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Biofuel plants site selection integrating multi-criteria decision aid methods and GIS techniques in Algeria: A case study of Ouargla

Presented by:

- **Maàmri Mohamed Abderrahmane**
- **Drid Mohamed Amine**

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In front of the jury:

President:	Mr H. Belahya	MCB	University Kasdi Merbah - Ouargla
Examiner:	Mr A. Gouareh	MCB	University Kasdi Merbah - Ouargla
Promoter:	Mrs B. Recioui	MCB	University Kasdi Merbah - Ouargla
Co-Promoter:	Mr D.Messaoudi	PHD	University Kasdi Merbah - Ouargla

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In their honor they made us agree to evaluate our project
Mr. Hocine Belahya *as President.*

Mr. Abderrahmane Gouareh *as an examiner.*

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Abbreviations List

AD:	Anaerobic Digestion
AHP:	Analytical Hierarch Process
AND:	National Waste Agency
C_A:	Conversion Coefficient Animal
CI:	Consistency Index
C_M:	Conversion Coefficient Municipal
C_P:	Conversion Coefficient Palm
CR:	Consistency Ratios
DM:	Decision Makers
EU:	European Union
GIS:	Geographic Information System
IEA:	International Energy Agency
kg:	Kilogram
km^2:	Square Kilometers
kt:	Kiloton
LSI:	Land Suitability Index
m:	Meter
m^3:	Cubic Meters
MCDA:	Multi-Criteria Decision Aid
n:	Matrix Size
N_A:	Number of Animals
N_P:	Number of Palms
N_{pop}:	Number of Populations
NREP:	National Renewable Energies Program
OM:	Organic Matter
ONS:	National Organization of Statistics
PR_P:	Residue to Product Ratio Per Palm
QW:	Quantity of Waste
QW_A:	Quantity of Animal Waste
QW_M:	Quantity of Municipal Waste
QWO_M:	Quantity of Organic Municipal Waste
QW_P:	Quantity of Palm Waste
RP_A:	Rate of Production Per Animal
RPM:	Percentage of waste Produce per capita
VB_A:	Biogas Volume of Animal waste
VB_M:	Biogas Volume of Municipal waste
VB_P:	Biogas Volume of Palm waste
Wi:	Weight Value for Each Criterion
λ:	Maximal Eigenvalue

GENERAL INTRODUCTION

General Introduction

The survival and development of human beings are threatened by environmental pollution and resource exhaustion. At this point, using renewable energy systems to produce the necessary energy has become a need all over the world due to increasing greenhouse gas emissions and environmental pollution. One of the most important sources of renewable energy in the world is biogas. To promote the development of biomass-based biogas systems, it is essential to find suitable locations for such development. Choosing an appropriate location for a biogas plant is a task for which Geographic Information Systems (GIS) and multi-criteria decision aid (MCDA) are helpful. MCDA provides significant support for the generation and comparison of alternatives taking into account the evaluation criteria. MCDA offers a set of procedures, techniques and algorithms for structuring decision problems, and designing, evaluating and prioritizing decision alternatives. Geospatial information systems (GIS) are designed to store, manage, analyze, and visualize geospatial data that is required by decision-making processes. This research aims to find the biogas potential from biomass and using the Wilayas of Ouargla as a case study. A variety of constraints, as well as economic, environmental and social factors are integrated in this approach to help determine the most suitable sites for installing such bio-energy systems. As an application of the approach proposed in this work, a land suitability map for locating biogas plants was developed. The result is a classification of each potential location into one of three categories of suitability: Very Low Suitable, Low Suitable, Moderately Suitable, or highly Suitable. The present work consists of three main parts:

-The first chapter will provide a bibliographical overview of biomass and bioenergy and its uses, biomass potentials in Algeria, and ways to produce bioenergy from biomass by seeing current technologies for converting biomass into biofuels.

-The second chapter presents the potential of biomass (municipal waste, animal waste and palm waste) and the estimated amount of biofuel produced from this waste for the Wilayas of Ouargla in 2019, and maps of the potential were generated using GIS.

-The objective of the third chapter is to determine the best sites for establishing biofuel stations in the Ouargla by studying the potential of biomass using GIS-MCDA. Where a set of standards and restrictions will be taken in GIS. Where the weights of these parameters are analyzed and calculated using the Analytical Hierarchy Process (AHP), which is one of the MCDA methods. Various scenarios of criteria weights were also considered and their overall impact on the land suitability index was assessed.

CHAPTER I

General on biomass and biofuels

1.1. Introduction

In current situation fossil fuel is being a primary energy and its contribution around 80% in which transport sector takes share of 58% in the world [1]. The sources of these fossil fuels and oil reserves are depleting very fast and they are found to be major contribution for emission of harmful gases. These gases lead to negative effects like, receding of glaciers, loss of biodiversity, climate change, rise in sea level, etc. High demand for this fossil fuel is also affecting the global economic activities as there is increase in the prices of crude oil. The high-speedy modern world travels by both industrialization and motorization and it is being a main cause for the unpredictable fuel demand [2]. Many alternative energy sources have been already available include biofuels. Researchers are continuously working in the biofuel production from the sustainable biomass since it is being an efficient alternative to replace non-renewable fuels [3]. The advantages of biofuels over petroleum fuels are (a) they can be easily extracted from the biomass, (b) they are sustainable due to biodegradable property, (c) its combustion based on carbon-dioxide cycle, (d) more environment friendly. The share of biofuel in automobile market will grow rapidly during the next decade because of its environmental merits in the world. This will definitely result strong growth in agriculture sector for more production and associated by-products [4]. This chapter will provide a bibliographical overview of biomass and bioenergy and its uses, biomass potentials in Algeria, and ways to produce bioenergy from biomass by seeing current technologies for converting biomass into biofuels.

1.2. biomass

Biomass is an industrial term rather than a scientific term. Popularly, biomass is associated with plant-based materials. However, the term biomass may extend to encompass any biologically formed matter. The approximate amount of biomass available annually is virtually 105 billion metric tons of carbon per year in the world. About half of this amount is produced on land. The other half is formed in the ocean, e.g., algal biomass.

Up till now, wood is still the main source of biomass for various applications. Wood source examples are forest trees and branches. Other sources of biomass include agricultural residues, e.g., sugarcane bagasse, rice straw, cotton stalks, wheat straw. Even municipal waste is considered biomass.

Converting biomass into energy by normal burning (combustion) releases carbon emissions and other pollutants. However, EU and UN legal regulations still consider it a renewable energy source. This is based on the fact that plant stocks are annually replaced by newly grown crops.

Instead of converting biomass directly into energy by traditional combustion, it can be converted to more clean fuels (biofuels). This conversion may be conducted through different pathways, e.g., thermal, chemical, and biochemical pathways. These processes change biomass properties to provide a much better fuel with less pollution effect, e.g., converting wood thermally into charcoal by pyrolysis, or converting biomass chemically—by hydrolysis—to sugars, which may be fermented to give bioethanol. [5]

1.3. Resources of biomass

Biomass comes from living things like plants and animals, and it's becoming a more feasible source of renewable energy. Biomass will either be processed into biofuels or burned directly to provide heat, regardless of where it comes from. Of course, various biomass sources create varied quantities of energy, which has an impact on their efficiency. [6]

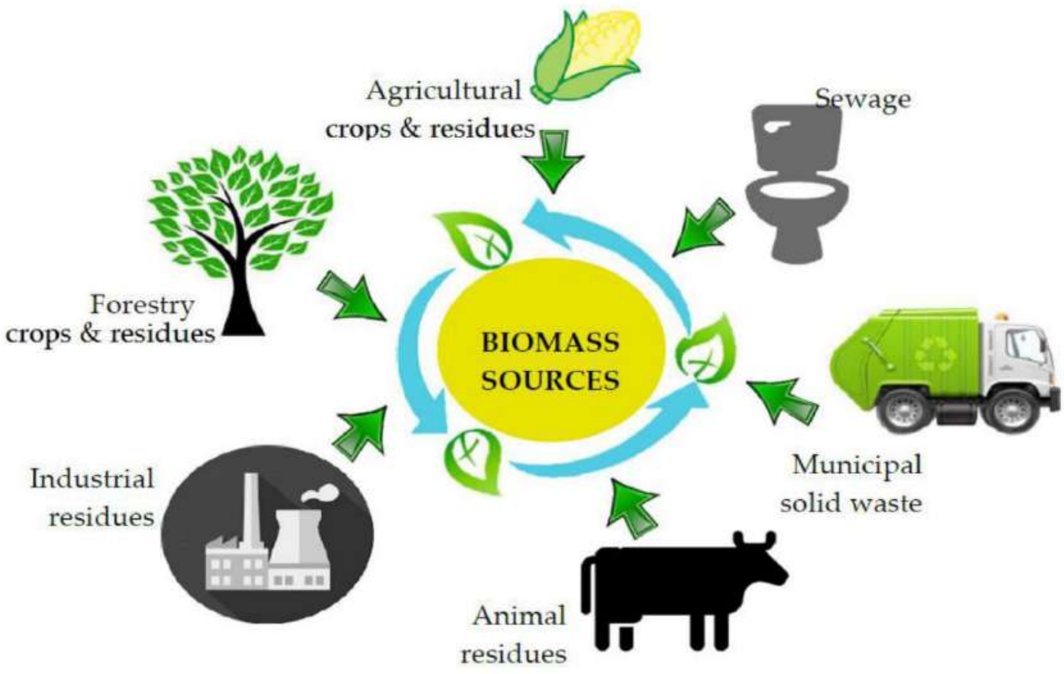


Figure 1.1: The different biomass resources.

