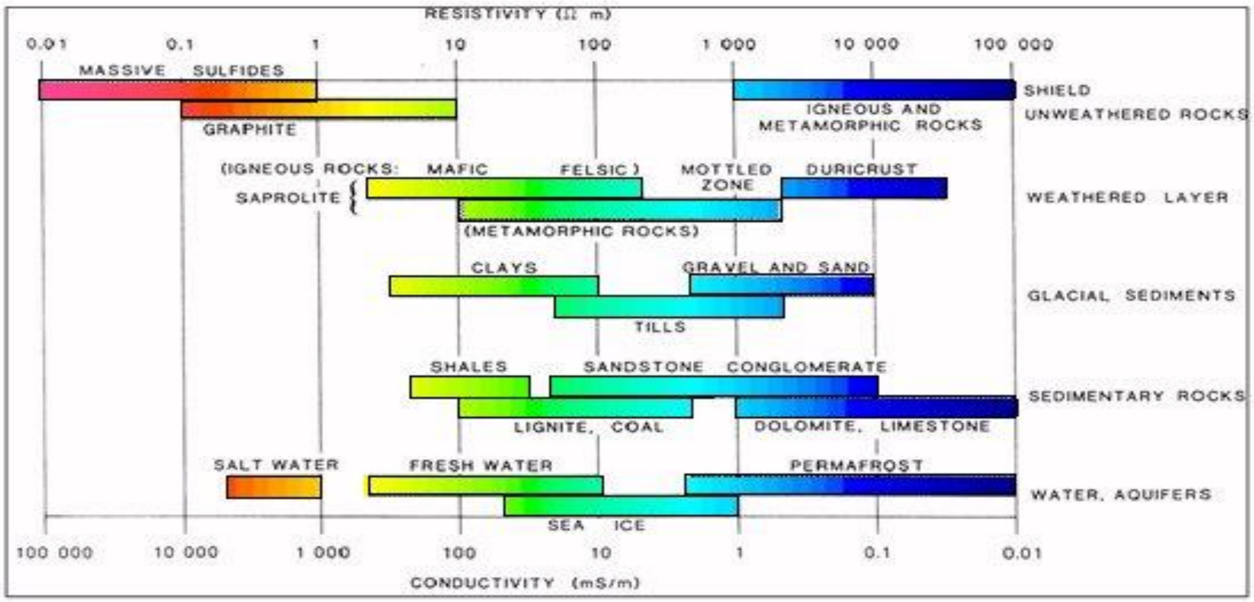


Figure4. 10: Comparison of resistivity among rock groups(source: Minsley, Wellman, Walvoord, & Revil, 2015)

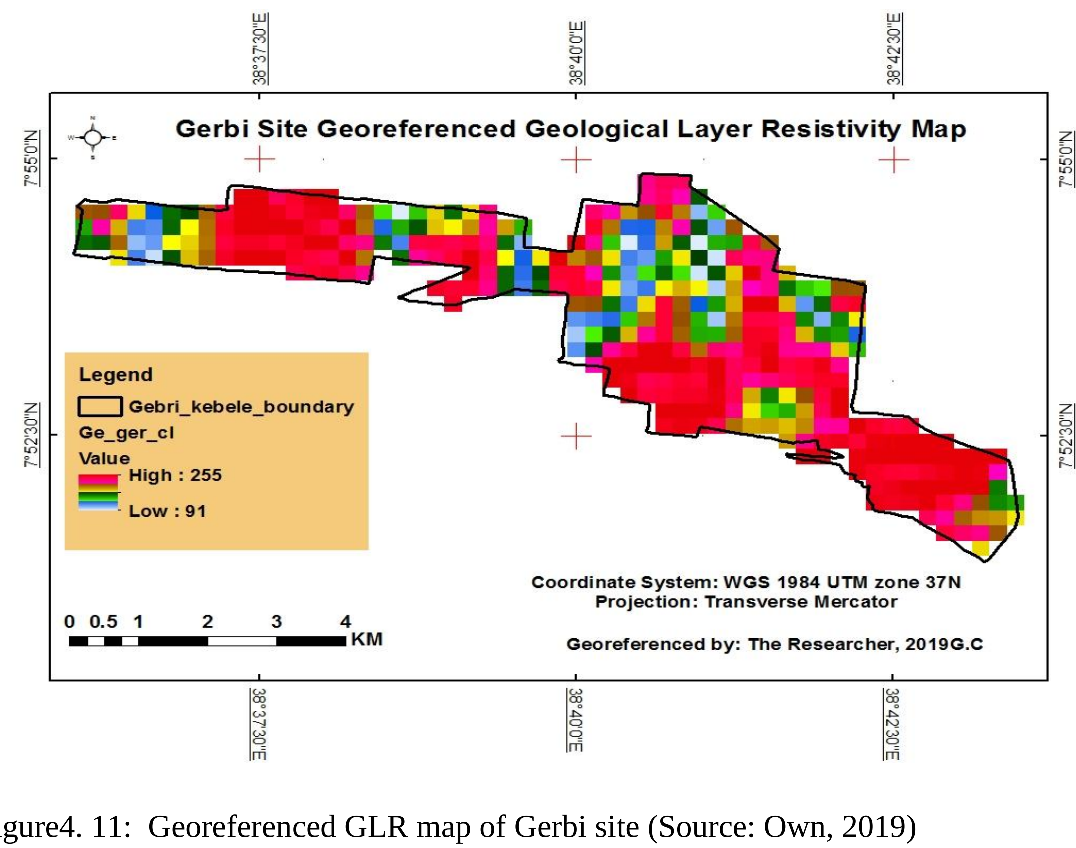


Figure4. 11: Georeferenced GLR map of Gerbi site (Source: Own, 2019)

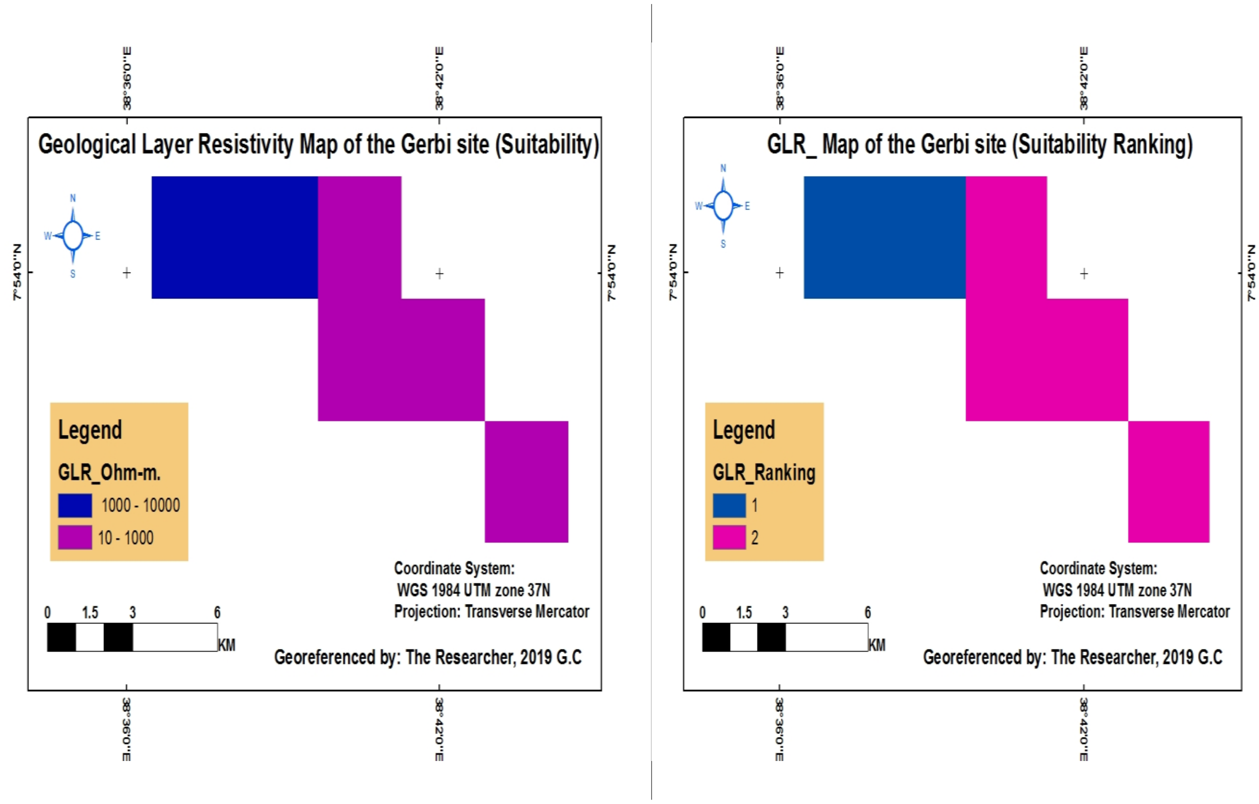


Figure4. 12: Georeferenced and ranked Geological Resistivity map

Considering the above information taken from the Ethiopian geological map and by making georeferencing of the case site, the type of rock and geological layer resistivity is produced as shown in the table below.

Table4. 5: Result of geological layer resistivity of Gerbi site

S.No	Geological layer type/rocks/	Resistivity(Ohm-m)
1	Q1~Silt, clay, diatomite, rhyolite, ignimbrite, siliceous doms,	1000 -10000
2	QWa ~ pyrolytic and trachytic lava	1- 1000
3	QWPV ~ Pumic and unwanted stuff	10 -1000

D. Slope

The slope can be described in percent or degree. The percentage description used in this study, which can be generated from the SPOT 5 image by using Surface analysis in GIS software which ranges from 0-79%. For constructing purposes, different slope thresholds have been chosen in the previous studies such as less than 10%. According to Sener et al. (2011) and Leao et al. (2001), the land with a slope of less than 10% is highly suitable for solid waste dumping. Depending on this, most of the land is suitable for the solid waste disposal site. This shows that slope is one of the significant factors for constructing a temporary storage house for storage, treatment, and disposal facility of obsolete pesticide chemical waste. The following figure illustrates the slope ranges of the case study.

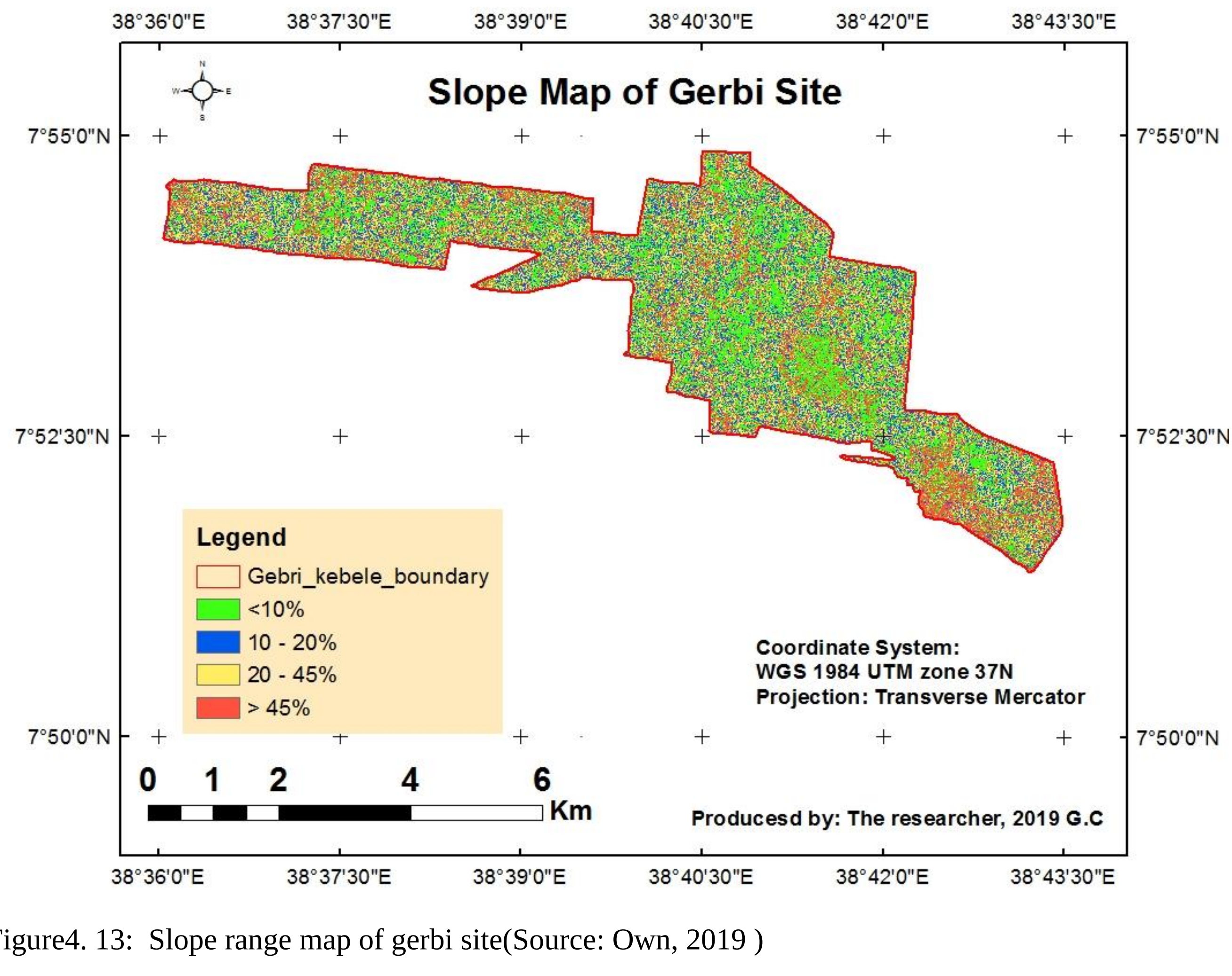


Figure4. 13: Slope range map of gerbi site(Source: Own, 2019)

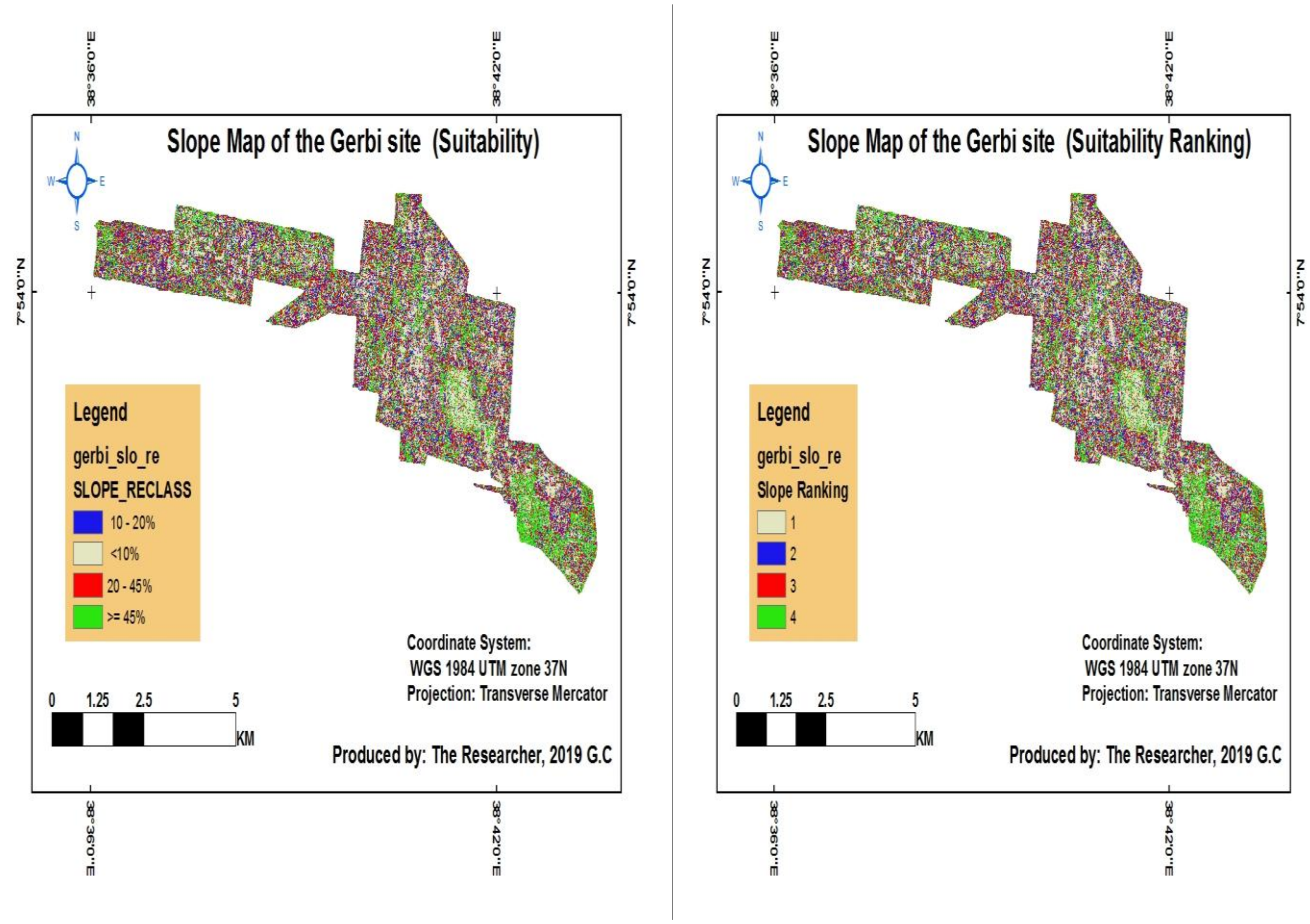


Figure4. 14: Original and ranked Slope range map (Source: Own, 2019)

E. Landcover

Land cover is the observed biophysical cover on the earth's surface. When considering land cover in a very pure and strict sense, it should be confined to the description of vegetation and man-made features. In this study, the mainland covers are Farmland, Grassland, bushland, and settlements. The classification results are shown in the figure below.