1.3.1. Wood and Products

Renewable sources of timber and the by-products of wood such as wood chips are burned in the home to create heat and, in industry, burned to generate electricity.

1.3.2. Agricultural Crops and Waste

With large amounts of waste produced from the farming sector, it is natural that this is an ideal source of energy. The materials are either converted to liquid biofuels or burned directly to generate heat or electricity.

1.3.3. Food and Household Waste

The amount of waste households produce has been increasing annually, and up until recently, the majority was disposed of in landfill sites. Nowadays, this garbage is thermochemically processed in waste-to-energy plants to produce electricity or converted into biogas at existing landfill sites.

1.3.4. Animal Manure and Human Waste

We frequently hear about the link between animal waste and global warming. Inevitably, the same is also true of human waste. Both can be converted into biogas and burned as a fuel.

1.4. Properties of biomass

Biomass fuels have relatively different physicochemical properties depending on their origin or provenance [7] .

They can be characterized by:

- A high level of volatile matter, typically between 65 to 70% and 80%;

- Variable humidity depending on the type of product:

• Low (15-30%) for fuels such as cereal straw, energy crops harvested dry (miscanthus, switchgrass (Panicum virgatum)) and recycled wood (shredded pallets),

• High (40 to 60%) for wood from forestry (chips), from the processing industry (bark, sawmill by-products).

- An ash content varies according to the type of biomass:

• low for chips or chips (1 to 2%) and certain energy crops such as miscanthus (2 to 3%),

• a little higher (6 to 8%) for bark (which concentrates a good part of the wood minerals) and agricultural co-products such as cereal straw (5 to 8%), [8]

1.5. Main conversions of energy recovery from biomass

Several technologies are available to harvest the energy from the miscellaneous biomass feedstock. Figure 1.2 illustrate the different conversion technologies:

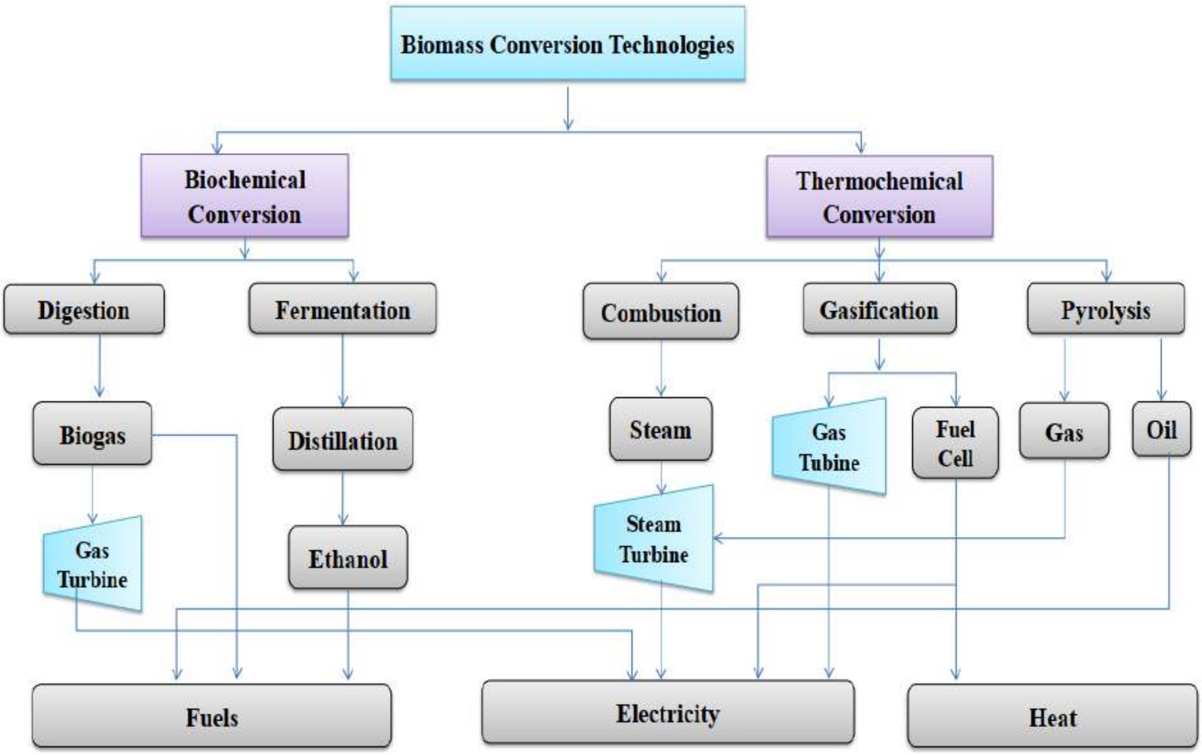


Figure 1.2: Schematic diagram for different options to convert biomass into biofuel

1.5.1. Thermo-chemical conversions of biomass

Thermochemical conversion can be defined as controlled heating which may or may not include oxidation of biomass to produce either heat or intermediate energy carriers. Among known thermochemical conversion processes, those for rice biomass are direct combustion, gasification, and pyrolysis. [9]

A) Gasification

Partially oxidation of biomass at higher temperatures, 800-900 °C, is used to transform biomass into a gaseous mixture enhanced biofuel product. The gas generated has a calorific value of up to 4-6 MJ/Nm^3 and may be burned directly to create energy or utilized in gas engines. [10]

B) Combustion

Direct combustion is the dominant energy pathway worldwide, where the oxidation process of biomass to water and CO_2 results in the production of heat. The process is one of the oldest and most used from which energy can be obtained. It is typically conducted in a combustion boiler, and steam is generated as a product. Oxygen is the oxidizing agent in combustion, where the overall reaction is exothermic. [9]

C) Pyrolysis

In the pyrolysis process, biomass is decomposed at high temperature in the absence of oxygen. Pyrolysis can be classified as gradual, rapid, or flash. For reforming biomass into liquid fuels such as bio-oil, flash pyrolysis is favored, whereas slow pyrolysis is employed for biochar production. Slow pyrolysis is also used to produce bio oil from a variety of sources. [10]

1.5.2. Biochemical conversions of biomass

Biochemical conversion can be defined by conversion of biomass into gaseous or liquid fuels, such as bio-alcohol, hydrogen, or methane through microbial or enzymatic reactions. Among the known methods for biochemical conversion of rice biomass are fermentation and anaerobic digestion. These two methods are preceded by pre-treatment of biomass and enzymatic hydrolysis. [9]

A) Fermentation

The fermentation process is used for the commercial production of bioethanol from sugar crops and starch crops. In this process, biomass is degraded into starch, which is then converted to sugar by enzymatic hydrolysis. Sugar is converted to bioethanol using yeast, and then the bioethanol is purified using a distillation process. The solid residue left behind after the fermentation process can be fed to cattle as a feeding source. [10]

B) Anaerobic Digestion

Anaerobic digestion is a process of biomass conversion by microorganisms into biogas in the absence of oxygen [10]. This process comprises of four interdependent steps, namely, hydrolysis, acidogenesis, acetogenesis, and methanogenesis, in which microbes responsible for a specific stage provide the intermediates for the subsequent step. Archaea, Bacteria, and Eukarya communities form the microbiome of the anaerobic digester and change during the stages of anaerobic digestion (AD) [11] [9].

1.6. Biofuels

Biofuels are renewable and they come from agricultural products such as sugarcane, oleaginous plants, forest biomass and other sources of organic matter. They can be used either isolated or added to conventional fuels in blends. As examples, it is possible to mention biodiesel, ethanol, methanol, methane and charcoal [1].

1.6.1. Types of biofuels

A) Biogas

Biogas are gaseous products obtained from biomass by different processes, they are produced by fermentation (microbial digestion in the absence of oxygen) of organic matter. This mainly results in the production of methane (a fuel molecule in natural gas), carbon monoxide and hydrogen [12].

Biogas can be obtained either by anaerobic digestion of organic waste, or by gasification (thermal cracking) of wood. Likewise, several natural processes lead to the production of biogas (digestion of ruminants and natural decomposition in marshy areas). However, sources generated by human activity are also important and, rather than representing waste, might be utilized as a source of energy. these sources of biogas are solid waste from sanitary or technical landfills (landfills) or sludge from wastewater treatment plants. [13] , [14]

B) Bioethanol

Bioethanol is produced from the alcoholic fermentation of simple sugars by yeasts. simple sugars must be obtained from biomass, and the following raw materials are used to make bioethanol:

• Simple sugars or hydrolyzed (degraded) starch from edible plants (sugar cane, corn, etc.), are agro-fuels.

• Plant debris of all kinds (forest residues, shavings from sawmills or paper mills, etc.) is rich in cellulose (cellulosic ethanol); cellulose can be hydrolyzed to fermentable simple sugar.

This fermentation produces flammable ethanol that may be mixed with traditional fuels. In some situations, alcohol can be utilized as a fuel additive, as well as a raw material in the manufacture of other fuels in engines designed for this purpose. Ethanol concentrations may reach 85 %, although a lower rate of 5-10 % is commonly added to automotive fuels without requiring any engine modifications. [15].

C) Biodiesel

Biodiesel is a biofuel intended for use in diesel engines and comes from the conversion of lipids (vegetable oils and animal fats) into fuel.

The most widely used raw material sources for the manufacture of biodiesel are:

• Vegetable oils, virgin or used; it is also an agro-fuel.

• Oils extracted from algae or microalgae (algo-fuel).

• Animal fats (relatively little used).

Biodiesel is very similar to conventional diesel and can be used without major engine modifications; it is a promising fuel that pollutes less. Currently, it is often added to conventional diesel in varying percentages [16].

D) Bio-oil

These are the liquid products formed when biomass is solvolyzed or pyrolyzed (wood, vegetable oils and animal fats). Bio-oil is a complex mixture of compounds from various chemical groups, including carboxylic acids, esters, alcohols, aldehydes, ketones, phenols, alkenes, and aromatics. Bio-oils are also simple to store and transport, and they may be utilized as a biofuel or in the production of big chemicals. [17], [18].

1.6.2. Production of biofuels

The production of biofuels is classified into three categories: first, second and third generation.

A) First generation the first generation

production process includes production of biodiesel and ethanol by conventional method. For production of biodiesel the transesterification process is adopted to extract oil from oleaginous plants and conversion of vegetable oil into fuel which can be used by the engines directly. The direct vegetable oils could be used just as a fuel in the modified engines. The transesterification uses enzymatic catalyzers or acids, alkaline and ethanol or methanol and produces glycerin and fatty acids as a residue [19] [20].

B) Second generation

The second-generation biofuel production processes are relied on cellulose hydrolysis followed by sugar fermentation. The biological matters can be very useful for production of syngas (synthesis gas) by gasification process. This syngas can be converted into liquid biofuels with the help of several catalytic processes. Methane and natural gas can be produced from anaerobic digestion process. The process includes digestion of agriculture waste or crops [19].

C) Third generation

The current production process of biofuels from algae is classified as third generation process. Algae can produce oil which can be further refined to diesel and some contents of gasoline easily. Genome and metabolic engineering approaches could direct carbon metabolic pathway towards ethanol as end product. The algal biomass production method can be achieved in both photo bioreactors and open raceway ponds. The disadvantage of the third-generation process is the biofuel produced from this process are less stable than the other processes [4].

1.7. Advantages and disadvantages of biomass and biofuels

The major advantages and disadvantages related to the use of biomass as fuel are listed as follows [21] [20]:

1.7.1. Advantages

Major advantages of biomass and biomass fuels:

- Renewable energy source for natural biomass.
- CO_2 neutral conversion and climate change benefits.

• Transition to low carbon economy, namely from hydrocarbon to carbohydrate and H resources.

• Use of nonedible biomass.

• Conservation of fossil fuels.

• Low contents of ash, C, FC, N, S, Si and most trace elements.

• High concentrations of volatile matter, Ca, H, Mg and P, structural organic components, extractives, water-soluble nutrient elements.

• Biodegradable resource with great reactivity and low initial ignition and combustion temperatures during conversion.

• Huge and cheap resource for production of biofuels, sorbents, fertilizers, liming and neutralizing alkaline agents, building materials, synthesis of some minerals and recovery of certain elements and compounds.

• Reduction of biomass residues and wastes.

• Decrease of hazardous emissions (CH_4, CO_2, NO_X, SO_X, toxic trace elements).

• Capture and storage of toxic components by ash.

• Use of oceans, seas, low-quality soils and non-agricultural, degraded and contaminated lands.

• Restoration of degraded and contaminated lands.

• Diversification of fuel supply and energy security.

• Rural revitalization with creation of new jobs and income.

1.7.2. Disadvantages

Major disadvantages of biomass and biomass fuels:

• Competition with edible biomass (food, feed), fibre and biomaterial productions.

• Damage of natural ecosystems (water, soil, land use changes, deforestation, biodiversity, land degradation, fertilizers, pesticides, contaminants).

• Indefinite availability of sustainable biomass resources for production of biofuels and chemicals.

• Omission of sustainable criteria for production of biomass resources for biofuels and chemicals.

• Lack of global monitoring and control of biofuels production with certification of origin and source.

- Miss of accepted terminology, methodologies, standards and classification and certification systems.
- Insufficient knowledge and variability of composition, properties and quality for assessment and validation.
- High contents of moisture, water-soluble fraction, Cl, K, Na, O and some trace elements (Ag, Br, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Se, Tl, Zn, others).
- Low energy density (bulk density and calorific value).
- Technological problems during processing (agglomeration, deposit formation, slagging, fouling, corrosion, erosion).
- Odor, emission and leaching of hazardous components during disposal and processing.
- Great growing, harvesting, collection, transportation, storage and pre-treatment costs.
- Limited practical experience in biofuel production and unclear utilization of waste products
- Insecurity of biomass feedstock supply.
- High investment cost.

1.8. Conclusion

Biomass is an alternative source of energy which is an effective solution to the energy crisis. The valorization of biomass can prove useful in the sustainable development of the country. It is currently only in its infancy, but should progress in the near future given the number of possible applications. The bibliographic study was carried out on the many forms of biomass that are available in our environment and are potentially recoverable (plant, animal, household waste, etc.). Harnessing such forms of energy will save the country's resources while significantly reducing the amount of greenhouse gases emitted into the atmosphere. The recovery of this energy is a solution that can bring many benefits in terms of energy, the economy, and the environment.

CHAPTER II

Potential of biomass and biofuel production: A case study of Ouargla

2.1. Introduction

Biomass energy was in the past a major source of fuel and is now an important part of research in renewable energy. According to historical accounts, people in the past mostly relied on dry leaves and wood for fuel. Biomass, as a derivative of biological materials, is a renewable resource. Any biological material including living organisms or the remains of living things such as wood and any other organic material such as forest debris from trees, materials from plant pruning and wood splinters can be used as a source of biomass. This chapter discuss the potential of biomass (municipal, animal and palm wastes) and biogas production based on the available potentials, as the biogas produced in this process consists of two components, methane and carbon dioxide with a small amount of other gases. Biogas usually contains about 55-65% methane, 30-35% carbon dioxide, and some hydrogen, nitrogen and other impurities. [22]

2.2. Description of study area (Ouargla)

The city of Ouargla is located in the southeast of Algeria. It is bordered on the north by Oued-Souf and Biskra and Djelfa, on the east by Tunisia, on the south by the states of Illizi and Tamanrasset, and on the west by the state of Ghardaia. Its area is 163,230 km^2 (old administrative division). It is a desert city characterized by its wide geographical area, and it is one of the largest cities in Algeria, see Figure 2.1.

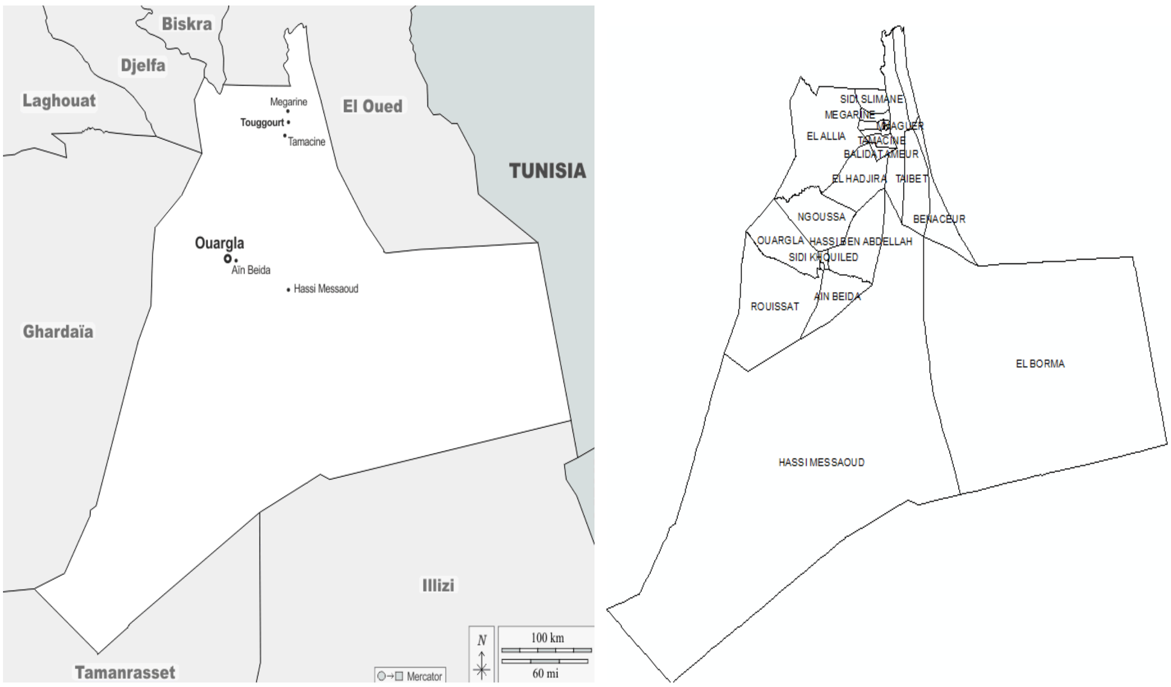


Figure 2.1: Borders and municipalities of the state of Ouargla

The population of the province is estimated to be about 708,463 in 2019 [23] , with a population density of 4.34 persons living within every square kilometer. The province constitutes an economic pole in gas and oil reserves, contained on the territory of Hassi-Messaoud. Ouargla has a desert climate typical of the Sahara Desert. The average temperatures are the highest. The temperature of July (the hottest month) is around 43 °C. [24]

2.3. Biomass potential in Algeria

2.3.1. Potential of the forest

The current potential is estimated at around 37 Mtoe. The recoverable potential is of the order of 3.7 Mtoe. The current recovery rate is of the order of 10%. The potential of biomass is relatively limited. The wooded area covers about 250 million hectares and represents 10% of the total area of the country where the Sahara covers almost 90% of the territory. Forests cover approximately 4.2 million hectares, or 1.8% of the total area, while alfatier zones cover only approximately 2.5 million hectares, or slightly more than 1% of the total area. On the other hand, so-called unproductive lands cover more than 188 million hectares, representing 79% of the total area [25] .