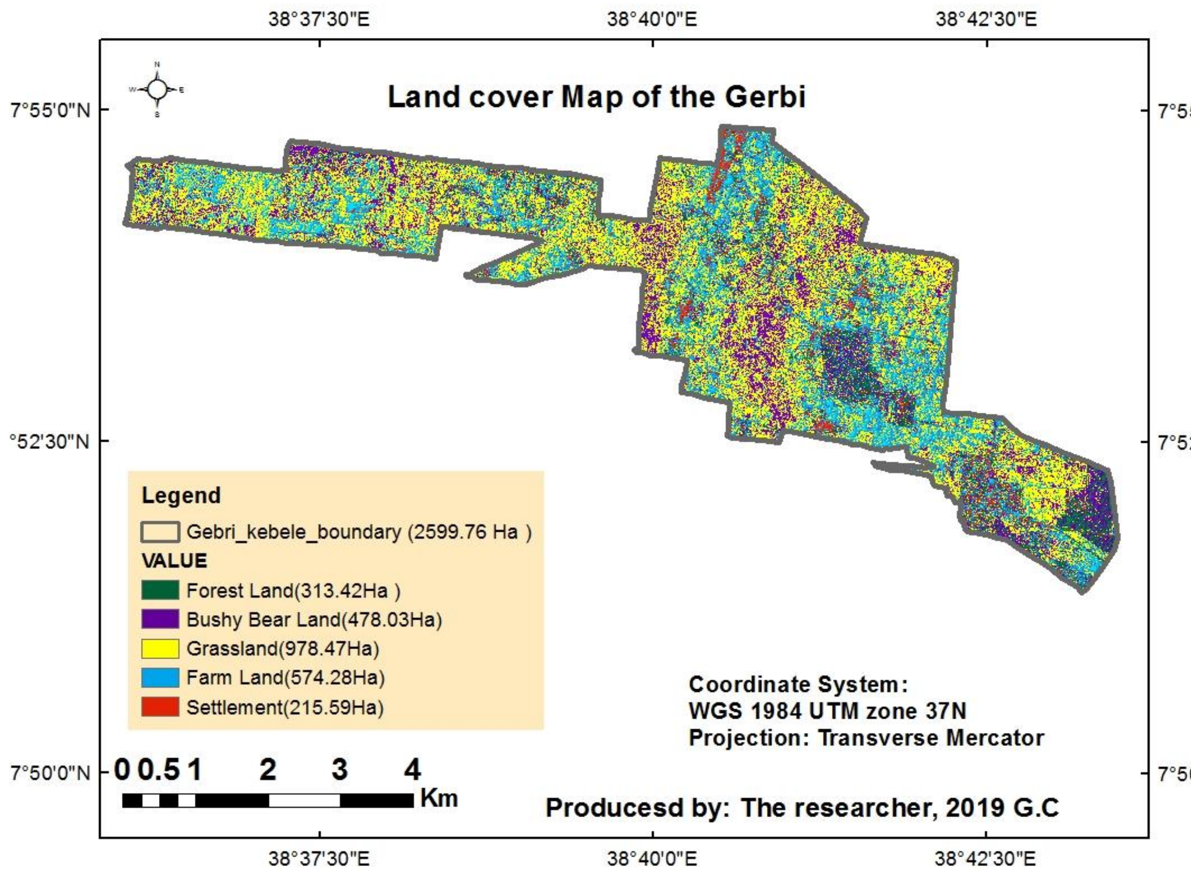


Figure4. 15: Land cover map of Gerbi site (Source: Own, 2019)

4.8.2 Proximity Analysis

The other way of site selection stage includes an analysis of district site data to determine potential district or sub-district proximity issues. In this case, six site-specific features could have an impact on the attractiveness of a district: (i) Settlement area, (ii) water source area, (iii) Farmland area, (iv) lake area, (v) factory site area, and (vi) the Main road. Careful evaluation of potential issues concerning land access and use should also be wisely evaluated during this process. The proximity analysis map which shows the existing situation of the case under study is shown in the following figure. The researcher made georeferencing, ranking, and the result was summarized as shown below.

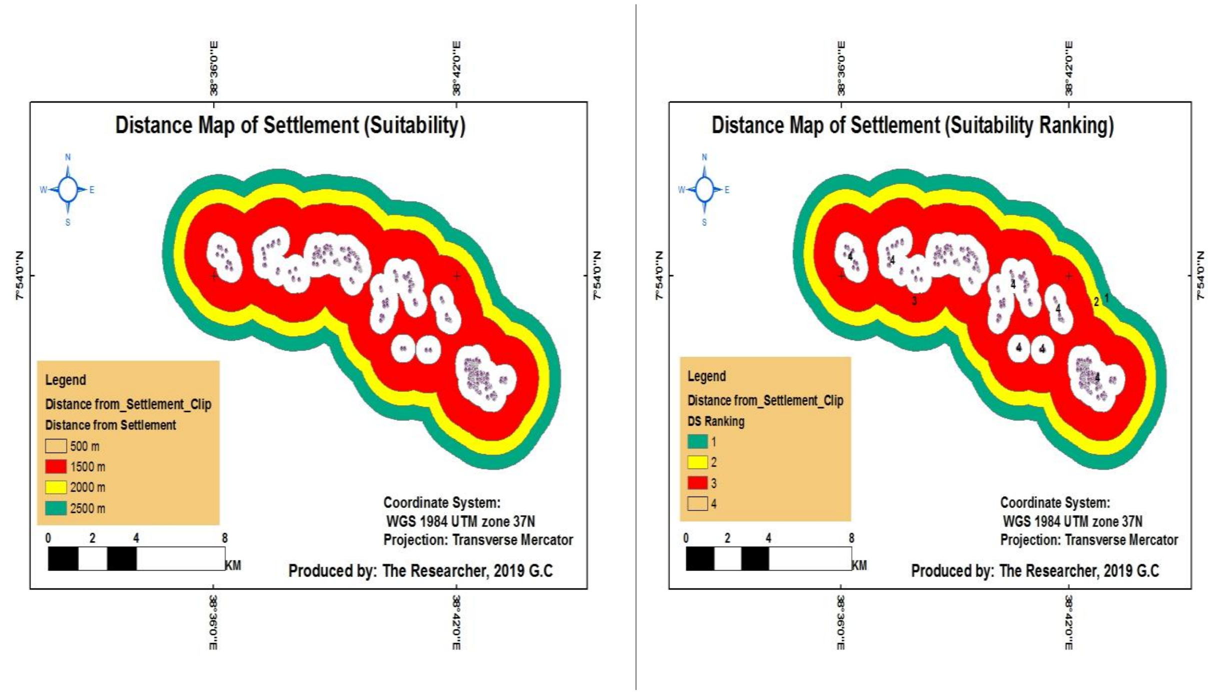


Figure4. 16: Original and ranked buffer map of distance from Settlement (Source: Own, 2019)

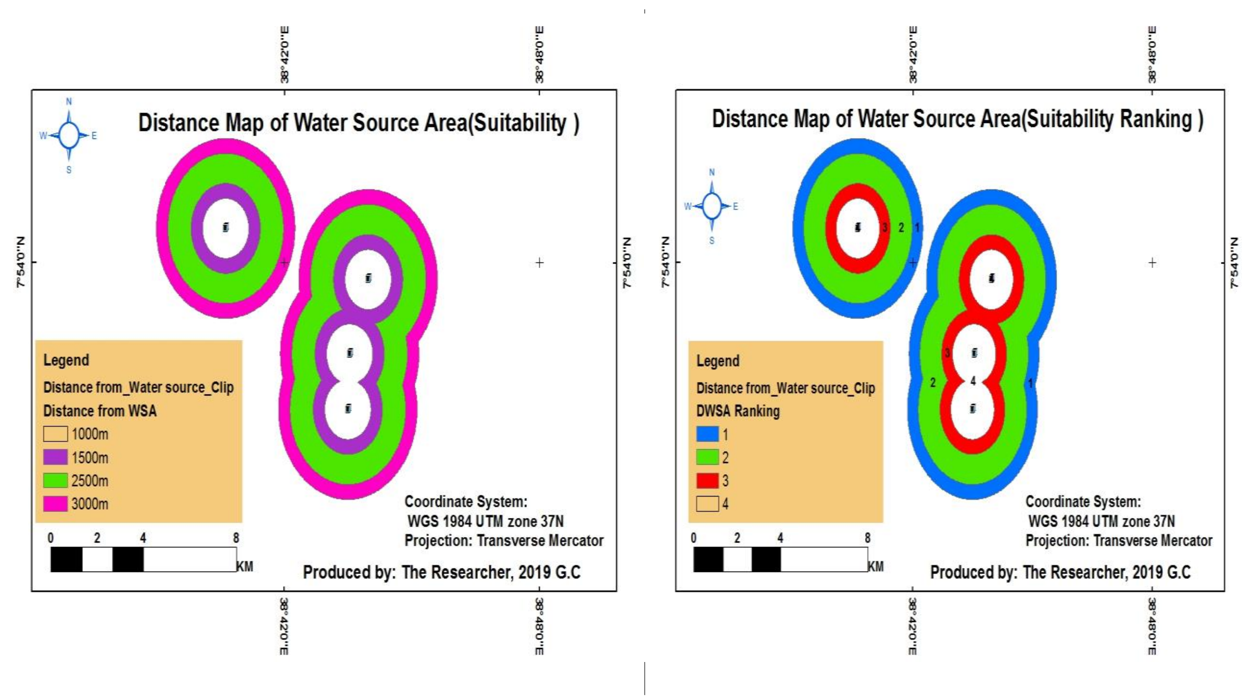


Figure4. 17: Original and ranked buffer map of distance from Water Source Area (Source: Own, 2019)

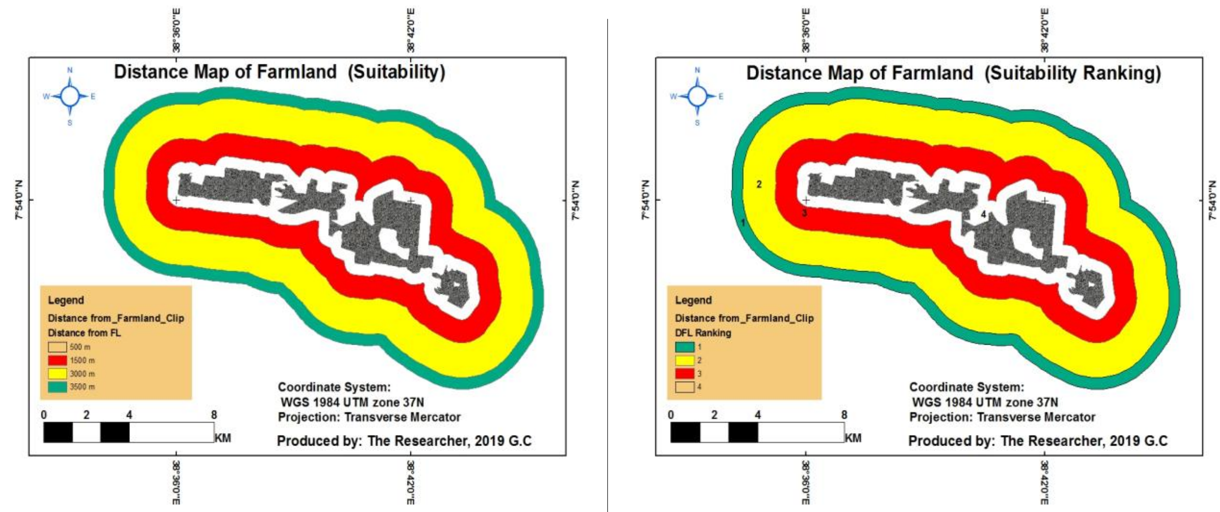


Figure4. 18: Original and ranked buffer map of distance from Farmland (Source: Own, 2019)

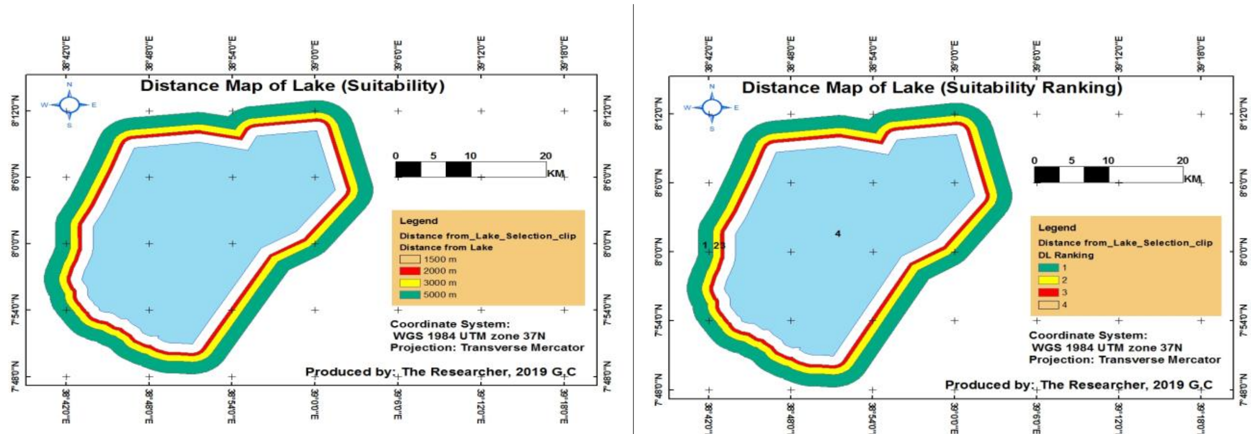


Figure4. 19: Original and ranked buffer map of distance from Lake (Source: Own, 2019)

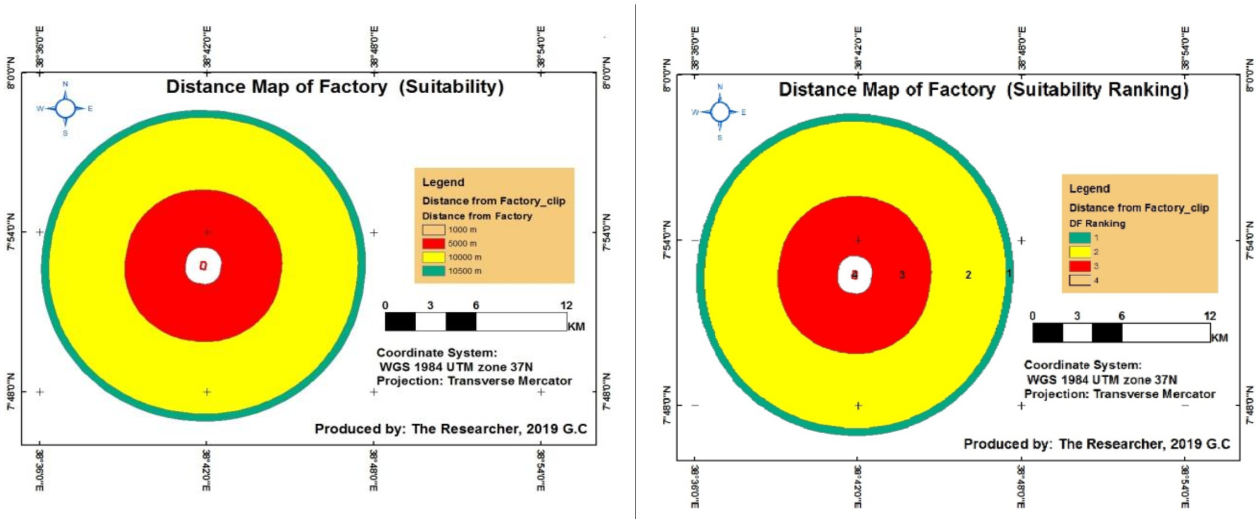


Figure4. 20: Original and ranked buffer map distance from Factory (Source: Own, 2019