2.3.2. Household and similar waste

The current potential is estimated at around 37 Mtoe. The recoverable potential is of the order of 3.7 Mtoe. The current recovery rate is around 10%. 5 million tons of urban and agricultural waste are not recycled. This potential represents a deposit of the order of 1.33 Mtoe / year [26].

2.4. Biomass potential and biofuel production in Ouargla

This work focuses on the assessment of the biogas potential from municipal biowaste and agricultural residues, derived from plants (date palms) and livestock (manure) of animals (sheep, cows, camels and goats). The technology used to produce biogas is the anaerobic digestion. Figure 2.2 illustrates the biomass classification used in this research work.

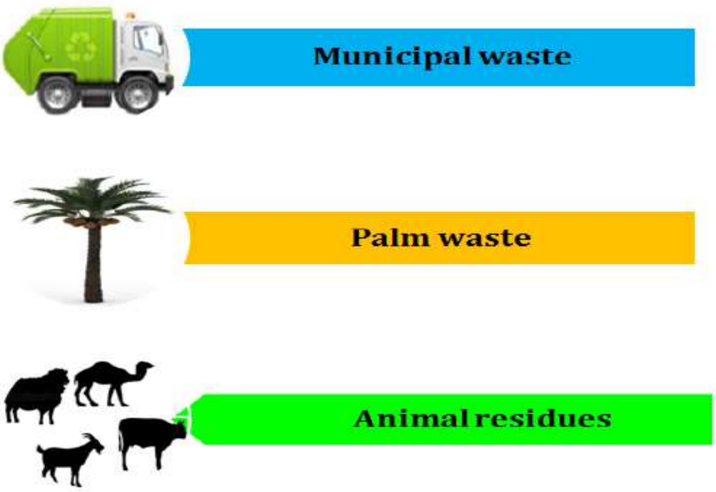


Figure 2.2: The classification of biomass used in this work.

The developed method is based on the combination of statistical and spatial explicit methods. The developed method is divided into the following main steps:

- Biomass potential assessment;
- Energy valorisation of potential (biogas);
- GIS mapping.

2.4.1. Biomass potential

A) Municipal waste production

According to Law No. 01-19 of 12-12-2001, "household and similar" and "municipal waste" waste is all waste from households (consumer waste), as well as similar waste from industrial activities, commercial, artisanal and other things which by their nature and composition are comparable to household waste. [27]

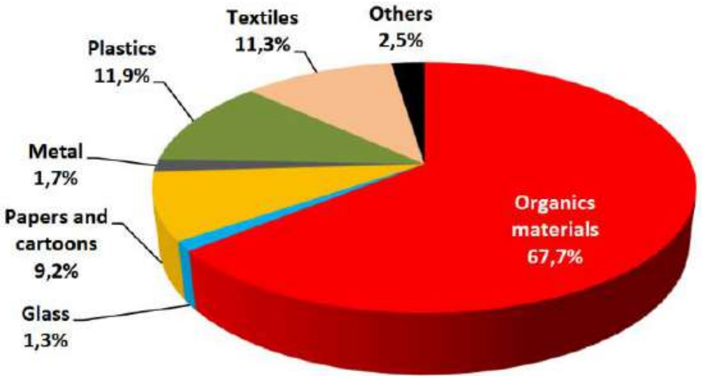


Figure 2.3: Composition of waste in Algeria (2011). [27]

The waste stream is a heterogeneous mixture of products and materials whose composition varies with its sources of generation. The amount of municipal waste generated in homes and public buildings in Ouargla is about 206.8712 kt / year, and it contains 67.7% biodegradable organic matter. In order to calculate the waste potential, the following data were set:

The amount of waste generated was evaluated at 0.8 kg per inhabitant per day, where 67.7% of waste is organic matter.

Data on the amount of municipal waste generated was obtained from the Environment Directorate and National Organization of Statistics and Budget in the Ouargla. [28],[24], [23].

The production of waste at the level of a wilaya (QW), during the reference year 2019, is estimated from the specific production ratio per inhabitant and per day estimated for the space in question (RP_M), multiplied by 365 (days) and multiplied by the number of the population (N_{pop}) of that city, based on estimates made for the base year. [27]

$$QW_M = N_{pop}.RP_M.365 \quad (2.1)$$

The total production of organic waste of urban origin (QWO_M) at the level of the city under study, during the reference year is estimated by multiplying the production of city waste (QW_M) and the percentage of average organic matter (OM) in this waste. These steps are summarized in the following equation:

$$QWO_M = QW_M.OM \quad (2.2)$$

According to the national waste agency [29], the percentage of organic matter OM is estimated at 67.7%. We assume that the composition of the waste is identical everywhere in Algeria. This composition is determined for the year 2011. [27]

B) Animal wastes production

Animal waste is one of the most important sources of biomass for the production of biogas. The province of Ouargla has a large number of animals that produce a significant amount of waste. Where the number of heads of sheep is 145,877 heads, and 213,680 head goats, and 999 head cows, and 41,503 head camels for the year 2019. [24], [28] [23].

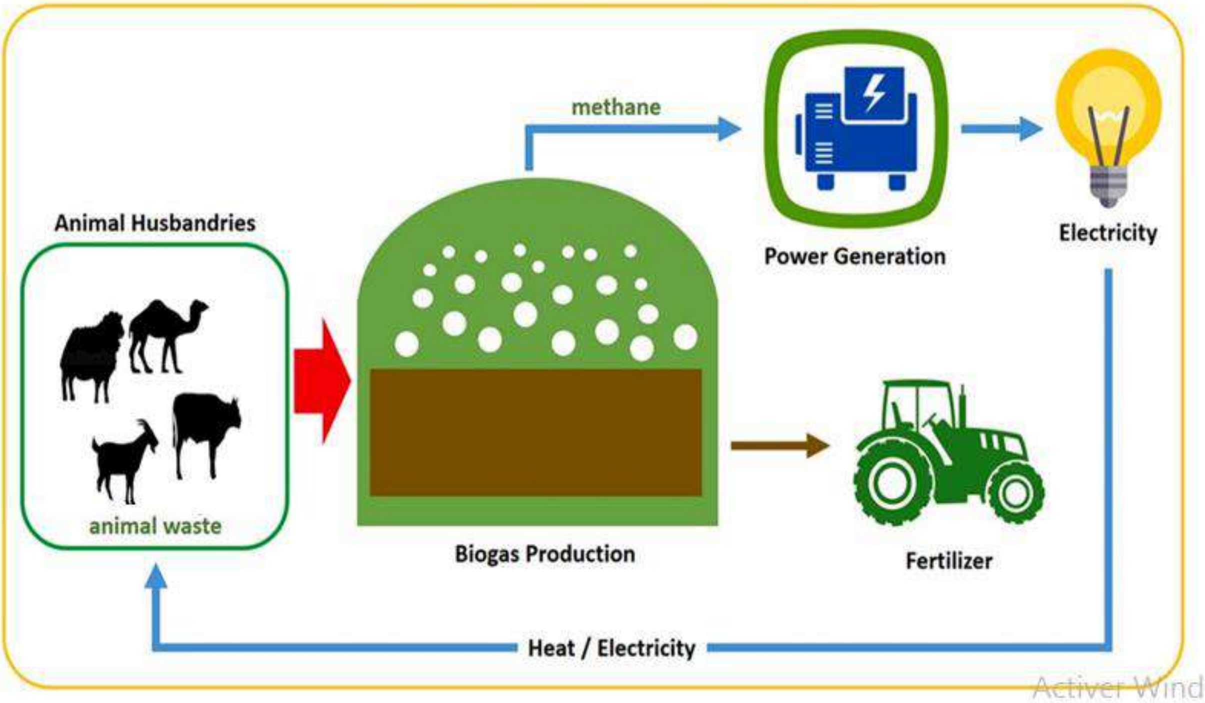


Figure 2.4: Biogas production from animal waste [30].

Considering these statistics, it can be argued that there is a great potential for utilizing the waste from cattle husbandries to generate biogas in Ouargla. Biogas production from livestock wastes depends on factors such as their animal feed, body weight, and solids in wastes.

Total animal waste production (QW_A) is estimated at the city level under study during the reference year by multiplying the number of livestock heads (N_A) and the rate of production per head (RP_A). These steps are summarized in the following equation:

$$QW_A = N_A . RP_A .365 \qquad (2.4)$$

The daily amount of manure as a percentage of the livestock weight is considered to be 9% for large livestock (cows and camels), 4% for small livestock (goats and sheep). [31]

C) Palm waste production

Palm waste is one of the most important sources of biomass for the production of biofuels, as the city of Ouargla has a large potential for palm trees, estimated at 262,8814 palm trees. [28], [32], [23]

Theoretical potential of residues from plant production is defined as the annual production of residues generated during agricultural production. The collected waste consists of leaves, leaf stems, and empty fruit clusters. On average, each palm tree produces 6 - 10 empty fruit clusters and 12 - 15 stems, and each stalk has about 120 - 240 leaves. Altogether, represents around 15-35 kg of annual waste per tree. Waste samples were first dried for a few days in an open atmosphere and under direct sunlight with a temperature peak of around 45 ° C, during the day. The dried material was then cut into small pieces before being converted into particles. [33]

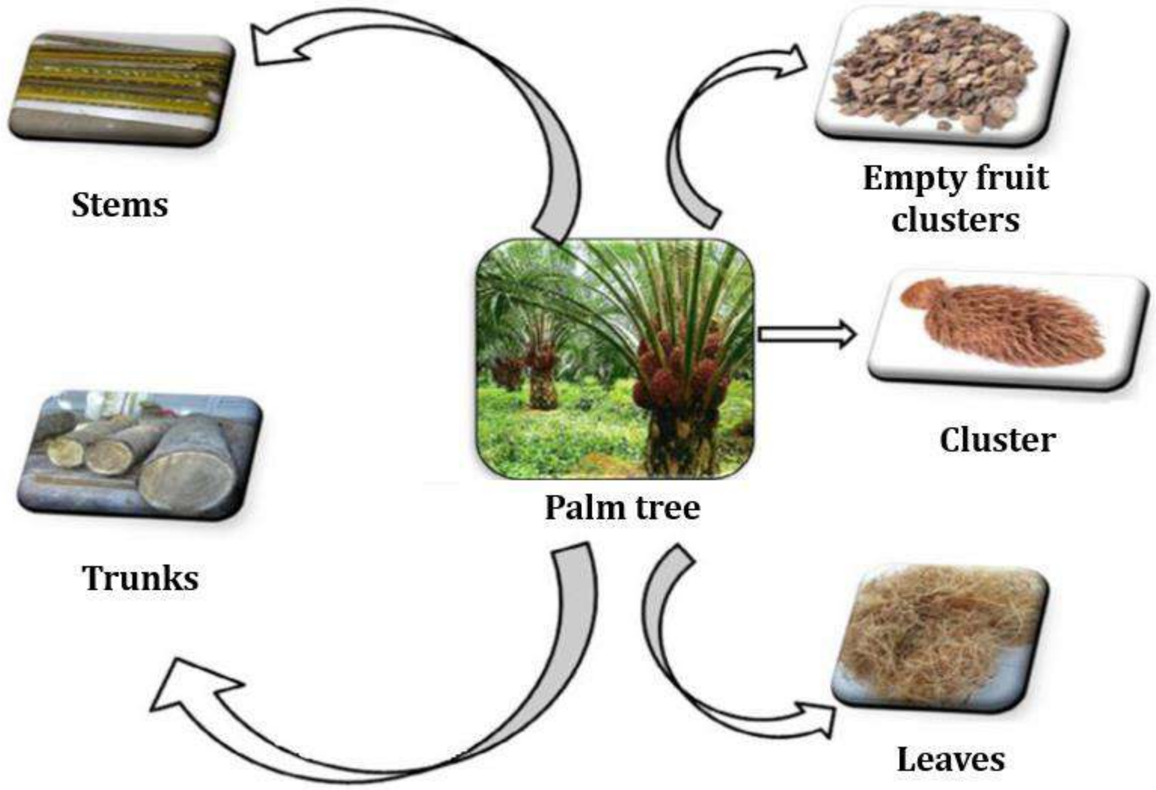


Figure 2.5: The use of palm waste in the production of biofuels [34]

The total production of palm waste (QW_P) at the province level under study during the reference year is estimated by multiplying the total number of palms (N_P) and the residue to product ratio per palm (PR_P). Total production is estimated according to equation (2.6):

$$QW_p = N_P . PR_p . 365 \quad (2.6)$$

The average production of palm waste ranges from 15 to 35 kg of residues per palm (fruit clusters, stems, stalk, leaves,… etc). According to scientific reports and published reference papers, an average of 25 kg was taken. This approach was used to assess the palm residue potential of 2019. [33] [35].

2.4.2. Biogas potential

A) Biogas production from municipal waste

The determination of the volume of biogas VB_M (m^3) estimated from the quantity of organic waste QOW_M (kt/year) and conversion coefficient C_M (m^3/tons) is as follows:

$$VB_M = QOW_M.C_M \qquad (2.3)$$

The conversion factor ranges (C_M) from 100 to 300 m^3 per ton of waste. In our study, we took an average of 200 m^3 / ton. This approach was used to assess biogas recovery from municipal waste [27].

B) Biogas production from animal waste

The quality and quantity of livestock manure produced varies according to the type of feed and the living conditions of the livestock. There can be differences in the amounts of biogas produced from livestock waste.

The determination of the volume of biogas VB_A (m^3) estimated from the quantity of animal waste QW_A (kt/year) and conversion coefficient C_A (m^3/ tons) is as follows:

$$VB_A = QW_A.\ C_A \qquad (2.5)$$

Therefore, in this study, according to published scientific reports and reference papers, different methods are used to calculate the biogas production factor from biomass (see Table 2.1) [31] [36] [37].

C) Biogas production from palm waste

Based on the great potential of palm waste in the city of Ouargla, which is estimated at 2628814 palm trees which can produce large quantities of biogas, according to published scientific reports and reference papers, the determination of the volume of biogas VB_P (m^3) estimated from the quantity of palm waste QW_P (kt/year) and conversion coefficient C_P (m^3 / tons) is as follows [31] [38] [37]:

$$VB_P = QW_P.\ C_P \qquad (2.7)$$

Table 2.1: Conversion coefficient to biomass and biogas. [31], [38], [13].

Resource	Biomass conversion coefficient (kg/head)	Biogas conversion coefficient (m^3/kg)
Cow and calf	22.5	75
Camels		
Sheep	1.6	13
Goats		

The conversion coefficient varies from animal to animal. According to published scientific reports and reference papers, the conversion coefficient for each animal has been determined in the Table 2.1.

2.4.3. Total Potential

Biogas is a practical way to recycle organic waste that can be used as fuel for cogeneration of electricity and heat. Livestock-based resources and agriculture have great potential for biofuel generation mainly due to their relatively low cost in Ouargla. This study aims to assess the potential of Ouargla in generating biofuel from both animal and agricultural resources to provide an accurate / realistic estimate of resource availability. Table 2.2 shows the calculation of the amount of biogas produced from biomass waste for the year 2019.

Table 2.2: The amount of biogas produced from biomass according to the municipalities of Ouargla province for the year 2019.

	biomass (kt/year)	Biogas (m^3)
animal waste	559.029	28,908.33
municipal waste	206.87	28,010.36
Palm waste	65.72	12,167.20
Total potential	831.621	69,085.895

The total palm waste is estimated at 65.720 kt / year, which can be considered as a potential raw material for the production of 12 167.203 $m^3$of biogas. In addition, the potential of biogas from 559.029 kt of livestock waste is estimated at 28,908.332 m^3/ year, and the municipal waste is estimated at 206.87 kt / year, which produces 28,010.36 m^3/ year, the results indicated that there is a great potential for generating biofuel.

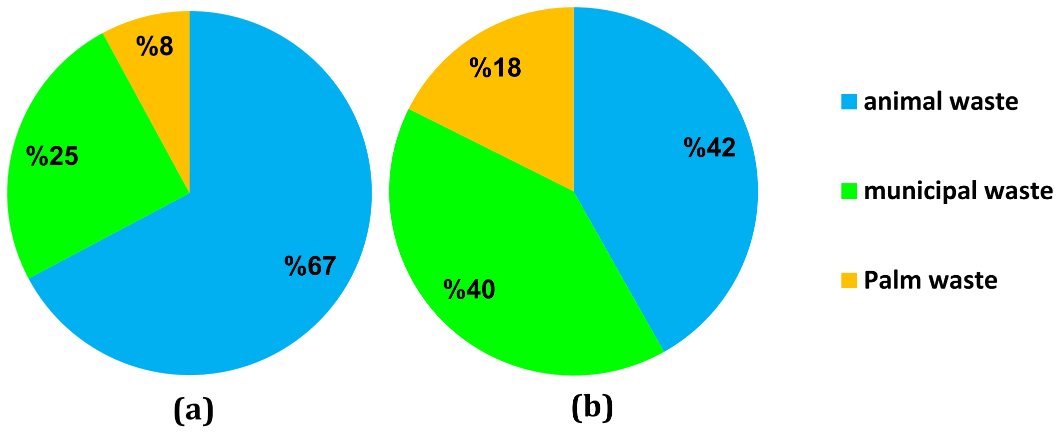


Figure 2.6: percentages of contribution according to source of waste. The total potential of (a) biomass waste and (b) biogas in Ouargla (2019)

Figure 2.6 shows the percentages of the biomass waste and biogas potential from livestock manure, municipal and palm waste in 2019 in the wilaya of Ouargla. It was seen that the most of waste production (67%) could be provided by livestock manure compared to municipal waste (25%) and palm waste (8%). As shown in Figure 2.6, the analysis estimated that the total potential to generate biofuel from these organic materials was about 69 085.89 m^3/ year which animal waste present 42% of total followed by municipal waste with 40% and palm waste with 18%. This research provides insights and valuable information for policymakers to formulate a long-term energy policy by making use of this vital waste in Ouargla as a case study.