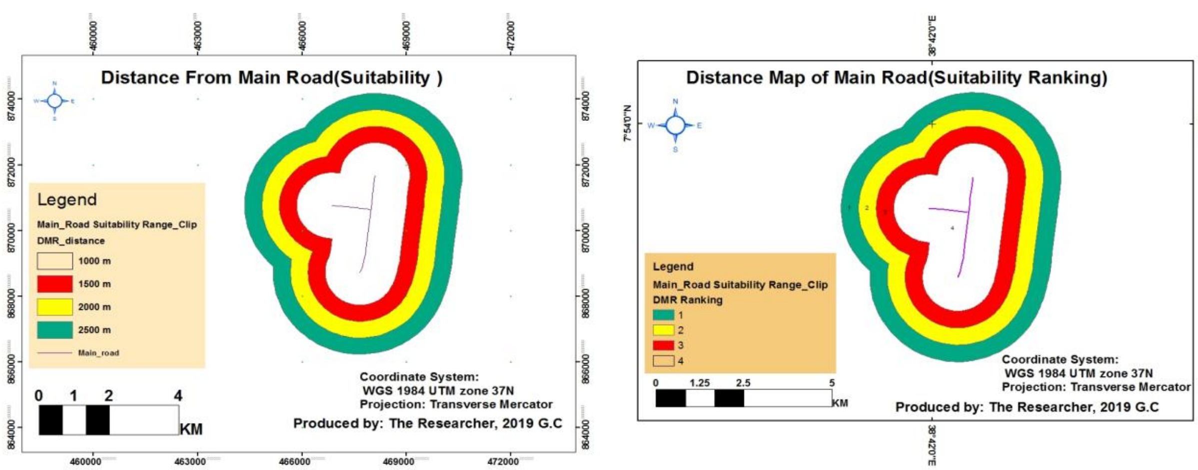


Figure4. 21: Original and ranked buffer map distance from Main road (Source: Own, 2019)

4.8.3 Protected and Sensitive Areas

A protected area is defined as an area of land and/or sea where protection and maintenance of biological diversity, natural resources, and cultural effects are required through legal or other means. Actions must be taken to protect the land, air, and water in the vicinity of a storage project during characterization, development, operation, and closure (Albany, et.al, 2017). During the site selection evaluation, consideration should be given to environmentally sensitive features in the district. Protected and sensitive areas such as a church, mosque, coastal wetlands, loges or recreational parks, protected or historical areas, and species-sensitive areas may require additional measures to protect them. The sensitivity analysis map which shows the existing situation of the case under study is shown in the following figure. The researcher made georeferencing, ranking, and the result was summarized as shown below.

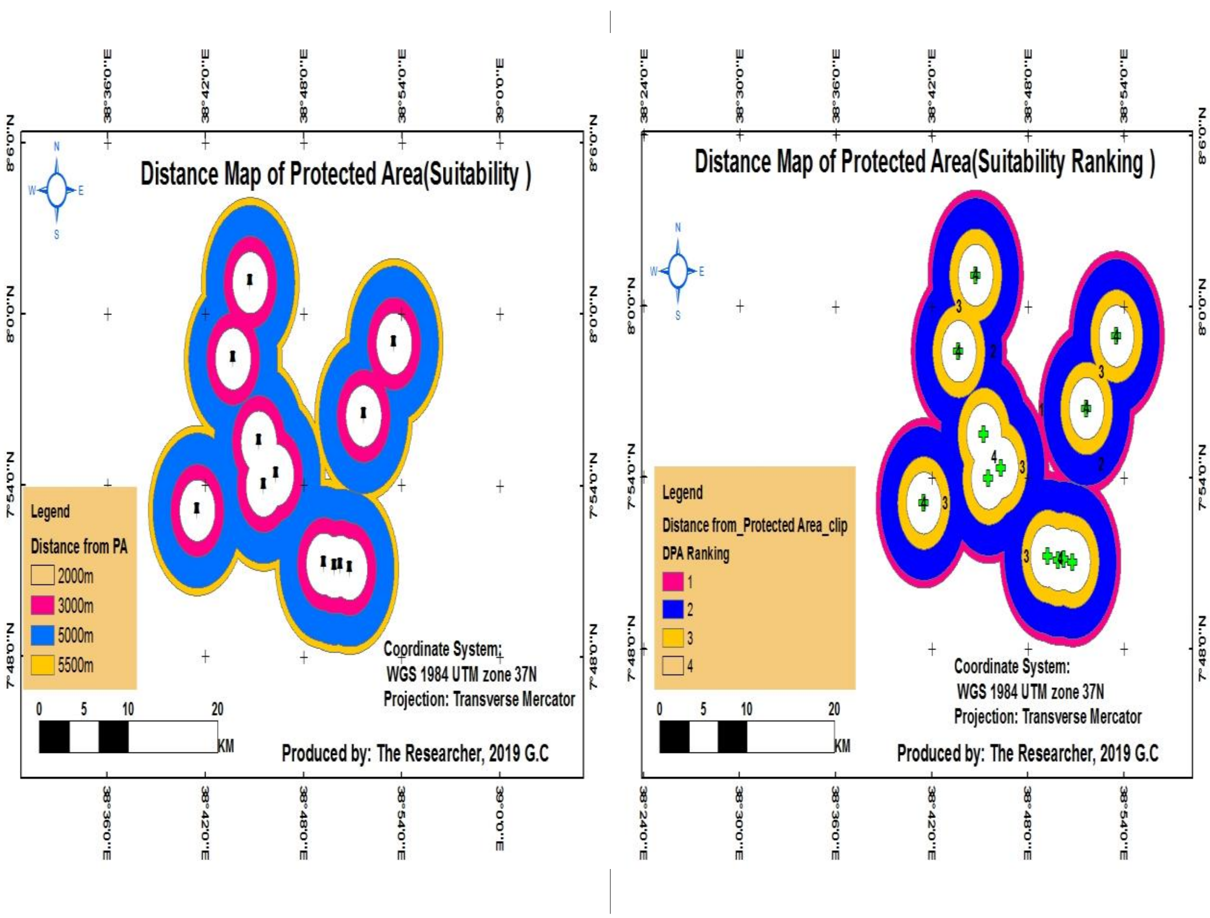


Figure4. 22: Original and ranked buffer map of distance from Protected Area (Source: Own, 2019)

4.8.4 Site Suitability Analysis

In the site selection process, the site suitability analysis focuses on ten primary criteria's: (1) Seismic risk zone, (2) Distance from the settlement, (3) Geological layer resistivity, (4) Distance from the water source area, (5) slope, (6) Distance from protected area, (7) Distance from factory, (8) Distance from lake, (9) Distance from the main road and (10) Distance from farmland. The purpose of the analysis is to determine if there are any local siting issues and feasible mitigating actions given the criteria established in the proposed project site. Even though a selected area may have a favorable seismic zone and other characteristics, it may not be suitable because of infrastructure needs, proximity analysis, or for other reasons. These issues should be identified during site selection. Specific data requirements are summarized in Table 4.14 and discussed further in the data analysis section.

4.8.5 Weighted Suitability Analysis

Suitability analysis describes the search for locations or areas that are characterized by a linear combination of certain properties. Often, the result of a suitability analysis is a suitability map. It shows which locations or areas are suitable for specific use in the form of a thematic map (e.g. chemical waste disposal site suitability map, see figure 5.8.6.2).

The analysis' suitability layer was then produced through map algebra by multiplying each reclassified data layer's values by the weight value associated with the criterion, as determined in the AHP, then finding the sum of these individual products, and multiplying by the restricted areas on surfing criterion layer. This map algebra task was conducted using Arc GIS's Raster Calculator tool: for SRZ, GLR, and SP, and vector overlay analysis tool for the remaining distinguished criteria i.e., DPA, DWSA, DMR, DS, DL, DFL, and DF; ranking each criterion by distance suitability class, then make the union of them and then multiplying each criterion by criteria weight which gives candidate sites.

For determining the best potential site; select the best candidate site using the attribute table selection tool and calculation by calculated candidate values. Finally made the union of the suitable map for both vector & raster data model after conversion of the same data model that give the final best 3-4 suitable potential sites, (see in figure4.24).

In conclusion, suitability analysis with GIS is an evaluation of a location or area for certain users, as a waste disposal site. The evaluation is usually done by intersecting social, ecological, economic, physical, biological, and other criteria.

Overlay refers to the digital integration of location and attributes information of several spatial layers. Therefore, layers based on weighted decision criteria are conducted. In this case, the weighting is based on ranking the criteria: the higher the rank of a layer the larger is its weight. Furthermore, weighting can be done using pairwise comparison: the essence of this approach is that two criteria are evaluated at a time to determine their relative importance. The weight of each layer is calculated in a comparison matrix (See Appendix XV). According to the level of importance, significant factors have a role in selecting a suitable chemical waste disposal site. After pairwise comparisons, the following suitable potential site map was created.

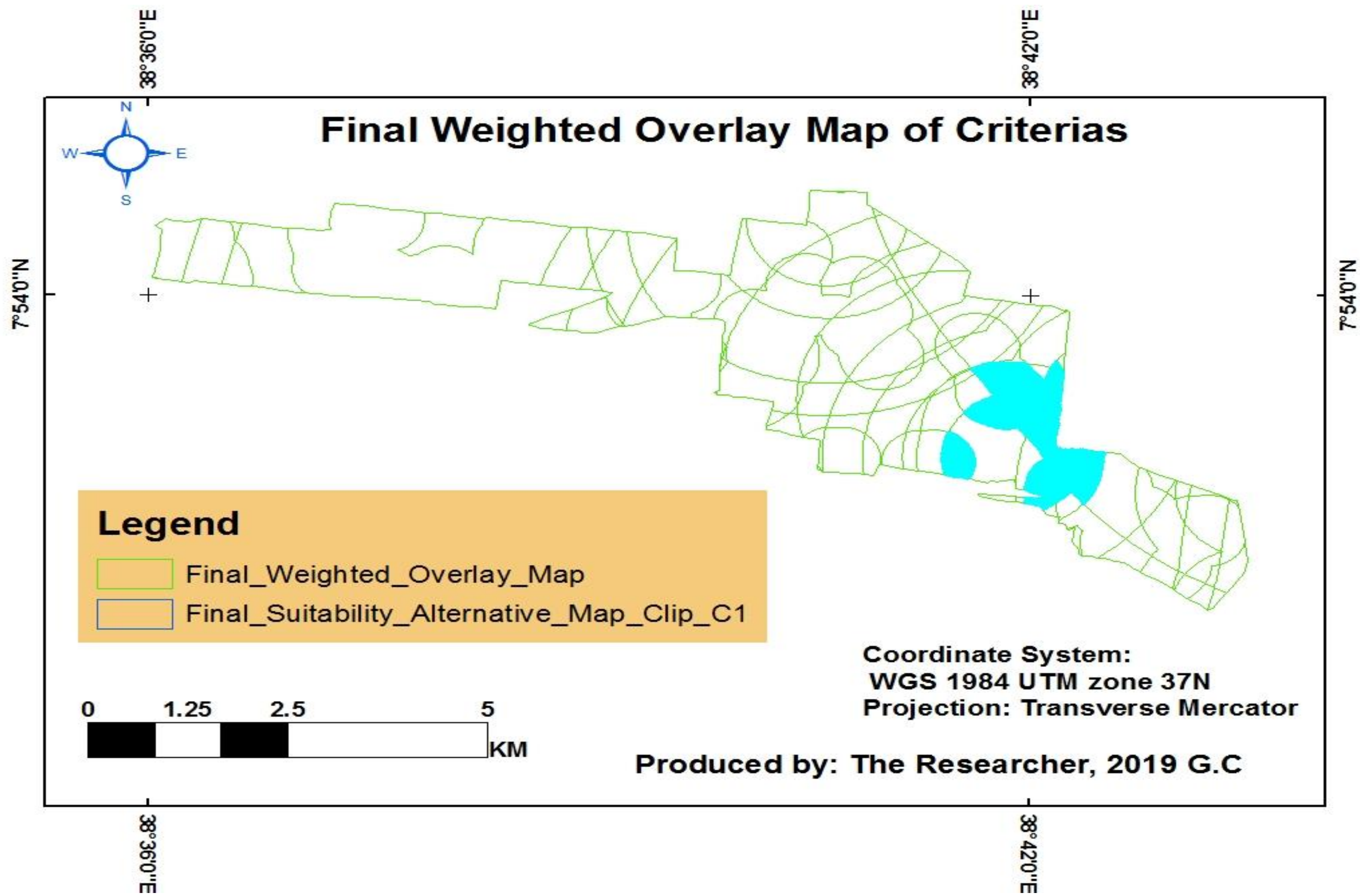


Figure4. 23: Final Weighted map of Alternative potential site (Source: Own, 2019)

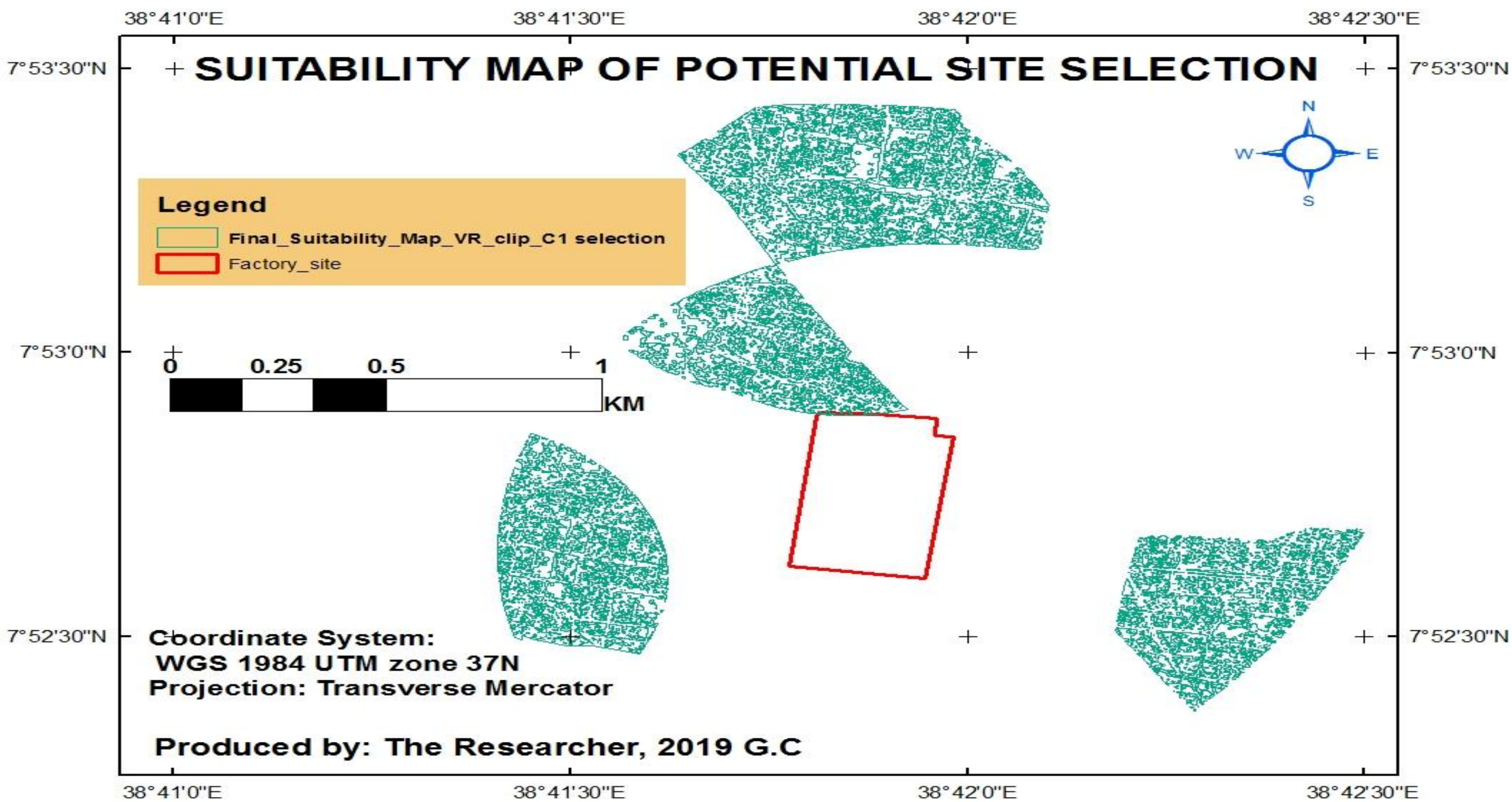


Figure4. 24: Final Suitability map of potential site selection (Source: Own, 2019)

4.9 Waste Management Implementation Framework Development

4.9.1 Phase One: Waste Characterization

The first phase of activities of the developed framework is waste characterization which includes: waste identification, waste inventory, determination of pesticide chemical wastes characteristics, and waste categorization. According to the definition of waste determination and characterization guidelines, waste is hazardous if the following properties exist. One of the properties is *corrosive* which is the ability to react dangerously with other waste, dissolve metal or other material, or burn the skin. The second one is *ignitability* which is the ability to cause fires during transport, storage, or disposal. The third property is *reactivity* which is the ability to become unstable or undergo a rapid or violent chemical reaction with water or other materials. The last one is *toxicity* which is the presence of toxic constituents above established regulatory levels (Laboratory, 2014).