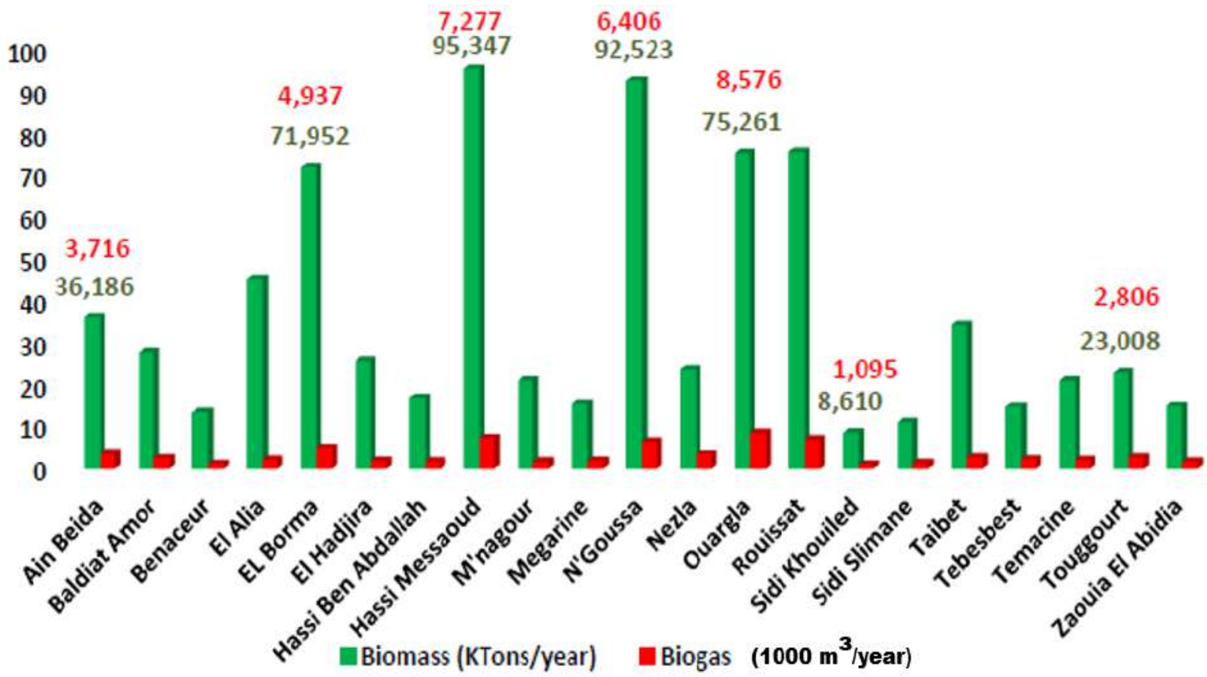


Figure 2.7: The total potential of biomass and biogas in Ouargla (2019)

According to the overall data, the biogas potential from manure was highest in Hassi Messaoud in 2019 at 4,979.8 m^3, which accounted for 17.23% of the total potential value; Hassi Messaoud was followed by N'Goussa, El Borma, Rouissat, and El Alia in potential. The anaerobic digestion potential of livestock in these five municipalities accounted for 66.92% of the total potential value. Tebesbest had the lowest biogas potential with an amount of only 42.79 m^3 (Figure 2.7).

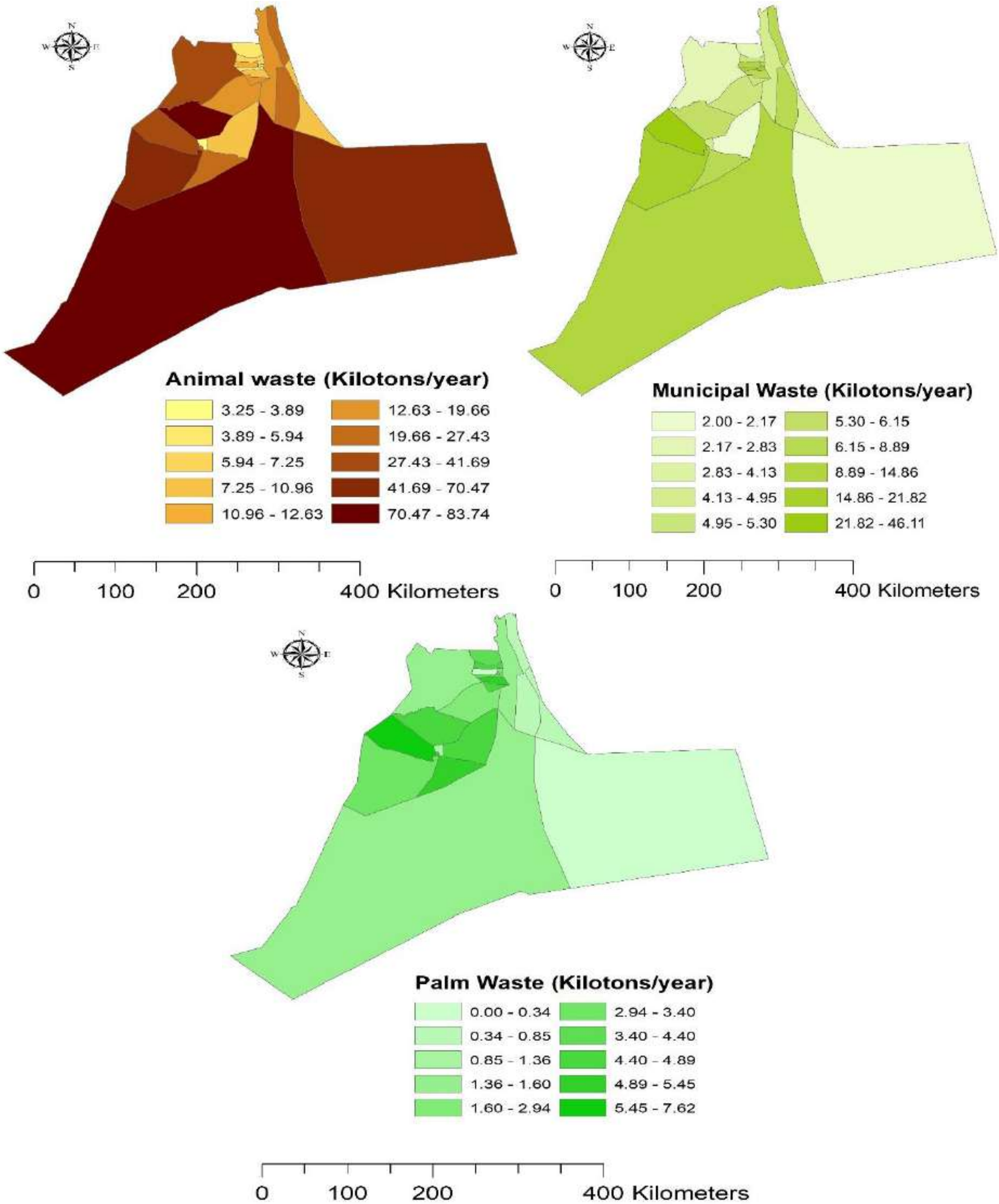


Figure 2.8: Geographical distribution of biomass waste potential in Ouargla (2019)

Figure 2.8 shows the biomass waste production potential maps for three types of waste. It was observed that the province of N'Goussa, Hassi Messaoud, Ouargla, and Rouissat could produce the highest waste potentials with the values of 94.51, 90.588, 90.156, and 82.56 kt/year, respectively. potential of livestock in these four municipalities accounted for 43 % of the total potential value. The map presents the potential of the biomass from municipal waste according to all the municipalities of the wilaya of Ouargla, using the GIS program. The total waste of the province of Ouargla is estimated at 206.87 kt / year, with organic matter at 67.7%, estimated at 140.05 kt / year of organic waste in the year (2019).

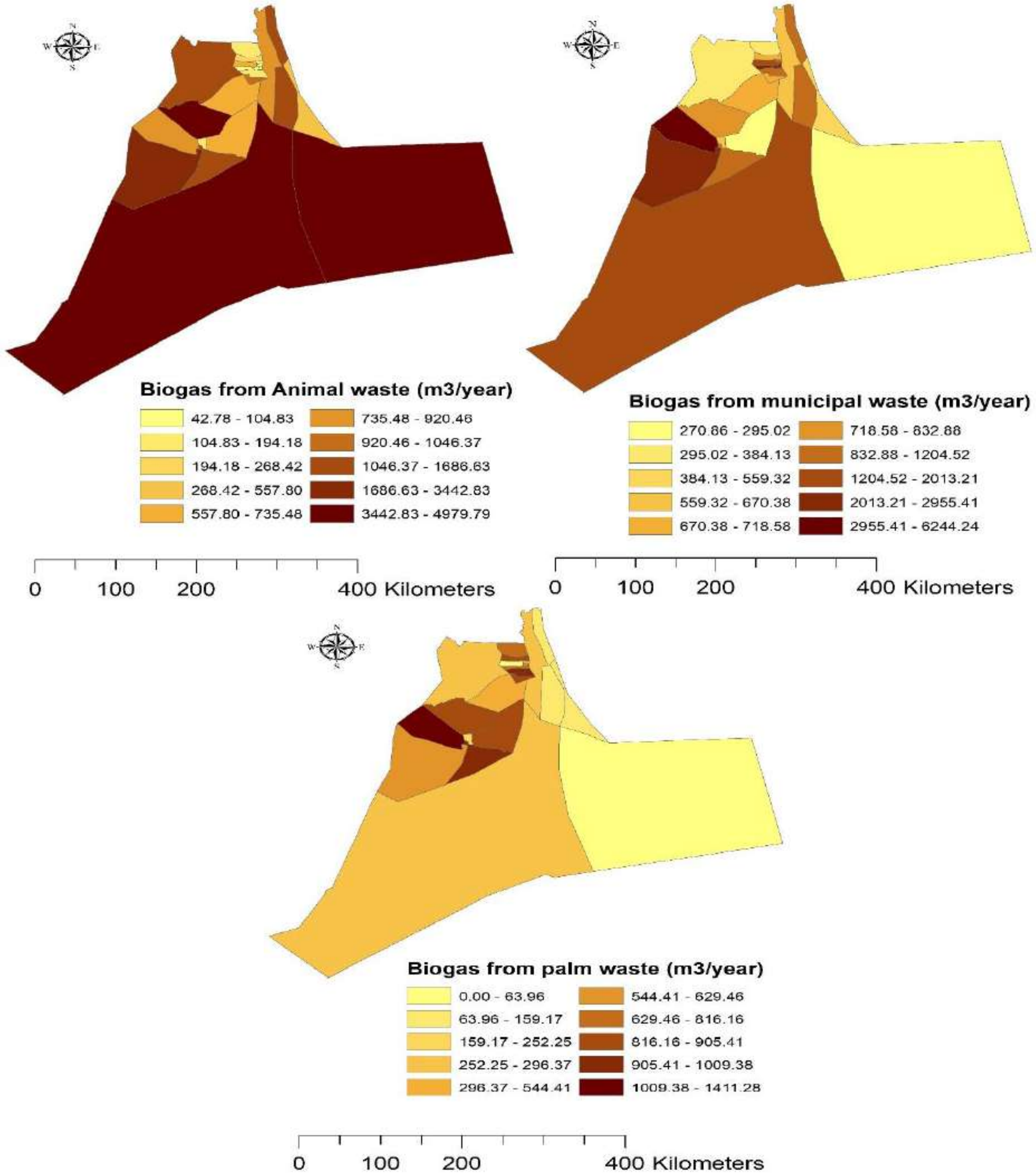


Figure 2.9: Geographical distribution of the biogas potential from biomass waste in Ouargla (2019)

Estimations of palm waste biogas potential and analysis results for its spatial distribution are shown in figure 2.9 for 21 municipalities in Ouargla province in 2019. The four municipalities had the highest potentials palm waste biogas with value of 1,411.29 m^3 (Ouargla), 1,009.39 m^3 (Ain Beida), 991.33 m^3 (Temacine), and 905.41 m^3 (Meggarine). The enormous date palm yields in these four municipalities led to an abundance of palm waste, which in turn yielded very high biogas potentials conducive to the development of biogas projects that use this waste.

2.5. Conclusion

For a long time, biomass was the most exploited source of energy by humans. After the industrial revolution came in the nineteenth century. Wood energy has been replaced by fossil fuels: coal, especially hydrocarbons. However, biomass is recovering today. Since the meeting of the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto, bioenergy has been seen as a distinct way to combat the impact of global warming. In addition to the positive impact on the environment, the increased use of bioenergy makes it possible to reduce dependence on fossil fuels. This chapter presents a study of the potential of biomass and biogas production in the wilaya of Ouargla where the potential of biomass (municipal, animal and palm wastes) is estimated at (764.801 kt/year) and a total amount of biogas was obtained that is approximately (69085.895 m^3/year).

CHAPTER III

Multi-criteria Decision Aid methods and GIS techniques

3.1. Introduction

Having seen in the previous chapter the availability of biomass potential in the province of Ouargla and how to convert it into biogas, we will see in this chapter the appropriate areas for creating a biofuel station by integrating MCDM technology with geographic information systems (GIS), based on the AHP method using the Expert Choice program, with Observance of several basic criteria.

3.2. GIS-based MCDA

3.2.1. Geographic Information Systems (GIS)

The term Geographic Information System (GIS) is hard to define. It represents the integration of many subject areas. Accordingly, there is no absolutely agreed upon definition of a GIS. A broadly accepted definition of GIS is the one provided by the National Centre of Geographic Information and Analysis: a GIS is a system of hardware, software and procedures to facilitate the management, manipulation, analysis, modelling, representation and display of georeferenced data to solve complex problems regarding planning and management of resources. [39]

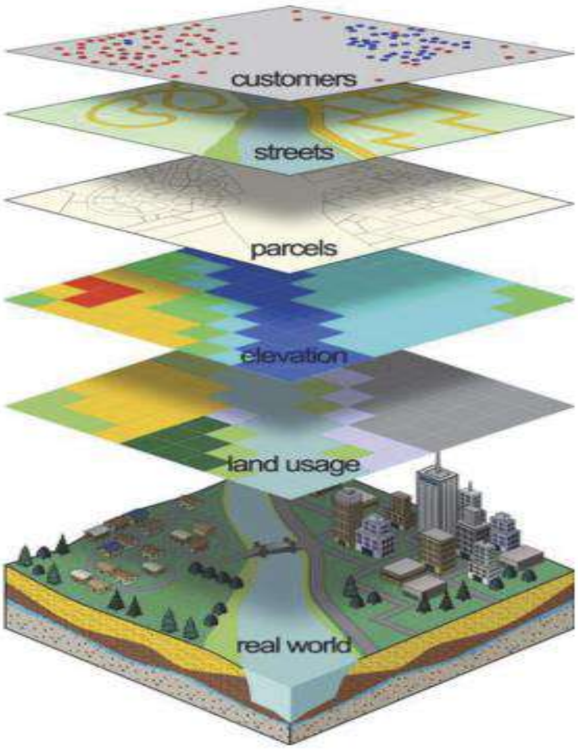


Figure 3.1: GIS layers model.

A more comprehensive and easy way to define GIS is the one that looks at the disposition, in layers (Figure 3.1), of its data sets. "Group of maps of the same portion of the territory, where a given location has the same coordinates in all the maps included in the system". This way, it is possible to analyses its thematic and spatial characteristics to obtain a better knowledge of this zone.

3.2.2. GIS uses

Geographic information systems have emerged in the last decade as an essential tool for urban and resource planning and management. Their ability to store, retrieve, analyze, model, and map large areas with massive amounts of spatial data has resulted in an unprecedented proliferation of applications. Geographic information systems are now used for land use planning, utilities management, ecosystems modelling, landscape assessment and planning, transportation and infrastructure planning, market analysis, visual impact analysis, facilities management, tax assessment, real estate analysis and many other applications.

Functions of GIS include data entry, data display, data management, information retrieval, analysis, and more [40] [41]:

- **Mapping locations:** GIS can be used to map locations. GIS allows the creation of maps through automated mapping, data capture, and surveying analysis tools.

- **Mapping quantities:** People map quantities, like where the most and least are, to find places that meet their criteria and take action, or to see the relationships between places. This gives an additional level of information beyond simply mapping the locations of features.

- **Mapping densities:** While you can see concentrations by simply mapping the locations of features, in areas with many features it may be difficult to see which areas have a higher concentration than others. A density map lets you measure the number of features using a uniform areal unit, such as acres or square miles, so you can clearly see the distribution.

- **Finding distances:** GIS can be used to find out what's occurring within a set distance of a feature.

- **Mapping and monitoring change:** GIS can be used to map the change in an area to anticipate future conditions, decide on a course of action, or to evaluate the results of an action or policy.

3.2.3. Multi-criteria decision Aid (MCDA)

Making decisions is a practice that is common to everyone and unavoidable in our daily life. Most of these decisions are simple to make and go without notice. However, certain scenarios occur where decisions involve cases with requirements that are many and conflicting in nature. A special type of these scenarios is when the requirements are qualitative, i.e., not measurable on a numerical scale. This may lead to taking wrong decisions due to subjective judgments that are inconsistent. These types of scenarios, however, can be structured in a way which ensures that judgments are consistent, and improves the chances of taking the right decision. Such structuring can be made according to special techniques such as the AHP, which was first proposed by Saaty [42].

The AHP is a very popular method, as evident in the literature through a wide spectrum of decision-making problems and applications. For example, some researchers used AHP for solar hydrogen production sites selection in Algeria [43], or for Proposing New Recreational Park Sites in University Technology Malaysia [44], or for optimizing the Location of Biomass Energy Facilities [45]. The use of AHP can be found in decision-making problems related to project management, medical and health care, safety and many other areas. Due to the importance of the subject, Ho [46] provided a detailed literature review on AHP and its applications.

Not to the surprise, choosing the right software, itself, had its share of interest by researchers. Therefore, two tables were prepared in Annex (**Table A3.1** and **Table A3.2**). Table A3.1 illustrates the most important software used in decision-making processes, and Table A3.2 illustrates the features and characteristics of most of the methods used in decision-making. In our study we chose the (Expert Choice) program, because it is easy to use and supports AHP technology.

3.3. Materials and methods

3.2.1. Software used

ArcGIS is a GIS software for operating with maps and geographic information. The version of ArcGIS used was ArcGIS 10.8. It has all the capability that would be required in the analysis process of this research work. Expert Choice was also used in this study because it is one of the most important decision-making software, and it supports AHP technology, in addition to being simple and easy to use.

3.2.2. Methods

This study is devoted to selecting the best sites for establishing biofuel stations, based on biomass (organic waste) as a basic material for the production of biogas. During our research, we used geographic information systems (GIS) in order to obtain potential cards by performing a statistical study of biomass (animal and municipal organic waste and palm remnants) and then processed by MCDA, where data is entered and AHP technology is implemented with the help of the Expert Choice program, which uses as a decision-making program, taking into account several basic criteria and limitations in order to define alternatives.