Wastes can be characterized as physical, chemical and biological. The physical characterization describes the material composition, particle size distribution, and particle shape-related subdivisions. Composition and shape-related subdivisions are evaluated through separating components by material groups with similar mechanical properties. The particle size distribution was determined by manually measuring particles. Solid waste degradability was evaluated by measuring the volatile solids (VS), biochemical methane potential (BMP), and cellulose (C), hemicelluloses (H), and lignin (L) contents (Bareither, Breitmeyer, Benson, & Edil, 2010), who present a characterization framework for solid waste (Bareither, Breitmeyer, Benson, & Edil, 2010, and Langer, 2006). Hence, in this model characterization of obsolete pesticide chemical wastes was considered as a foundation for managing wastes.

4.9.2 Phase two: Determination of Disposing Techniques

The second phase which comes after waste characterization is the determination of waste disposing techniques. The methods can be grouped into physical, chemical and biological. As discussed by Arıkan, Şimşit, & Vayvay, 2015 (2015), methods for solid waste disposal can be categorized into storing, biological, thermal systems and recovery. Again, storing methods classified into two sub-classes as disordered storing (industrial or urban wastes are stored without any drainage or isolation system) and ordered storing (special places to bury underground are built for wastes). Another biological method, bio mechanization is a process of transferring urban wastes to biogas under controlled circumstances (Arıkan, Şimşit&Vayvay, 2015). The third category in biological disposal methodologies is bio ethanol/biodiesel which is a process of transferring urban wastes to ethanol and diesel fuel under controlled circumstances. Thermal systems; burning, plasma, pyrolysis and gasification techniques are used in developed countries for a long time(Arıkan et al., 2015).The last category of solid waste disposal methodologies is recovery which means gained energy from waste disposing of (Arıkan et al., 2015).

According to Chang, Hsieh & Chiu (2016), liquid-liquid extraction (LLE) is the most common pre-concentration/matrix isolation technique in analytical chemistry (Farajzadeh & Sorouraddin, 2014) (Farajadeh, Sorouraddin&Mogaddam, 2014). Solid-phase extraction (SPE), has also been developed for pesticide analysis(Tankiewicz et al., 2011). Solid Phase Extraction (SPE) offers several significant advantages over LLE, such as less consumption of organic solvent, shorter analysis time, no phase emulsion, higher method recovery, and more efficient removal of interfering compounds. Pesticide Analysis Using Capillary Electrophoresis one of the most attractive analytical techniques for the rapid qualitative and quantitative analysis of molecules with a wide range of polarities and molecular weights, including both small molecules such as amino acids and large macromolecules such as proteins and nucleic acids (Chang et al., 2016).

As described by(Samsidar & Shaarani, 2018), pesticides are conventionally detected by classical analytical methods such as gas and liquid chromatography, high performance liquid chromatography(Guan, Brewer, Garris, & Morgan, 2010 and Ye, Wu, & Liu, 2009), enzyme-linked immune absorbent assays (Rekha et al., 2000), and capillary electrophoresis (Hsu & Whang, 2009). However, these methods are limited with shortcomings such as complicated, laborious, costly instruments and high skilled-manpower. The second approach to determine pesticides is via advanced methods which are based on sensors principles. Advanced methods offer several advantages including rapid, simple and low-cost operation, high sensitivity and selectivity, and onsite detection (Songa & Okonkwo, 2016). Therefore, determining the appropriate waste disposing of techniques is crucial for cost and time optimization and to have an environmental friendly approach.

4.9.3 Phase Three: Setting Criteria for the Selected Techniques

Setting criteria for analyzing the selected techniques will come after the determination of disposing techniques. It is undeniable facts that managing pesticide wastes properly can help to reduce potential hazards to the environment and employees.

Rules and regulations to dispose of chemical wastes consider the location of disposing of, amount of wastes to be disposed of, conventional signs to identify the type of wastes, secondary contaminants, segregation of Incompatibles, duration, duplication of waste streams and several inspections(Chauhan & Singh, 2016). Hence, setting the proper criteria for suitability analysis is an important phase in the waste management process.

4.9.4 Phase Four: Site Suitability Analysis and Selection

Site suitability analysis is a critical phase in this implementation Framework. As discussed by Gumusay, Koseoglu, & Bakirman (2016), the goal of site suitability analysis is to define the areas that are appropriate for building waste disposal areas, with the use of topographic and demographic data in a present shoreline applying analytical hierarchy process multi-criteria decision-making method. According to their thought: erosion, landslide, tsunami, land use, geologically hazardous areas, transfer lines, sea traffic data, neighborhood-scale population, age patterns, and house income data have been used. The analytical hierarchy process method is used to give a weight to each data set, and a grading system has been developed for the area selection. The result maps of the analysis that show the study area as classified into four categories from good to not suitable (Gumusay, Koseoglu, & Bakirman ,2016)

According to El, Benaissa, Laila, & Salah (2016), choosing the appropriate site for waste elimination is a very complex process that depends on several criteria and regulations. Many environmental, social and economic requirements have to be met in the analysis process. The choice of the disposal site was performed using multi-criteria decision analysis (MDA), a geographic information system (GIS), and remote sensing. Several criteria were discussed, such as waste production, distance from houses, surface and groundwater, land use, the slope of the land, transport network, etc. A final map was produced by overlaying the criteria map layers, which enabled us to propose three potential sites for the establishment of the landfill (El, Benaissa, Laila, & Salah ,2016). Benchmarking the work of the above scholars, the researcher uses GIS and RS along with MCE.

4.9.5 Phase Five: Site Construction

After the proper temporary storage site is selected, proper construction of the site will come to store obsolete pesticide chemical wastes safely. The construction of temporary storage for obsolete pesticide chemical wastes needs the knowledge of engineering disciplines (civil engineering, mechanical engineering, chemical engineering, etc.). Hence, the detail of this phase is left for future researchers.

4.9.6 Phase Six: Pretreatment

Pre-treating of obsolete pesticide chemical wastes before their disposal has both economic and environmental benefits. The United States Environmental Protection Agency (USEPA) defines innovative treatment technologies as those that lack the cost and performance data necessary to support their routine use (FAO, 1997). Most of the innovative treatment research is focused on remediation of relatively low levels of specific contaminants from environmental media such as air, soil, wastewater, and groundwater (FAO, 1997). Innovative technologies that could potentially be used for the disposal of obsolete pesticide stocks or contaminated environmental media can be grouped into three categories:

1. Those that destroy the pesticide, such as chemical dechlorination, photocatalytic oxidation, and bioremediation;
2. Those that extract the contamination from specific environmental media, such as thermal desorption;
3. Those that simply contain or immobilize the contamination in place, including solidification, stabilization, nitrification and molten technologies(FAO, 1997).

As discussed by (Taherzadeh & Karimi, 2008), pretreatment by physical, chemical or biological means is a well-investigated process for ethanol production. The pretreatment can enhance the bio-digestibility of the wastes for ethanol and biogas production and increase the accessibility of the enzymes to the materials. The pretreatment leads to bio-ethanol which involves hydrolysis, fermentation and distillation, and biogas which involves hydrolysis, *acidogenesis*, *acetogenesis* and *methanogenesis* (Taherzadeh & Karimi, 2008).

Felsot, Racke, Hamilton (2003) discussed that biological treatment which involves pretreatment of contaminants with various reagents to produce degradates more amenable to microbial mineralization is one of the common pretreatment approaches. Hence, before transporting wastes for disposal, it is important to pre-treat wastes provided that if the pretreatment process is economical.

4.9.7 Phase Seven: Waste Transportation

Waste collection is an important service that charges large expenditures to waste management (WM) system. Wastes can be transported via canals, pipes or vehicles. One of the major challenges in designing a transportation system for a supply chain is the selection of vehicle types and routing. Wastes are derived from a large amount of manufacturing, industrial, service, residential and healthcare activities(Maimoun et al., 2013) which can be classified into three groups generally: Residential, Commercial, and Industrial (S. Kim et al., 2004). Industrial wastes are mainly produced in factories, in the size of bins is used to collect them in industrial and production sites. Developing a multimodal transportation system to convey wastes is an approach to increase access to different sites and reduce the destructive effects of an invariable transportation system (Rabbani et al., 2016).

Sanjeevi & Shahabudeen(2016) described that transport cost alone constitutes more than 50% of the total expenditure on solid waste management (SWM) in major cities of the developed world and the collection and transport cost is about 85% in the developing world. Since 2000, new technologies such as geographical information systems (GIS) and related optimization software have been used to optimize the haul route distances. The GIS method used all the developed geographical data such as road network, the various zone boundaries, location of ward-centroids, location of transfer stations, etc. (Sanjeevi & Shahabudeen, 2016). By analyzing the existing situation of the site, selecting an optimized waste transport system is an essential step in this implementation model development.

4.9.8 Phase Eight: Degradation and Conversion of Wastes into Usable Form

This is the last but not the least phase in this implementation Framework development. The degradation and conversion process is done using physical, chemical or biological techniques. As discussed by (Hamad et al., 2014), the management of solid waste and valorization is based on an understanding of Management of Solid Wastes MSW's composition and physicochemical characteristics. A biological method, known as composting, is used to recover organic material from waste. Solid waste clean and reuse processes contribute to the recovery of part of the economic value of solid wastes. They contribute to the provision of work opportunities and financial revenue for the community. Various energy conversion technologies are available. The selection, however, is based on the physicochemical properties of the waste, both the type and quantity of the available waste feedstock and the form of energy desired (Hamad, Agll, Hamad, & Sheffield, 2014; Scarlat, Motola, Dallemand, Monforti-Ferrario, & Mofor, 2015; Matsakas, Gao, Jansson, Rova, & Christakopoulos, 2017).

The conversion of waste to energy can be undertaken with three main process technologies: biochemical extraction (use of the enzyme in bacteria and other microorganisms to breakdown biomass), thermo-chemical extraction, and mechanical extraction. Four main conversion technologies have emerged for the treatment of both dry and solid wastes: combustion, gasification, pyrolysis, and liquefaction. Combustion is the burning of biomass in air. It is used over a wide range of commercial land industrial combustion plant outputs to convert the chemical energy stored in the solid waste into either heat or electricity. The gasification process involves treating carbon-based material with either oxygen or steam to produce gaseous fuel. Pyrolysis is the heating of biomass in the absence of oxygen to produce liquid (termed bio-oil or bio-crude), solid, and gaseous fractions in varying yield. Pyrolysis depends on a range of parameters such as heating rate, temperature level, particle size, and retention time. Liquefaction is the low-temperature cracking of biomass molecules as a result of high pressure to produce a liquid- diluted fuel(Hamad, Agll, Hamad, & Sheffield, 2014; Scarlat, Motola, Dallemand, Monforti-Ferrario, & Mofor, 2015; Matsakas, Gao, Jansson, Rova, & Christakopoulos, 2017).

Mechanical extraction can also be used to produce oil from the seeds of solid waste. Rapeseed oil can be processed further by reacting it with alcohol, a process known as *esterification*, to obtain biodiesel. Electricity generation includes: Combined heat and power (CHP) generation, also known as cogeneration, is an efficient, clean, and reliable approach to generating both power and thermal energy from waste. The conversion of biogas to electricity via fuel cell technology offers significant increases in efficiency and, hence, is highly sought after technology. Biogas can be used as motive power for the production of electricity using engines.

Heat and steam generation includes producing and selling both heat and steam require the existence of available industrial customers(Hamad, Agll, Hamad, & Sheffield, 2014; Scarlat, Motola, Dallemand, Monforti-Ferrario, & Mofor, 2015; Matsakas, Gao, Jansson, Rova, & Christakopoulos, 2017).

4.9.9 Drivers of Waste Management

As discussed by Contreras et al. (2010), drivers of waste management systems in current and future chemical industries scenario are grouped into four categories: legislation and regulation drivers, technology development and institutional drivers, regional and international drivers and socio-economic drivers. Zaman (2013) described drivers of waste management system into three, as: social drivers (population, human behavior, local management practices and urbanization), environmental drivers (global climate change, environmental awareness and national environmental target) and economic drivers (economic value of waste, resource value, GDP, waste tax and cost-benefits).

According to McAllister, (2015), the waste problem is caused by human behavior and therefore the solution lies in changing that behavior. Therefore, public awareness and attitudes about waste can affect the whole SWMS(McAllister, 2015). The participation of the community in the production and use of scientific knowledge is considered the best approach to environmental management of waste. Another major constraint seen throughout the developing world is the lack of education and awareness of effective waste-management practices(McAllister, (2015).

McAllister, (2015) also argued that people of lower socio-economic groups tend to have less regard for environmental issues on the basis that employment and housing are their main priorities. Introducing incentives have also been considered as one of the most effective social interventions in establishing sustainable SWMS. Improvements in education and awareness have a great impact to implement recycling and disposal programs in many developing. Another major social intervention for more effective SWM is public participation and empowerment, decision transparency, networking, cooperation and collective action, communication, and accessibility of information (Allister, 2015). Media can play an important role in increasing public participation and awareness and can serve as an instrument for many socio-psychological incentives(McAllister, (2015).

Constraints that have been categorized under infrastructure and technology from the perspectives of developing nations include budgetary constraints, inadequate service coverage and operational inefficiencies of services including unskilled manpower, ineffective technologies and equipment, inadequate landfill disposal, and limited utilization of waste reduction activities such as recycling, Lack of policy enforcement, responsibility monitoring and regulation. Four specific areas for improvement under intervention are the role of institutions, better enforcement and/or enactment of policies and regulations, privatization and decentralization of waste systems, and finally, more public involvement and cooperation in the waste management systems. Continuity (the establishment of annual and short-term goals and systematic frameworks for evaluating system performance) and Integration (public participation and empowerment, decision transparency, networking, cooperation and collective action, communication, and accessibility of information) are also important drivers for the proper waste management system (McAllister, (2015).

Benchmarking, the work of the above-stated scholars, the researcher grouped the driving factors into; Finance (economic), technology and infrastructure, knowledge, awareness creation, and training and follow up. All these driving factors foster temporary storage site selection and waste conversion process. As a result, the environmental cost will be minimized, disposal costs will be reduced and wastes will be converted into usable forms effectively and efficiently. These will lead to an environmentally sound, economically viable and socially acceptable system as a whole which contributes to fast and sustainable economic development

Based on the overall execution of the research, the researcher develops the following Implementation model.

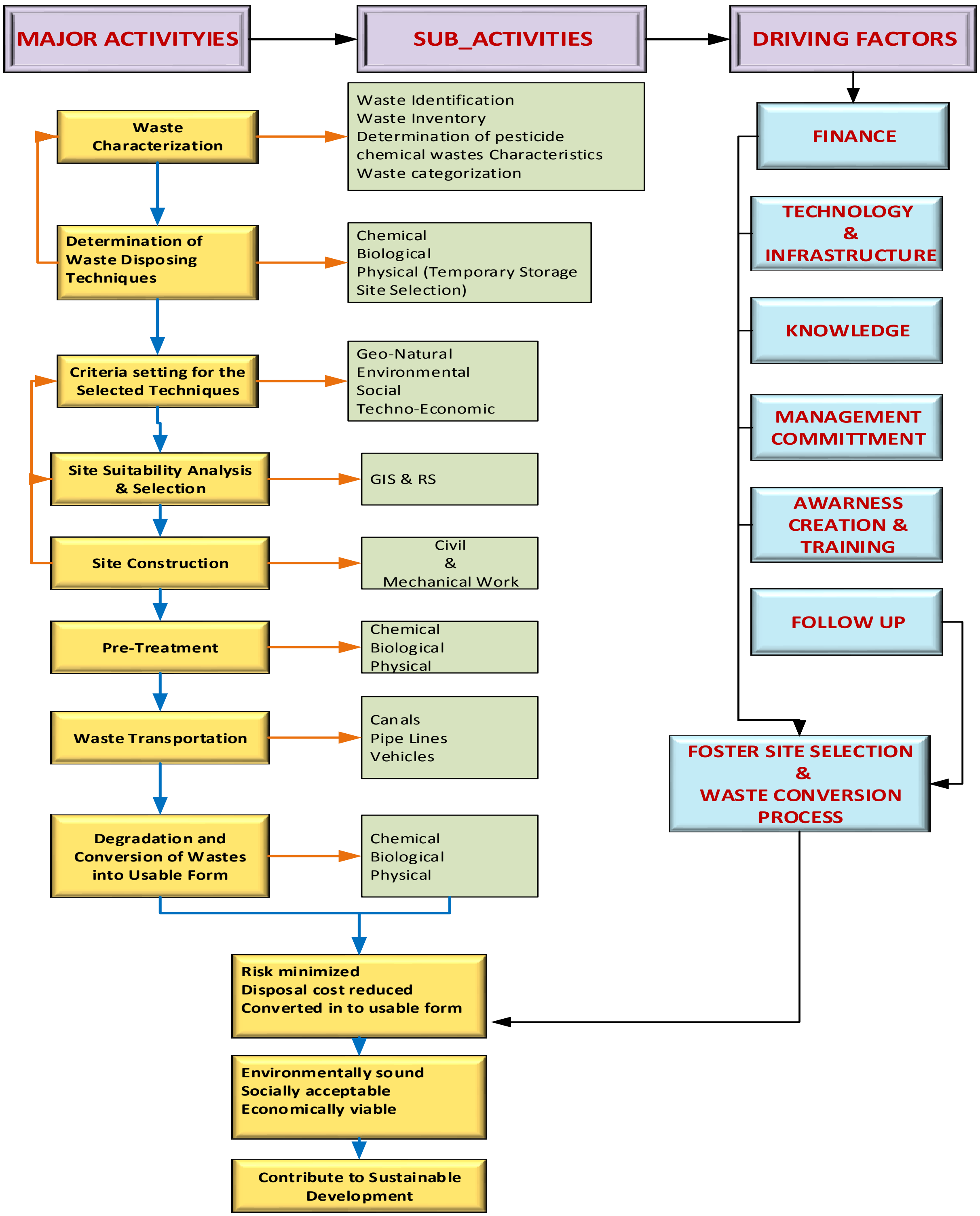


Figure4. 25: Developed Implementations Framework (Source: Own, 2019)

CAPTER: FIVE

Conclusion and Recommendation

5.1 Conclusion

Obsolete pesticide chemical wastes are hazardous to human health and to the environment unless they are treated through environmentally friendly techniques. As the researcher investigated using semi-structured interview, focused group discussion and site observation on the case factory, chemical wastes are collected and stored improperly within the factory compound and at the store. Lake of knowledge, skill, and commitment with regard to the management and disposing techniques of chemical wastes are bottlenecks of the case company.

Inaccurate forecasting and poor production planning , importing chemicals from abroad for technology transfer which are not considered the existing demand of the consumers, problem of registration due to lack of quality assurance institution which has certified testing laboratories to assure the transferred product for registration within the country, absence of R&D, unplanned production orders from practitioners, unbalance inventory of recipe and formulation during production, improper handling of tracing material, product wastes due to quality problems and absence of implementation guideline for disposing obsolete pesticide chemical wastes.

The researcher triangulated the focused group discussion and the interview through site observation and verified that lack of knowledge in pesticide chemicals production engineering and management, improper organizational structure, absence of world-class accreditation institute at national level which gives accreditation through critical investigation, lake of attention , infant stage of R&D with regard to obsolete pesticide chemicals issues at national level and absence of implementation guidelines are the critical challenges of the sector in general and the case factory in particular.

By comparing the three major treatment/disposal techniques with regard to cost, technology, knowledge and risk reduction, this research selects physical disposing techniques, i.e., temporary site selection using Arc GIS and RS software. The analysis was done using MCA and weightage overlay analysis. GIS has a great role to solve problems related to environmental issues such as site selection and suitability analysis. The major attributes used to select the potential site include seismic risk zone, geological layer resistivity& soil permeability, slope, distance from the settlement, distance from protected area, distance from water source area, distance from farmland, distance from main road, distance from the factory and distance from the lake.

Integrated disposal siting is difficult, complex and tedious process requiring evaluation of various criteria. The major optimized criteria used to select potential temporary storage site include geo-natural factors, environmental factors, climatic factors, social factors and techno-economic factors which are discussed in chapter 4 figures 4.7.

Using the above criteria and tools, the researcher selected the best potential site among the four site alternatives (see in figure 4.24).

5.2 Recommendation

A. Suggestions for the further researcher:

The researcher recommends for other interested researchers to conduct researches on waste characterization and environmental impact assessment. Besides, training with regard to disposing techniques should be given for implementers. In addition to this, civil engineering and mechanical engineering knowledge are important for constructing the waste disposing site, hence, integrated work with other professionals is required. Furthermore, the degrading and conversion process of stored wastes to usable form is left for future research work.

B. Suggestions for the policy makers:

The researcher recommends for the policy makers to develop an environmental protection strategy associated with obsolete pesticide chemical disposal system that is both resilient to the realities of the policy making process and appropriate for summiting future challenges. It is also important to develop implementation guidelines for disposing obsolete pesticide chemical wastes at the national level.

6 Reference

Ababa, A. (2009). *Ethiopia : Building on Progress A Plan for Accelerated and Sustained Development to End Poverty (PASDEP) Volume I : Main Text*. *I*.

Adeli, Z., & Khorshiddoust, A. (2011). Application of geomorphology in urban planning: Case study in landfill site selection. *Procedia - Social and Behavioral Sciences*, *19*, 662–667. https://doi.org/10.1016/j.sbspro.2011.05.183

Alavi, N., Goudarzi, G., Babaei, A. A., Jaafarzadeh, N., & Hosseinzadeh, M. (2013). Municipal solid waste landfill site selection with geographic information systems and analytical hierarchy process: A case study in Mahshahr County, Iran. *Waste Management and Research*, *31*(1), 98–105. https://doi.org/10.1177/0734242X12456092

Albany, OR • Anchorage, AK • Houston, TX • Morgantown, WV • Pittsburgh, P. (2017). *BEST PRACTICES : Site Screening , Site Selection , and Site Characterization for Geologic Storage Projects 2017 Revised Edition*.

Amera, T., & Abate, A. (2008). *An assessment of the pesticide use , practice and hazards in the ethiopian rift*. *February*.

Arıkan, E., Şimşit, Z. T., & Vayvay, Ö. (2015). Solid Waste Disposal Methodology Selection Using Multi-Criteria Decision Making Methods and an Application in Turkey. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2015.10.054

Arora, D. K. (2015). *Chemicals and Waste Management*. 2015.

Astrium. (2010). *Astrium Services SPOT Accuracy and Coverage Combined*.

ASTU. (2019). *Strategic plan of CIC*.

Babalola, A., & Busu, I. (2011). Selection of Landfill Sites for Solid Waste Treatment in Damaturu Town-Using GIS Techniques. *Journal of Environmental Protection*, *02*(01), 1–10. https://doi.org/10.4236/jep.2011.21001

Banar, M., Cokaygil, Z., & Ozkan, A. (2009). Life cycle assessment of solid waste management options for Eskisehir, Turkey. *Waste Management*, *29*(1), 54–62. https://doi.org/10.1016/j.wasman.2007.12.006

Banuri, T. (2010). *Chemicals mining transport trends in sustainable development waste*.

Bareither, C., Breitmeyer, R., Benson, C. H., & Edil, T. B. (2010). *Physical , chemical , and biological characterization of solid waste samples Physical , Chemical , and Biological Characterization of Solid Waste Samples*. *January*.

Benoît-Norris, C., Vickery-Niederman, G., Valdivia, S., Franze, J., Traverso, M., Ciroth, A., & Mazijn, B. (2011). Introducing the UNEP/SETAC methodological sheets for subcategories of social LCA. *International Journal of Life Cycle Assessment*, *16*(7), 682–690. https://doi.org/10.1007/s11367-011-0301-y

Blackman Jr, W. C. (2001). *Basic Hazardous waste management* (Third).

Bourke, J. B., Felsot, A. S., Gilding, T. J., Jensen, J. K., & Seiber, J. N. (1992). Pesticide Waste Management Technology and Regulation. In *American Chemical Society, W*.

Chang, P., Hsieh, M., & Chiu, T. (2016). *Recent Advances in the Determination of Pesticides in Environmental Samples by Capillary Electrophoresis*. https://doi.org/10.3390/ijerph13040409

Chauhan, A., & Singh, A. (2016). A hybrid multi-criteria decision-making method approach for selecting a sustainable location of healthcare waste disposal facility. *Journal of Cleaner Production*, *139*, 1001–1010. https://doi.org/10.1016/j.jclepro.2016.08.098

Djoumbou Feunang, Y., Eisner, R., Knox, C., Chepelev, L., Hastings, J., Owen, G., Fahy, E., Steinbeck, C., Subramanian, S., Bolton, E., Greiner, R., & Wishart, D. S. (2016). classifier: automated chemical classification with a comprehensive, computable taxonomy. *Journal of Cheminformatics*, *8*(1), 1–20. https://doi.org/10.1186/s13321-016-0174-y

Eastman, J. R., & Longley, P. (2005). Chapter 35: Multi-criteria evaluation and GIS. *Geographical Information Systems: Principles, Techniques, Applications and Management*, 493–502.

Ebistu, T. A., & Minale, A. S. (2013). Solid waste dumping site suitability analysis using geographic information system (GIS) and remote sensing for Bahir Dar Town, North Western Ethiopia. *African Journal of Environmental Science and …*, *7*(11), 976–989. https://doi.org/10.5897/AJEST2013.1589

El, A., Benaissa, M., Laila, K., & Salah, I. (2016). Landfill site selection using GIS , remote sensing and multicriteria decision analysis : case of the city of Mohammedia , Morocco. *Bulletin of Engineering Geology and the Environment*. https://doi.org/10.1007/s10064-016-0889-z

Estoque, R. C., & Murayama, Y. (2012). Examining the potential impact of land use/cover changes on the ecosystem services of Baguio city, the Philippines: A scenario-based analysis. *Applied Geography*, *35*(1–2), 316–326. https://doi.org/10.1016/j.apgeog.2012.08.006

Ethiopia, N. P. C. and the U. N. in. (2015). *Assessment of Ethiopia'sprogress towards the MDGS*.

FAO. (1997). *Prevention and Disposal of Obsolete and unwanted pesticide stock in Africa and the near East second consultation meetin*.

Farajzadeh, M. A., & Sorouraddin, S. M. (2014). *Liquid phase microextraction of pesticides : a review on current methods*. https://doi.org/10.1007/s00604-013-1157-6

Glanville, K., & Chang, H. C. (2015). Remote sensing analysis techniques and sensor requirements to support the mapping of illegal domestic waste disposal sites in Queensland, Australia. *Remote Sensing*, *7*(10), 13053–13069. https://doi.org/10.3390/rs71013053

Group, T. F. (2016). *Catalog of Industry Studies*. *April*.

Guan, H., Brewer, W. E., Garris, S. T., & Morgan, S. L. (2010). Disposable pipette extraction for the analysis of pesticides in fruit and vegetables using gas chromatography / mass spectrometry. *Journal of Chromatography A*, *1217*(12), 1867–1874. https://doi.org/10.1016/j.chroma.2010.01.047

Guerrero, L. A., Maas, G., & Hogland, W. (2013). Solid waste management challenges for cities in developing countries. *Waste Management*, *33*(1), 220–232. https://doi.org/10.1016/j.wasman.2012.09.008

Gumusay, M. U., Koseoglu, G., & Bakirman, T. (2016). An assessment of site suitability for marina construction in Istanbul , Turkey , using GIS and AHP multicriteria decision analysis. *Environmental Monitoring and Assessment*, *2025*. https://doi.org/10.1007/s10661-016-5677-5

Hamad, T. A., Agll, A. A., Hamad, Y. M., & Sheffield, J. W. (2014). Solid Waste as Renewable Source of Energy: Current and future posibility in Libya. *Case Studies in Thermal Engineering*, *4*(November), 144–152. https://doi.org/10.1016/j.csite.2014.09.004

Honkonen, Tuula, A.Khan, S. (2017). *Chemicals and Waste Governance Beyond 2020*.

Hsu, C., & Whang, C. (2009). *Microscale solid phase extraction of glyphosate and aminomethylphosphonic acid in water and guava fruit extract using alumina-coated iron oxide nanoparticles followed by capillary electrophoresis and electrochemiluminescence detection*. *1216*, 8575–8580. https://doi.org/10.1016/j.chroma.2009.10.023

Issa, S.M, Shehhi, B. A. (2012). *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XXXIX-B2, 2012 XXII ISPRS Congress, 25 August – 01 September 2012, Melbourne, Australia*. *XXXIX*(September), 133–138.

Jacobs, Massye Rachel and and Molly, A. B. and W. C. R. (2013). *Global Chemicals Outlook Towards Sound Management of Chemicals*.

Jensen, J. R., & Christensen, E. J. (1986). *Solid and Hazardous Wast Disposal Site Selection using Digital Geographic Information System Techniques*. *56*, 265–276.

Kharat, M. G., Kamble, S. J., Raut, R. D., Kamble, S. S., & Dhume, S. M. (2016). Modeling landfill site selection using an integrated fuzzy MCDM approach. *Modeling Earth Systems and Environment*, *2*(2), 1–16. https://doi.org/10.1007/s40808-016-0106-x

Kim, M., Jang, Y. C., & Lee, S. (2013). Application of Delphi-AHP methods to select the priorities of WEEE for recycling in a waste management decision-making tool. *Journal of Environmental Management*, *128*, 941–948. https://doi.org/10.1016/j.jenvman.2013.06.049

Kim, S., Sahoo, S., Kim, B. I., & Marshall, J. (2004). Routing optimization for waste management. *IIE Annual Conference and Exhibition 2004*, *October 2014*, 2553–2593.

https://doi.org/10.1287/inte.1040.0109
Kim, Y., Chung, E. S., Jun, S. M., & Kim, S. U. (2013). Prioritizing the best sites for treated wastewater instream use in an urban watershed using fuzzy TOPSIS. *Resources, Conservation and Recycling*, *73*, 23–32. https://doi.org/10.1016/j.resconrec.2012.12.009
Kontos, T. D., Komilis, D. P., & Halvadakis, C. P. (2005). Siting MSW landfills with a spatial multiple criteria analysis methodology. *Waste Management*, *25*(8), 818–832. https://doi.org/10.1016/j.wasman.2005.04.002
Koroleva, E. V., & Nikitin, Y. Y. (2014). Principles of Geographic Information Sysyem. *Journal of Multivariate Analysis*. https://doi.org/10.1016/j.jmva.2014.02.006
Laboratory, N. A. (2014). *Waste Determination and Characterization Guidelines 1 Purpose 2 Guidelines*. *June*, 2–4.
Lagnaoui, A., Dasgupta, S., Meisner, C., & Blankespoor, B. (2017). *Reducing the Human and Environmental Risks of Obsolete Pesticides A GIS-Based Tool for Priority-Setting*. 7–46.
M.I., G., C.B., B., T., R., P., P.-A., J., M., A., C., B., C., & B., T. (2013). Post-green revolution food systems and the triple burden of malnutrition. *Food Policy*, *13*.
Maimoun, M. A., Reinhart, D. R., Gammoh, F. T., & McCauley Bush, P. (2013). Emissions from US waste collection vehicles. *Waste Management*, *33*(5), 1079–1089. https://doi.org/10.1016/j.wasman.2012.12.021
Martin, A. (2011). *Pesticides and Formulation Technology Pesticides and Formulation Technology*.
Martinez, J. (2004). *Practical Guidline on Environmentally sound Management of Obsolet Pesticides In the Latin America and Caribbean Countries*.
Matsakas, L., Gao, Q., Jansson, S., Rova, U., & Christakopoulos, P. (2017). Green conversion of municipal solid wastes into fuels and chemicals. *Electronic Journal of Biotechnology*, *26*, 69–83. https://doi.org/10.1016/j.ejbt.2017.01.004
Mboin, I., Yator, E., & Box, P. O. (2012). Application of Digital Elevation Models in Menengai Geothermal Field. *Proceedings of the 4th African Rift Geothermal Conference Nairobi, Kenya, 21-23*.
McAllister, J. (2015). Factors influencing solid-waste management in the developing world. *All Graduate Plan B and Other Reports*, 1–95. https://doi.org/10.1016/j.jhydrol.2004.08.002
Mengistie, B. T. (2016). *Environmental Governance of Pesticides in Ethiopian Vegetable and Cut Flower Production Belay Tizazu Mengistie*.
Ministry of Finance and Economic Development. (2013). *Annual Report Progress for F.Y. 2011/2012 Growth and Transformation Plan (GTP I)*. *March*. https://doi.org/Volume II: Policy Matrix
Minsley, B. J., Wellman, T. P., Walvoord, M. A., & Revil, A. (2015). Sensitivity of airborne geophysical data to sublacustrine and near-surface permafrost thaw. *Cryosphere*, *9*(2), 781–794. https://doi.org/10.5194/tc-9-781-2015
Molugaram, K., & Rao, G. S. (2017). *Learn more about Moving Average Analysis of Time Series*.
Naivasha, L. (2010). *Resistivity of rocks*.
Nas, B., Cay, T., Iscan, F., & Berktay, A. (2010). Selection of MSW landfill site for Konya, Turkey using GIS and multi-criteria evaluation. *Environmental Monitoring and Assessment*, *160*(1–4), 491–500. https://doi.org/10.1007/s10661-008-0713-8
Nations, U. (2002). International Code of Conduct on the Distribution and Use of Pesticides (Revised Version) (adopted by the Hundred and Twenty-third Session of the FAO Council in November 2002). *Organization*, *November*.
Nishant.T, Prakash M.N, V. . (2010). Suitable site determination for urban solid waste disposal using GIS and remote sensing techniques in Kottayam municipality , India . *International Journal of Geomatics and Goescieces*, *1*(2), 197–210. https://doi.org/10.5194/hess-11-1609-2007
Paul, S. (2012). Location allocation for urban waste disposal site using multi-criteria analysis: A study on Nabadwip Municipality, West Bengal, India. *International Journal of Geomatics and Geosciences*, *3*(1), 74–88.

Rabbani, M., Sadri, S., & Rafiei, H. (2016). A multimodal transportation system routing implemented in waste collection. *Decision Science Letters*, *5*(1), 61–80. https://doi.org/10.5267/j.dsl.2015.8.003

Rekha, K., Thakur, M. S., & Karanth, N. G. (2000). *Biosensors for the Detection of Organo- phosphorous Pesticides*. *20*(3), 213–235.

Saaty, T.L, et al. (2001). *The seven pillars of the analytic hierarchy process*.

Saaty, T. L. (2008). *Decision making with the analytic hierarchy process*. *1*(1).

Samsidar, A., & Shaarani, S. (2018). *Trends in Food Science & Technology A review of extraction , analytical and advanced methods for determination of pesticides in environment and foodstu ff s*. *71*(June 2017), 188–201. https://doi.org/10.1016/j.tifs.2017.11.011

Sanjeevi, V., & Shahabudeen, P. (2016). Optimal routing for efficient municipal solid waste transportation by using ArcGIS application in Chennai. *Waste Management and Research*, *34*(1), 11–21. https://doi.org/10.1177/0734242X15607430

Scarlat, N., Motola, V., Dallemand, J. F., Monforti-Ferrario, F., & Mofor, L. (2015). Evaluation of energy potential of Municipal Solid Waste from African urban areas. *Renewable and Sustainable Energy Reviews*, *50*, 1269–1286. https://doi.org/10.1016/j.rser.2015.05.067

Sener, B., Süzen, M. L., & Doyuran, V. (2006). Landfill site selection by using geographic information systems. In *Environmental Geology* (Vol. 49, Issue 3). https://doi.org/10.1007/s00254-005-0075-2

Shahabi, H., Keihanfard, S., Ahmad, B. Bin, & Amiri, M. J. T. (2014). Evaluating Boolean, AHP and WLC methods for the selection of waste landfill sites using GIS and satellite images. *Environmental Earth Sciences*, *71*(9), 4221–4233. https://doi.org/10.1007/s12665-013-2816-y

Songa, E. A., & Okonkwo, J. O. (2016). Talanta Recent approaches to improving selectivity and sensitivity of enzyme-based biosensors for organophosphorus pesticides : A review. *Talanta*, *155*, 289–304. https://doi.org/10.1016/j.talanta.2016.04.046

Taherzadeh, M. J., & Karimi, K. (2008). *Pretreatment of Lignocellulosic Wastes to Improve Ethanol and Biogas Production : A Review*. https://doi.org/10.3390/ijms9091621

Tankiewicz, M., Fenik, J., & Biziuk, M. (2011). Talanta Solventless and solvent-minimized sample preparation techniques for determining currently used pesticides in water samples : A review. *Talanta*, *86*, 8–22. https://doi.org/10.1016/j.talanta.2011.08.056

THOSO, M., & A. (2007). *The Construction of a Geographic Information Systems (GIS) Model for Landfill Site Selection MAKIBINYANE THOSO A dissertation submitted in partial fulfillment for the requirements for the degree of MAGISTER ARTIUM In the Department of Geography, Faculty*. *November*.

UN. (2011). Globally harmonized system of classification and labeling of chemicals (GHS) and its implementation in Japan. In *Nippon eiseigaku zasshi. Japanese journal of hygiene* (Vol. 65, Issue 1). https://doi.org/10.1265/jjh.65.5

UNEP. (1989). *Basel convention on the control of transboundary movements of hazardous wastes protocol on liability and compensation basel convention protocol on liability and compensation*.

Wilks, M., Wilks, M., Ayele, A., Kendall, J., & Wookey, J. (2016). The 24th January 2016 Hawassa earthquake : Implications for seismic hazard in the Main Ethiopian Rift Journal of African Earth Sciences The 24th January 2016 Hawassa earthquake : Implications for seismic hazard in the Main Ethiopian Rift. *Journal of African Earth Sciences*, *125*(January), 118–125. https://doi.org/10.1016/j.jafrearsci.2016.11.007

Ye, J., Wu, J., & Liu, W. (2009). Enantioselective separation and analysis of chiral pesticides by high-performance liquid chromatography. *Trends in Analytical Chemistry*, *28*(10), 1148–1163. https://doi.org/10.1016/j.trac.2009.07.008

Zelenović Vasiljević, T., Srdjević, Z., Bajčetić, R., & Vojinović Miloradov, M. (2012). GIS and the analytic hierarchy process for regional landfill site selection in transitional countries: A case study from Serbia. *Environmental Management*, *49*(2), 445–458. https://doi.org/10.1007/s00267-011-9792-3

7 Appendices

Appendix I: Check List and Semi structured interview questions for X factory &federal level

A. Introduction:

This checklist is prepared to gather data on Potential Site Selection for Obsolete Pesticide Chemical Waste Disposal Using RS and GIS Techniques: A Case Study for Ethiopian Pesticides Processing Factory. Your cooperation in providing correct information is highly important for the success of this study. Your responses will be kept confidential that will be used only for academic purposes. Therefore, you are kindly requested to give your genuine and tangible answers to all questions. You are also expected to:-

- Read/listen to the raised issues carefully and answer based on your company background and your technical experience.
- Attaché reports and other secondary data of your company when they are needed.
- Discuss freely with your colleagues about the raised issues without restriction.

Thank you in advance for your cooperation.

B. Semi-structured interview& Data gathering checklist for the X-factory

1. Does the factory have a Factory profile (recent & updated)?
2. Does the factory have its working procedures, operational manuals legal manuscripts, and other related documents that are vital to performing their duties and responsibilities?
3. Does the factory evaluate its operational & financial performances since its establishment?
4. Does your company have data for Obsolete Pesticide Chemical waste? If your answer is "yes", please fill in the following table carefully.

Detail data for Expired Finished Products and Raw materials									
Item code	Description	Unit	Quantity	Manufacturing date	Expiry date	Batch no	Unit Cost (Birr)	Total Cost (Birr)	Remark

5. Does the factory have laboratory test to identify the usable chemicals from the Obsolete Pesticide chemical waste?
6. Do you have a mechanism to treat and re-use obsolete or expired pesticide chemical wastes?
7. For question number 6, if your answer is "Yes", which mechanism does your factory use?
8. Does the factory have performed any remedial actions related to Environmental impacts (nature degradation, health, social, economic, cultural, and political impacts)?
9. Do you have your working procedures, operational manuals, legal manuscripts, and other vital documents for Obsolete Pesticide Chemical waste disposal techniques?
10. Does the factory have License and ISO certificate for their Production Quality Management and Environmental Quality Management?
11. Does the factory have data for Environmental, Health, and Safety issues since its establishment?
12. Any other pesticide chemical waste treatment-related data?

C: Check List for Semi-structured interview questions for *woreda* and community level

1. Do you know any disaster occurred due to the impact of obsolete pesticide chemical waste in the district?

2. Does the factory have mechanisms to control illegal chemical waste disposal techniques?
3. Do you know any death happened due to poison by obsolete pesticide chemical waste?

D: Check List for field observation & FGD questions

1. Describe the overall working system of the factory?
2. How much you understand Knowledge about pesticide chemical wastes' characteristics, type, management, use, and their impact on human health and the environment?
3. What are the major causes of obsolete pesticide chemical wastes in the case factory?
4. Explain the trends of obsolete pesticide chemical waste disposal in the factory?
5. What are the positive and negative Impacts of obsolete pesticide chemical wastes disposal on the community and the environment?
6. Which mechanisms do you use to reduce the effect of obsolete pesticide chemical waste?
7. What are the major challenges observed in the factory?
8. What is your opinion about the objective of this research?
9. Please, discuss any other suggestions related to the study?

Appendix II: Raw data for ORM

Raw data for Obsolete Raw Materials obtained from field survey from the X factory				
Expired Raw materials				
S.No	Description	Unit	Quantity	Expiry date
1	*1.2 PROPLENE glyoc*	kg	899.00	2012
2	*ANTIOXIDANT BHT*	kg	311.40	2012
3	*DISPERSANT HS*	kg	291.00	2012
		kg	1,210.40	
		Tone	1.21	
4	*DISPERSANT*	kg	4,793.20	2013
5	*BORIK ACID*	kg	1,009	2013
6	*HIGH BOILLING AROMETIC*	kg	15,054	2013
7	*Calcium Lignosulphonate*	kg	3,475	2013
S.No	*Description*	Unit	Quantity	Expiry date
		kg	24,331	
		Tone	24	

8	*DOWANOL DPM*	kg	3,222.60	2014
9	*Dimethoate tech*	kg	18,125.00	2014
		kg	21,347.60	
		Tone	21.35	
10	*EMULSIFIER M-270-1*	kg	1,466.00	2015
11	*SARFECTANT FOR BENDO CARBON*	kg	150	2015
12	*EMULSIFIER 0226*	kg	200	2015
		kg	1,816.00	
		Tone	1.82	
13	*DEHSCOTIX CO-130F*	kg	461.00	2016
14	*EVA 67/N*	kg	537.00	2016
15	*EMULIFIRE 0213*	kg	514	2016
16	*PROPICONAZOL 95% TECH*	kg	1,031.80	2016
		kg	2,543.80	
		Tone	2.54	
17	*CYCLOHEXANON*	kg	31,152.00	2017
		Tone	31.15	
18	*MANCOZEB TECH*	kg	20,900	2018
19	*DELTAMTRINE TECH*	kg	105.5	2018
20	*ANTFOMER*	kg	180	2018
21	*EPICHLOREHYDRIN*	kg	241.4	2018
22	*EMULSIFIER -CF 971B*	kg	376.8	2018
23	*Metelaxil tech*	kg	19.2	2018
		kg	21,823	
		Tone	21.82	

Appendix III: Raw data for OFP

Raw data for Obsolete Finished Products obtained from field survey from the X factory				
Expired Finished Products				
S.No	Description	Unit	Quantity	Expiry date
1	*DDT 75% WDP*	kg	400,000.00	2012
		Tone	400	
2	*MANCOZEB 80 WDP 500GM*	KG	2006.5	2014
3	*Mancozeb 80% WDP*	kg	1410	2014
4	*Ethioconazole 25%E.C*	Lit	731	2014
5	*Ethiomiraz 12.5%E .C*	Lit	4000	2014
		kg	8,147.50	
		Tone	8.15	
6	*Ethiolation 50%ec 1l*	lit	4	Before 2015
7	*ETHIOCONAZOL 25% EC 1LIT*	lit	732	2015
8	*Ethiobenidocarbon 80% wp*	kg	3477	2015
9	*Vetazinon 60%ec 1lit*	lit	4	Before 2015
		Lit	4213	
		Tone	4.21	
10	*Ethiotoate 40%ULV200LIT*	lit	2600	2017
11	*ETHIOSULFAN 1/2KG DUST*	kg	2	2017
		kg	2602	
		Tone	2.60	
12	*FENITROTHION 50% EC 1 LIT*	lit	5951	2018
		Tone	5.95	
13	*ETHIOCONAZOL 25% EC 1LIT*	lit	4625	2016
14	*ETHIO-2--4--D 1LIT*	lit	9423	2016
		Lit	14048	
		Tone	14.05	

Appendix IV: **Profile of Participants and Data source**

I. Federal & Factory level officials

S.No	Name of office	Department	Data source type	Type of data	Remarks
1	Ministry of Agriculture	Plant protection	• Interview • Pesticide registration guideline • Proc-no-674-2010-pesticide-registration-and-control-proclamation.	Primary and Secondary	Collaboration
		Natural resource	• Soil data • Watershed data • climatologic data • Infrastructure data • Basin data		Collaboration
2	Geospatial Information Institute (GII)	Remote Sensing	• SPOT-5 Image • Land use land cover map	Primary& secondary	Bought + pledge
		Cartography	• Geographical map(Toposheet) • Administration map of Ethiopia • Map catalogue		Bought + pledge
3	Geological survey (GS)	Geological Information Library	• Generalized geological and industrial mineral map of Ethiopia • Generalized geological and metallic mineral occurrence map of Ethiopia 2000 • Geological Map of Ethiopia Rift • Geological Map of Ethiopia 2nd Ed. • Hydrogeological Map of Ethiopia • Geology of Ethiopia Explanatory Note.pdf • METALIC Mineral Research & Exploration.pdf • Industrial Minerals And Rocks resource potential of Ethiopia.pdf • Hydrology of Ethiopia and Water resourc	Primary& secondary	Collaboration
4	EFCC		• Different guidelines • Report	Secondary	Collaboration
5	CIC	R&D	• Plan& Report • Strategic plan& road map	Secondary	Collaboration
6	Factory (APPF)	• Mgt • Operation • Laboratory • Store • Production improvement • Environment& safety	• FGD • Interview • Plan& Report • Different guidelines • Lab reports	Primary& secondary	Collaboration + Ethical clearance
7	Ministry of Health		• DDT and Agober document	secondary	Collaboration

S.No	Name of office	Department	Data source type	Type of data	Remarks
8	Chemical and construction Input Institute (CCII)		• Pesticide chemicals dialogued document	secondary	Collaboration

II. Woreda level

S. No	Name of office	Department	Data source type	Type of data	Remarks
1	Agriculture	Extension	• Interview	Primary	Collaboration
		Natural resource	• Interview • Soil data	Primary &secondary	Collaboration
2	Environmental protection		• Interview • Woreda profile data	Primary& secondary	Collaboration
3	Disaster Risk management		• Interview • Kebele population data	Primary& secondary	Collaboration
4	Administration		• Interview	Primary	

III. Kebele level

S.No	Name of office	Department	Data source type	Type of data	Remarks
1	Agriculture	Extension	• Interview	Primary	Collaboration
		Natural resource	• Interview	Primary	Collaboration
2	Administration		• Interview	Primary	Collaboration
3	Community	Representative	• Interview	Primary	Collaboration

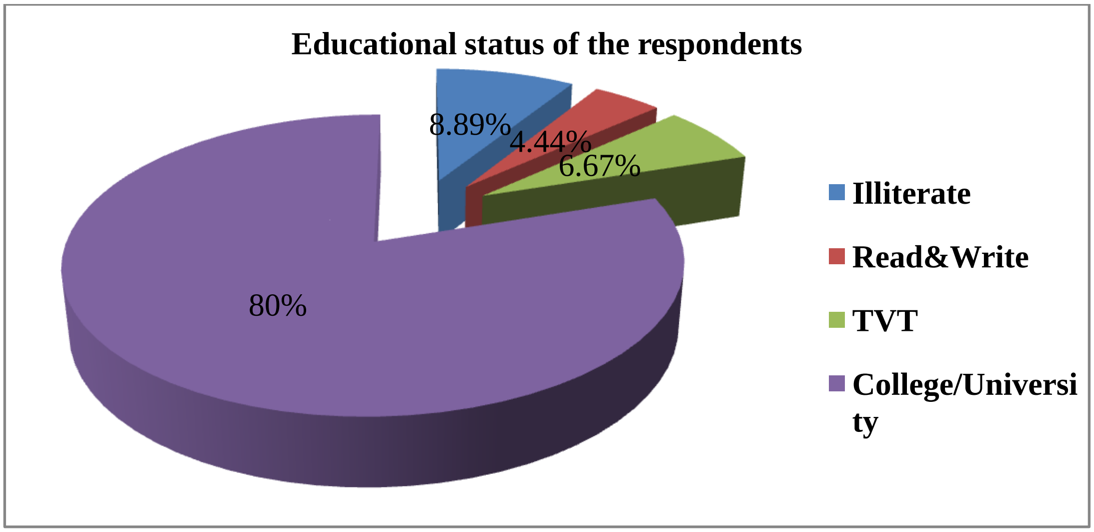
Appendix V: Interview respondents and FGD

A. Interview respondents by sex

Federal level					
S.No	Department	Male (n=37)	Female (n=10)	Total (n=47)	Percentage from total
1	Agriculture				
1.1	Plant protection	2	0	2	4.26
2	Factory				0.00
2.1	Management	1	0	1	2.13
2.2	Operation	5	0	5	10.64
2.3	Laboratory& quality assurance	2	0	2	4.26
2.4	Environment and safety	1	0	1	2.13
2.5	Production improvement	1	0	1	2.13
2.6	Store	1	1	2	4.26
	Sub total	13	1	14	29.79
	%	35.14	10.00	29.79	63.38
Woreda level					
1	Agriculture				
1.1	Extension	3	2	5	10.64
1.2	Natural resource	3	1	4	8.51
2	Environmental Protection	3	1	4	8.51
3	Disaster risk management	3	0	3	6.38
4	Administration	1	0	1	2.13
	Sub total	13	4	17	36.17
	%	35.14	40.00	36.17	36.17
Kebele level					
1	Agriculture				
1.1	Extension	2	1	3	6.38
1.2	Natural resource	3	1	4	8.51
2	Administration	1	0	1	2.13
3	Community	3	3	6	12.77
	Sub total	9	5	14	29.79
	%	24.32	50.00	29.79	29.79
	Grand total	37	10	47	100.00
	%	78.72	21.28	100.00	100.00

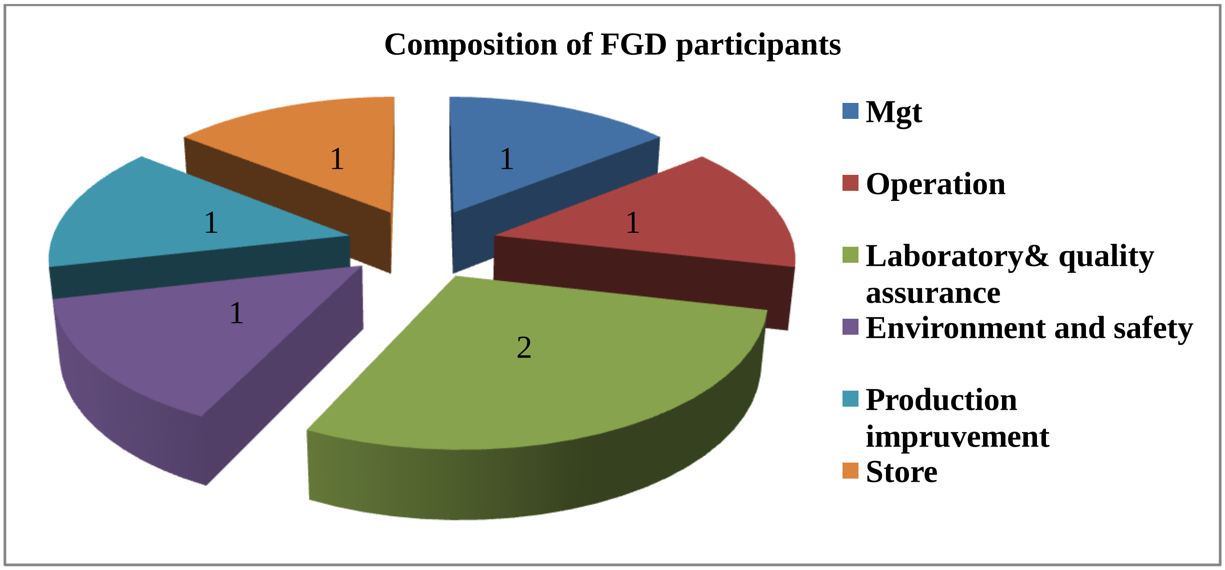
B. **Interview Respondents by Educational Status**

Concerning educational status, the four categories significantly represented in the survey: 36(80%) of the respondents were college /university/ graduate, 3(6.67%) were TVT, 2(4.44%) can only reading and writing, and 4(8.89%) were illiterate of the total participants. The results are illustrated in the following pie chart.



C. FGD respondents with sex and Educational status

		Sex			Educational status	
S.No	Department	Male	Female	Total	College/University	Remark
2	Factory					
2.1	Mgt	1	0	1	1	Vice Manager
2.2	Operation	1	0	1	1	Process owner
2.3	Laboratory& quality assurance	2	0	2	2	Process owner and Senior expert
2.4	Environment and safety	1	0	1	1	Senior expert
2.5	Production improvement	1	0	1	1	Process owner
2.6	Store	1	0	1	1	Process owner
	Sub total	7	0	7	7	



Appendix VI: Aspects Covered Under General Evaluation of Site Selection

(Source: Krishna & Babu, 1999)

Physical Features ✓ Topography ✓ Land Stability ✓ Seismic Stability ✓ Surface soil ✓ Surface Water & streams ✓ Surface Geology and Aquifers	**Human Values** ✓ Landscape ✓ Recreation ✓ Historical and Archeological Monuments ✓ Population Density ✓ Employment Opportunities ✓ Health Status of Population
Ecological Features ✓ Flora & Fauna ✓ Conservation Value ✓ Habitat	**Climate** ✓ Wind Direction ✓ Temperature ✓ Moisture
Land Use Features ✓ Development Potential ✓ Land Use Designation ✓ Agricultural Use ✓ Transportation Corridor ✓ Extraction Industries/Mining	**Logistics** ✓ Proximity to Users ✓ Transport access ✓ Availability of Utilities (hospitals, fire services, etc.) ✓ Adjacent Land use

Appendix VII: Location estimation and identification of the candidate sites

The following table shows location estimation and identification of the candidate sites.

Lake/Pond	>200m (>500m DW)
Flood plain	Protective enbankment
Highway	>500m
Habitation	>500m
Public park	>500m
Critical habitat	No
Wetland	Yes, but little
Coastal regulation zone	No
Airport	No
Water supply well	>500m
Groundwater level	3m above the base of the landfill
others	local needs

Appendix VIII: Score of Attributes

Figure Score of Attributes for Determining Appropriate Sites for Disposing Obsolete Chemical Wastes (Data for Gerbi Site)

Sn.No	Attribute	Attribute measurement	Sensitivity index	Weightage	Attribute score
	Accessibility Related				
1	Type of road	State highway	0.25	25	6.25
2	Distance from the factory	<10 km	0.12	35	4.2
	Receptor-Related				0
3	Population within 500meters	0-100	0.25	50	12.5
4	Distance nearest to a drinking water source	>5000	0	55	0
5	Use of site nearby residents	Not Used	0.12	25	3
6	Distance to the nearest building	>3000m	0	15	0
7	Land use/ zoning	Agricultural	0.25	35	8.75
8	The decrease in property value with respect to distance	>5000m	0	15	0
9	Public utility facility within 2 km	Not used	0	25	0
10	Public acceptability	Acceptance(suggestions)	0.25	30	7.5
	Environmental Related				0
11	Critical environment	Wetlands, flood plain, preserved areas	0.25	45	11.25
12	Distance to nearest surface water	> 8000 m	0	55	0
13	Depth to groundwater	15- 30 m	0.25	65	16.25
14	Contamination	Air, water or food	0.25	35	8.75
15	Water quality	Polluted	0.25	40	10
16	Air quality	Polluted	0.25	35	8.75
17	Soil quality	Contaminated	0.25	30	7.5

Sn.No	Attribute	Attribute measurement	Sensitivity index	Weightage	Attribute score
	Socio-economic Related				0
18	Health	Moderate	0.25	40	10
19	Job opportunity	Low	0.5	20	10
20	Odor	High	0.5	30	15
21	Vision	Site not seen	0	20	0
	Waste Management Practice Related				0
22	Waste quantity/day	< 250 tons	0.25	45	11.25
23	Life of site	> 20 years	0.25	40	10
	Climatological Related				0
24	Precipitation effectiveness index	31 - 63	0.5	25	12.5
25	Climatic features contribution to air pollution	Moderate	0.5	15	7.5
	Geological Related				0
26	Soil permeability	< $1*10^{-5}$ cm/sec to $1*10^{-7}$ cm/sec	0.5	35	17.5
27	Depth to bedrock	10 - 20 m	0.5	20	10
28	Susceptibility to erosion and Runoff	Moderate	0.5	15	7.5
29	Physical characteristics of rock	Weathered	0.25	15	3.75
30	Depth of soil layer	> 5m	0.25	30	7.5
31	Slope pattern	2-5%	0.35	15	5.25
32	Seismicity	zone 3&4	0.75	20	15
					247.45

Appendix IX: **Site investigation and preliminary data collection**

Sn.No	**Aspects**	**Remark**
1	Landform	flat, undulating, and sloppy
2	Current land use	farmland, grassland, bushland, settlement, forestland
3	Depth to groundwater	nearby wells
4	Depth of soil and bedrock	nearby well, depth
5	Distance to the nearest settlement	>2000m
6	The population within 500m	100
7	Availability of buffer zone	Available
8	Distance from the factory	<10km
9	Distance to the surface water body	>1500m
10	Surface water drainage	dry lines
11	Existence of drains presence of overground utilities (transmission lines, underground utilities(pipes))	Not available
11	Exposed bedrock(geology	Available
12	Ponds	Not available
13	Soft soil	Silty and sandy
14	Mining/deep pit	Available
15	Any obstructions for landfill	public acceptability
16	Natural vegetation, shrubs, trees	Available

Appendix X. Ranking of sites was done using the following steps.

1. Selection of attributes: 32-factors affecting environment, cost, etc.
2. Grouping of the attribute into 7 categories
3. Weightage of categories (247-point scale)
4. Weightage of each attribute within the group
5. Site sensitivity index: five levels 0(lowest) to 1(highest)
6. Weighted score for each attribute: Multiplicative
7. Aggregation of the score: Additive.

The weightage of the seven categories of 32 attributes was given as shown in the table below.

Categories	Weightage
Accessibility related	10.45
Receptor-related	31.75
Environmental related	62.5
Socioeconomic-related	35
Waste management practice	21.25
Climatological related	20
Geological related	66.5
Total	247

Appendix XI: Soil permeability classes

Soil permeability classes	Permeability rates	
	cm/hour	cm/day
Very slow	Less than 0.13	Less than 3
Slow	0.13 - 0.3	3 - 12
Moderately slow	0.5 - 2.0	12 - 48
Moderate	2.0 - 6.3	48 - 151
Moderately rapid	6.3 - 12.7	151 - 305
Rapid	12.7 - 25	305 - 600
Very rapid	More than 25	More than 600

Saturated samples under a constant water head of 1.27 cm

A. Soil permeability classes for civil *Engineering*

Soil permeability classes	Coefficient of permeability (K in m/s)	
	Lower limit	Upper limit
Permeable	2×10^{-7}	2×10^{-1}
Semi-permeable	1×10^{-11}	1×10^{-5}
Impermeable	1×10^{-11}	5×10^{-7}

B. Soil permeability level based on texture

Soil	**Texture**	**Permeability**
Clayey Soils	Fine	From very slow to very rapid
Loamy soils	Moderately fine	
	Moderately coarse	
Sandy soils	Coarse	

C. Average permeability for different soil textures

Sand	***5.0***
Sandy Loam	***2.5***
Loam	***1.3***
Clay Loam	***0.8***
Silty clay	***0.25***
Clay	***0.05***

Appendix XII: Pair wise Comparison for disposal techniques

A. Make Pair wise Comparison for criteria

	Cost	Technology	Knowledge	Risk
Cost	1	3	4	6
Technology	1/3	1	4	5
Knowledge	¼	1/5	1	3
Risk	1/6	1/5	1/3	1

B. Pair wise comparisons for criteria (total sum)

	Cost	Technology	Knowledge	Risk
Cost	1	3	4	6
Technology	1/3	1	4	5
Knowledge	¼	1/5	1	3
Risk	1/6	1/5	1/3	1
Total	21/12	22/5	28/3	15

The normalized pair wise matrix to determine priorities are given in the table below.

C. Normalized Pair wise Matrix

	Cost	Technology	Knowledge	Risk	Average
Cost	1.7500	13.2	37.33	0.4	13.17 (47.69%)
Technology	0.5833	4.4	37.33	0.33	10.66 (38.58%)
Knowledge	0.4375	0.88	9.33	0.2	2.71 (9.80%)
Risk	0.2917	0.88	3.11	0.0667	1.0871 (3.93%)

D. Pair wise Comparison Matrix for Cost (Cost Relative Priorities)

	Physical M.	Biological M.	Chemical M.
Physical M.	1	4	6
Biological M.	¼	1	2
Chemical M.	1/6	1/2	1
Sum	17/12	11/2	9

E. Normalized pair wise comparison matrix for cost

	Physical M.	Biological M.	Chemical M.	Avg.
Physical M.	1.4166	22	0.6667	8.0277 (78.71%)
Biological M.	0.3541	5.5	0.2222	2.0254 (19.86%)
Chemical M.	0.2361	0.0909	0.1111	0.1460 (1.43%)

F. Pair wise Comparison Matrix for Technology Simplicity

	Physical M.	Biological M.	Chemical M.
Physical M.	1	3	4
Biological M.	1/3	1	3
Chemical M.	1/2	1/4	1
Sum	11/6	17/4	8

G. Normalized pair wise comparison matrix for Technology Simplicity

	Physical M.	Biological M.	Chemical M.	Avg.
Physical M.	1.8333	12.75	0.5	5.0278 (67.27%)
Biological M.	0.6111	4.25	0.375	1.7454 (23.35%)
Chemical M.	0.9167	1.0625	0.125	0.7014 (9.38%)

H. Pair wise Comparison Matrix for Knowledge Simplicity

	Physical M.	Biological M.	Chemical M.
Physical M.	1	2	3
Biological M.	1/5	1	2
Chemical M.	1/6	1/4	1
Sum	41/30	13/4	6

Knowledge Simplicity Relative Priorities

I. Normalized pair wise comparison matrix for Knowledge Simplicity

	Physical M.	Biological M.	Chemical M.	Avg.
Physical M.	1.3667	6.5	0.5	2.7889 (62.3%)
Biological M.	0.2733	3.25	0.3333	1.2855 (28.71%)
Chemical M.	0.2278	0.8125	0.1667	0.4023 (8.99%)

J. Pairwise Comparison Matrix for Risk Reduction

	Physical M.	Biological M.	Chemical M.
Physical M.	1	3/2	7/3
Biological M.	2/3	1	3/2
Chemical M.	3/7	2/3	1
Sum	44/30	19/6	29/6

K. Normalized pair wise comparison matrix for risk reduction

	Physical M.	Biological M.	Chemical M.	Avg.
Physical M.	1.4667	0.4737	0.4827	0.8077 (20.95%)
Biological M.	0.4545	3.1667	0.3103	1.3105 (33.65%)
Chemical M.	0.2922	0.2105	4.833	1.7786 (45.4%)

Appendix XIII: Scale of relative importance

Scale of relative importance(Source: Saaty, 2008)

Definition	**Index**	**Definition**	**Index**
Equally important	1	Equally important	1/1
Equally or slightly more important	2	Equally or slightly less important	1/2
Slightly more important	3	Slightly less important	1/3
Slightly too much more important	4	Slightly to weigh less important	1/4
Much more important	5	Way less important	1/5
Much too far more important	6	Way too far less important	1/6
Far more important	7	Far less important	1/7
Far more important to extremely more important	8	Far less important to extremely less important	1/8
Extremely more important	9	Extremely less important	1/9

Appendix XIV: Random Consistency Index, Random Consistency Index (Source: Saaty, T.L, 2001)

N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Random Consistency Index (R.I.)	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

Appendix XV: Pair wise Comparison matrix of the attribute/criteria for site selection

A. Pair wise comparison matrix for the criteria

Pair wise comparison matrix										
	SRZ	**GLR**	**SP**	**DST**	**DPA**	DWRA	**DFL**	**DL**	**DF**	**DMR**
SRZ	**1**	**5**	**2**	**3**	**2**	**2**	**2**	**2**	**2**	**2**
GLR	**1/5**	**1**	**2**	**1**	**1**	**2**	**1**	**2**	**1**	**1**
SP	**1/2**	**1/2**	**1**	**2**	**1/2**	**1**	**2**	**1**	**1**	**1**
DST	**1/3**	**1**	**1/2**	**1**	**2**	**1**	**1**	**1**	**3**	**2**
DPA	**1/2**	**1**	**2**	**1/2**	**1**	**1**	**2**	**1**	**1/2**	**1**
DWRA	**1/2**	**1/2**	**1**	**1**	**1**	**1**	**2**	**1**	**2**	**1**
DFL	**1/2**	**1**	**1/2**	**1**	**1/2**	**1/2**	**1**	**1**	**1**	**1**
DL	**1/2**	**1/2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
DF	**1/2**	**1**	**1**	**1/3**	**2**	**1/2**	**1**	**1**	**1**	**1**
DMR	**1/2**	**1**	**1**	**1/2**	**1**	**1**	**1**	**1**	**1**	**1**

B. Pair wise comparison matrix with sum

Pair wise comparison matrix with sum										
	SRZ	**GLR**	**SP**	**DST**	**DPA**	**DWRA**	**DFL**	**DL**	**DF**	**DMR**
SRZ	1	5	2	3	2	2	2	2	2	2
GLR	**0.20**	1.00	**2.00**	**1.00**	**1.00**	**2.00**	**1.00**	**2.00**	**1.00**	**1.00**
SP	**0.50**	**0.50**	1.00	**2.00**	**0.50**	**1.00**	**2.00**	**1.00**	**1.00**	**1.00**
DST	**0.33**	**1.00**	**0.50**	1.00	**2.00**	**1.00**	**1.00**	**1.00**	**3.00**	**2.00**
DPA	**0.50**	**1.00**	**2.00**	**0.50**	1.00	**1.00**	**2.00**	**1.00**	**0.50**	**1.00**
DWRA	**0.50**	**0.50**	**1.00**	**1.00**	**1.00**	1.00	**2.00**	**1.00**	**2.00**	**1.00**
DFL	**0.50**	**1.00**	**0.50**	**1.00**	**0.50**	**0.50**	1.00	**1.00**	**1.00**	**1.00**
DL	**0.50**	**0.50**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	1.00	**1.00**	**1.00**
DF	**0.50**	**1.00**	**1.00**	**0.33**	**2.00**	**0.50**	**1.00**	**1.00**	1.00	**1.00**
DMR	**0.50**	**1.00**	**1.00**	**0.50**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	1.00
Sum	5.03	12.50	12.00	11.33	12.00	11.00	14.00	12.00	13.50	12.00

C. Normalized Pair wise comparison matrix

Normalized Pair wise comparison matrix										
	SRZ	**GLR**	**SP**	**DST**	**DPA**	**DWRA**	**DFL**	**DL**	**DF**	**DMR**
SRZ	0.1987	0.4000	0.1667	0.2647	0.1667	0.1818	0.1429	0.1667	0.1481	0.1667
GLR	0.0397	0.0800	0.1667	0.0882	0.0833	0.1818	0.0714	0.1667	0.0741	0.0833
SP	0.0993	0.0400	0.0833	0.1765	0.0417	0.0909	0.1429	0.0833	0.0741	0.0833
DST	0.0662	0.0800	0.0417	0.0882	0.1667	0.0909	0.0714	0.0833	0.2222	0.1667
DPA	0.0993	0.0800	0.1667	0.0441	0.0833	0.0909	0.1429	0.0833	0.0370	0.0833
DWRA	0.0993	0.0400	0.0833	0.0882	0.0833	0.0909	0.1429	0.0833	0.1481	0.0833
DFL	0.0993	0.0800	0.0417	0.0882	0.0417	0.0455	0.0714	0.0833	0.0741	0.0833
DL	0.0993	0.0400	0.0833	0.0882	0.0833	0.0909	0.0714	0.0833	0.0741	0.0833
DF	0.0993	0.0800	0.0833	0.0294	0.1667	0.0455	0.0714	0.0833	0.0741	0.0833
DMR	0.0993	0.0800	0.0833	0.0441	0.0833	0.0909	0.0714	0.0833	0.0741	0.0833
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

D. Normalized Criteria weight

Normalized Criteria weight											
	SRZ	**GLR**	**SP**	**DST**	**DPA**	**DWRA**	**DFL**	**DL**	**DF**	**DMR**	**CW**
SRZ	0.1987	0.4000	0.1667	0.2647	0.1667	0.1818	0.1429	0.1667	0.1481	0.1667	**0.2003**
GLR	0.0397	0.0800	0.1667	0.0882	0.0833	0.1818	0.0714	0.1667	0.0741	0.0833	**0.1035**
SP	0.0993	0.0400	0.0833	0.1765	0.0417	0.0909	0.1429	0.0833	0.0741	0.0833	**0.0915**
DST	0.0662	0.0800	0.0417	0.0882	0.1667	0.0909	0.0714	0.0833	0.2222	0.1667	**0.1077**
DPA	0.0993	0.0800	0.1667	0.0441	0.0833	0.0909	0.1429	0.0833	0.0370	0.0833	**0.0911**
DWRA	0.0993	0.0400	0.0833	0.0882	0.0833	0.0909	0.1429	0.0833	0.1481	0.0833	**0.0943**
DFL	0.0993	0.0800	0.0417	0.0882	0.0417	0.0455	0.0714	0.0833	0.0741	0.0833	**0.0709**
DL	0.0993	0.0400	0.0833	0.0882	0.0833	0.0909	0.0714	0.0833	0.0741	0.0833	**0.0797**
DF	0.0993	0.0800	0.0833	0.0294	0.1667	0.0455	0.0714	0.0833	0.0741	0.0833	**0.0816**
DMR	0.0993	0.0800	0.0833	0.0441	0.0833	0.0909	0.0714	0.0833	0.0741	0.0833	**0.0793**
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

E. Calculating the consistency value of each criteria

Calculating the consistency										
	SRZ	**GLR**	**SP**	**DST**	**DPA**	DWRA	**DFL**	**DL**	**DF**	**DMR**
CW	0.2003	0.1035	0.0915	0.1077	0.0911	0.0943	0.0709	0.0797	0.0816	0.0793
SRZ	**1**	**5**	**2**	**3**	**2**	**2**	**2**	**2**	**2**	**2**
GLR	**0.20**	**1.00**	**2.00**	**1.00**	**1.00**	**2.00**	**1.00**	**2.00**	**1.00**	**1.00**
SP	**0.50**	**0.50**	**1.00**	**2.00**	**0.50**	**1.00**	**2.00**	**1.00**	**1.00**	**1.00**
DST	**0.33**	**1.00**	**0.50**	**1.00**	**2.00**	**1.00**	**1.00**	**1.00**	**3.00**	**2.00**
DPA	**0.50**	**1.00**	**2.00**	**0.50**	**1.00**	**1.00**	**2.00**	**1.00**	**0.50**	**1.00**
DWRA	**0.50**	**0.50**	**1.00**	**1.00**	**1.00**	**1.00**	**2.00**	**1.00**	**2.00**	**1.00**
DFL	**0.50**	**1.00**	**0.50**	**1.00**	**0.50**	**0.50**	**1.00**	**1.00**	**1.00**	**1.00**
DL	**0.50**	**0.50**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
DF	**0.50**	**1.00**	**1.00**	**0.33**	**2.00**	**0.50**	**1.00**	**1.00**	**1.00**	**1.00**
DMR	**0.50**	**1.00**	**1.00**	**0.50**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
Sum	5.03	12.50	12.00	11.33	12.00	11.00	14.00	12.00	13.50	12.00

F. Consistency value of each criterion

Consistency value of Each criteria										
	SRZ	**GLR**	**SP**	**DST**	**DPA**	**DWRA**	**DFL**	**DL**	**DF**	**DMR**
CW	0.2003	0.1035	0.0915	0.1077	0.0911	0.0943	0.0709	0.0797	0.0816	0.0793
SRZ	0.2003	0.5176	0.1831	0.3232	0.1822	0.1886	0.1417	0.1595	0.1633	0.1586
GLR	0.0401	0.1035	0.1831	0.1077	0.0911	0.1886	0.0709	0.1595	0.0816	0.0793
SP	0.1001	0.0518	0.0915	0.2155	0.0455	0.0943	0.1417	0.0797	0.0816	0.0793
DST	0.0668	0.1035	0.0458	0.1077	0.1822	0.0943	0.0709	0.0797	0.2449	0.1586
DPA	0.1001	0.1035	0.1831	0.0539	0.0911	0.0943	0.1417	0.0797	0.0408	0.0793
DWRA	0.1001	0.0518	0.0915	0.1077	0.0911	0.0943	0.1417	0.0797	0.1633	0.0793
DFL	0.1001	0.1035	0.0458	0.1077	0.0455	0.0471	0.0709	0.0797	0.0816	0.0793
DL	0.1001	0.0518	0.0915	0.1077	0.0911	0.0943	0.0709	0.0797	0.0816	0.0793
DF	0.1001	0.1035	0.0915	0.0359	0.1822	0.0471	0.0709	0.0797	0.0816	0.0793
DMR	0.1001	0.1035	0.0915	0.0539	0.0911	0.0943	0.0709	0.0797	0.0816	0.0793
Sum	1.01	1.29	1.10	1.22	1.09	1.04	0.99	0.96	1.10	0.95

G. Consistency Weighted sum value

Consistency Weighted sum value											
	SRZ	**GLR**	**SP**	**DST**	**DPA**	**DWRA**	**DFL**	**DL**	**DF**	**DMR**	**WSV**
CW	0.2003	0.1035	0.0915	0.1077	0.0911	0.0943	0.0709	0.0797	0.0816	0.0793	
SRZ	0.2003	0.5176	0.1831	0.3232	0.1822	0.1886	0.1417	0.1595	0.1633	0.1586	**2.2180**
GLR	0.0401	0.1035	0.1831	0.1077	0.0911	0.1886	0.0709	0.1595	0.0816	0.0793	**1.1053**
SP	0.1001	0.0518	0.0915	0.2155	0.0455	0.0943	0.1417	0.0797	0.0816	0.0793	**0.9811**
DST	0.0668	0.1035	0.0458	0.1077	0.1822	0.0943	0.0709	0.0797	0.2449	0.1586	**1.1544**
DPA	0.1001	0.1035	0.1831	0.0539	0.0911	0.0943	0.1417	0.0797	0.0408	0.0793	**0.9676**
DWRA	0.1001	0.0518	0.0915	0.1077	0.0911	0.0943	0.1417	0.0797	0.1633	0.0793	**1.0006**
DFL	0.1001	0.1035	0.0458	0.1077	0.0455	0.0471	0.0709	0.0797	0.0816	0.0793	**0.7614**
DL	0.1001	0.0518	0.0915	0.1077	0.0911	0.0943	0.0709	0.0797	0.0816	0.0793	**0.8481**
DF	0.1001	0.1035	0.0915	0.0359	0.1822	0.0471	0.0709	0.0797	0.0816	0.0793	**0.8720**
DMR	0.1001	0.1035	0.0915	0.0539	0.0911	0.0943	0.0709	0.0797	0.0816	0.0793	**0.8460**
Sum	1.01	1.29	1.10	1.22	1.09	1.04	0.99	0.96	1.10	0.95	

H. Pair Wise Comparisons consistency value

Pair Wise Comparisons consistency value													
	SRZ	**GLR**	**SP**	**DST**	**DPA**	DWRA	**DFL**	**DL**	**DF**	**DMR**	**CWSV**	CW	RWSV / CW
CW	0.2003	0.1035	0.0915	0.1077	0.0911	0.0943	0.0709	0.0797	0.0816	0.0793			
SRZ	0.2003	0.5176	0.1831	0.3232	0.1822	0.1886	0.1417	0.1595	0.1633	0.1586	**2.2180**	**0.2003**	**11.0743**
GLR	0.0401	0.1035	0.1831	0.1077	0.0911	0.1886	0.0709	0.1595	0.0816	0.0793	**1.1053**	**0.1035**	**10.6764**
SP	0.1001	0.0518	0.0915	0.2155	0.0455	0.0943	0.1417	0.0797	0.0816	0.0793	**0.9811**	**0.0915**	**10.7191**
DST	0.0668	0.1035	0.0458	0.1077	0.1822	0.0943	0.0709	0.0797	0.2449	0.1586	**1.1544**	**0.1077**	**10.7151**
DPA	0.1001	0.1035	0.1831	0.0539	0.0911	0.0943	0.1417	0.0797	0.0408	0.0793	**0.9676**	**0.0911**	**10.6217**
DWRA	0.1001	0.0518	0.0915	0.1077	0.0911	0.0943	0.1417	0.0797	0.1633	0.0793	**1.0006**	**0.0943**	**10.6126**
DFL	0.1001	0.1035	0.0458	0.1077	0.0455	0.0471	0.0709	0.0797	0.0816	0.0793	**0.7614**	**0.0709**	**10.7462**
DL	0.1001	0.0518	0.0915	0.1077	0.0911	0.0943	0.0709	0.0797	0.0816	0.0793	**0.8481**	**0.0797**	**10.6368**
DF	0.1001	0.1035	0.0915	0.0359	0.1822	0.0471	0.0709	0.0797	0.0816	0.0793	**0.8720**	**0.0816**	**10.6812**
DMR	0.1001	0.1035	0.0915	0.0539	0.0911	0.0943	0.0709	0.0797	0.0816	0.0793	**0.8460**	**0.0793**	**10.6655**
Sum	1.01	1.29	1.10	1.22	1.09	1.04	0.99	0.96	1.10	0.95			**107.15**
					λmax = Σ of RWS/n						10.71		
					CI = (λmax - n)/(n-1))						0.08		
					CR = (CI/RI)						**0.05**	**Consistent**	

Key for the abbreviations

SRZ = Seismic Risk Zone	CR = Consistency Ratio
GLR = Geological Layer Resistivity	CI = Consistency Index
SP = Slope	RCI = Random Consistency Index
DST = Distance from Settlement	RWSV = Ratio of Weighted Sum Value
DPA = Distance from Protected Area	CW = Criteria Weight
DWRA = Distance from Water Source Area	CWSV = Consistency Weighted Sum Value
DFL = Distance from farm land	CWSV = Consistency Weighted Sum Value
DL = Distance from Lake	DMR = Distance from Main Road
DF = Distance from Factory	n = number of criteria being compared.

With the CR below 10%, the importance rankings used in comparing criterion in the decision matrix were applied consistently, meaning the weights (i.e., principal eigenvectors in Table 5.8.4.8) calculated from the AHP were acceptable for use in suitability analysis.

After assigning weights to each criterion layer weighted summation /combination technique was applied to produce an overall temporary storage site suitability map that combines all criteria. Finally, ground checking by field investigation using GPS ground control points and participatory observation was carried out to validate the output generated from the model, and a suitable temporary storage site lastly arrived.

Appendix XVI: Types of pesticide processed by APPF

Types and Kinds of Pesticides Processed by APPF (Sources: APPF annual plan and reports, 2018)

Type	Formulation	Product
Acaricides	EC	*Vetazinon 60% E.C*
		Ethiomiraz 12.5 E.C
Fungicides	WDP	*Ethiozeb 80% wdp*
	EC	*Ethioconazole 25% ec*
Herbicide	SL	*Ethio 2,4-D 72% SL*
Insecticide	EC	*Ethiosulfan 35% EC*
		Ethiolathion 50%EC
		Ethiozinon 60%EC
		Ethiothioate 40%EC
		Ethiotrothion 50%EC
		Ethiodemethrin 2.5 EC
		Ethiopyrifos 48%EC
	ULV	*Ethiosulfan 25% ULV*
		Ethiothioate 40%ULV
		Ethiodemethrin 0.6% ULV
		Ethiopyrifos 24% ULV
	DUST	*Ethiolathion 5% DUST*
		Ethiosulfan 5% DUST
	WP	*Ethiotrothion 40%WP*
		Ethiopoxur 50%WP
		Ethiodemethrin 2.5 wdp
		Ethiobendiocarb 80% wdp