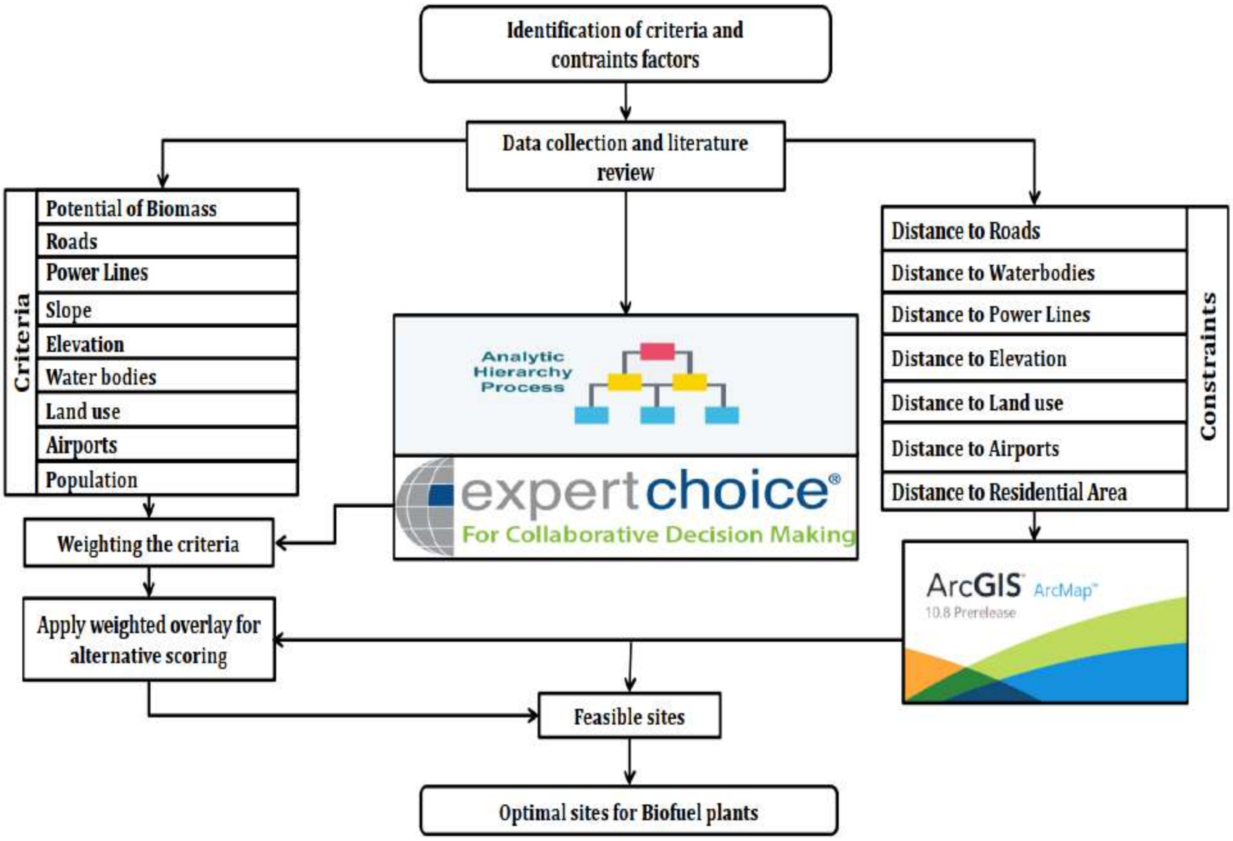


Figure 3.2: Flowchart of the methodology.

Finally, the results of AHP and sensitivity analysis are presented. As shown in (Figure 3.2), the following steps were used in this study as stated by [47]:

1) Identification of the study area (Ouargla),

2) Setting criteria for MCDA (AHP) operation,

3) Obtaining existing data and maps,

4) Evaluation of criteria by AHP method,

5) Determination of sub-criteria depending on the main criteria,

6) Transfer of criteria to GIS environment in a common coordinate system,

7) Reclassification of layers by sub-criteria values,

8) Reclassify layers with distance values with Euclidean distance,

9) Weighing the layers and analyzing them in the GIS environment to determine the most suitable areas.

10) Creating a dynamic model with a modular structure within the GIS software for location selection.

3.2.3. Analytical Hierarch Process (AHP)

Pairwise comparison matrices were used with AHP software in order to value the selected factors and their classes. To each criterion is assigned an established value ij from each class in order to determine numerical values calculated from the pairwise comparison matrices. The aim was to determine the final values of each factor (Value ij) in each of the hierarchies and to obtain the matrix consistency ratios (CR), which indicate the arithmetic consistency of the values assigned in each matrix. Through a pairwise comparison matrix, the AHP calculates the weight value for each criterion (W_i) by taking the eigenvector corresponding to the largest eigenvalue of the matrix, and then normalizing the sum of the components to a unity. It is necessary to verify the consistency of the matrix after obtaining the weight values. The consistency is judged on the basis of a consistency ratio CR. The determination of CR value is critical. In our case study, we adopted a standard CR threshold value of 0.10 which has been widely used as a measure of the consistency in a set of judgments of AHP applications in literature. If CR < 0.10, it deems that the pairwise comparison matrix has acceptable consistency and the weight values calculated are valid and can be utilized [48].

The pair-wise comparison of criteria/sub-criteria I with criteria/sub-criteria j yields a square matrix Ann where a ij denotes the comparative importance of criteria/ sub-criteria i with respect to criteria/sub-criteria j. In the matrix, aij = 1 when i = j and aij = 1/aij. [43]

Main Criteria / Sub-Criteria

$$\mathbf{A_{nxn}} = \begin{matrix} A1 \\ A2 \\ . \\ . \\ An \end{matrix} \begin{bmatrix} C11 & C12 & ... & ..... & C1n \\ C21 & C22 & .... & ..... & C2n \\ ... & ..... & . & . & . \\ . & . & . & . & . \\ Cn1 & Cn2 & . & . & Cnn \end{bmatrix} \qquad (3.1)$$

The consistency ratio (CR) was calculated as follows:

$$CR = CI / RI \qquad (3.2)$$

Here the Consistency Index (CI) was determined. The calculation of CI is based on the observation that is always greater or equal to the number of criteria, this measure was standardized as follows:

$$CI = (\lambda_{max} - n) / (n-1) \qquad (3.3)$$

where CI is the consistency index, λ_{max} is the maximum eigenvalue, n is the matrix size (n x n)

In this study, AHP method was implemented with the help of Expert Choice because it is one of the most important decision-making software, in addition to being simple and easy to use.

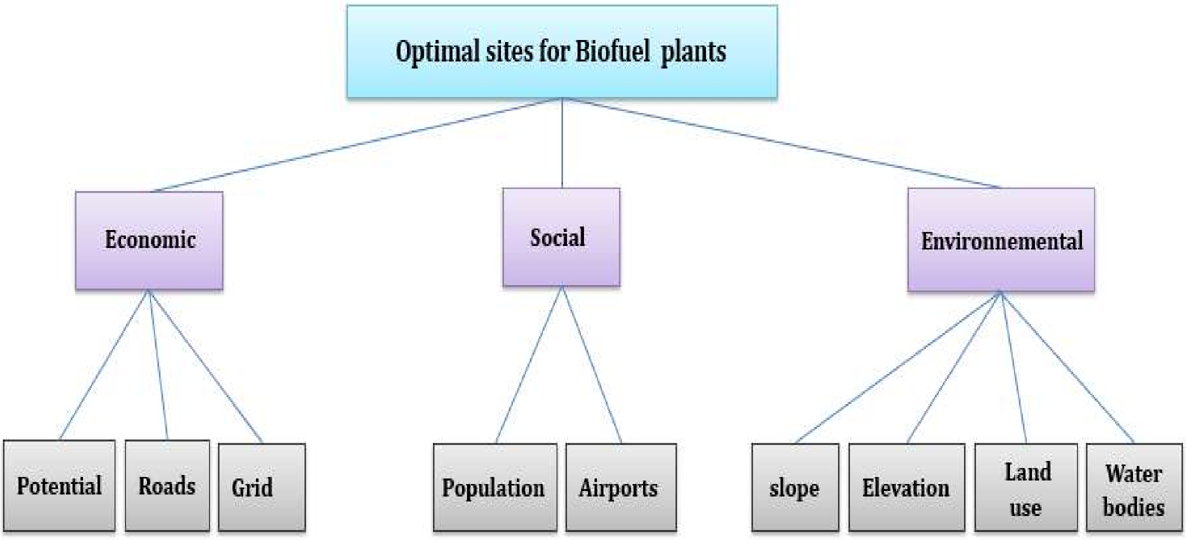


Figure 3.3: Implementation of AHP method.

Figure 3.3 shows the working principle of AHP method, and the implementation of the multi-criteria decision-making process. Where (Optimal sites for biofuel plants) is the objective of this study, (Economic, Environmental, Social) represents the main criteria, and (Potential of Biomass, Roads, Grid, slope, Elevation, water bodies, Land use, Airports, Population) is the sub-criteria.

3.4. Results and discussion

3.4.1. Criteria and constrains used in the study

The decision-making approach prepared for the selection of the most suitable sites for the establishment of biofuel stations is shown in (Table 3.1 and Table 3.2). Where a set of criteria and restrictions were prepared as input layers for the digital map for the most appropriate choice.

Table 3.1: Criteria for suitable lands.

Main Criteria	Sub-Criteria	References
Economic	**Biomass Potential**	[50] [49] [45]
	Roads	[53] [52] [51] [43] [47]
	Power Lines	[51] [56] [55] [54]
Environmental	**Slope**	[45] [43] [58] [57]
	Elevation	[45] [43]
	Water bodies	[52] [51] [56]
	Land use	[43] [58] [57]
Social	**Airports**	[51]
	Population	[52] [45] [51]

The criteria that were taken into consideration in this study are economic, environmental and social. Each of the aforementioned criteria contains a number of criteria and sub-restrictions: the potential of biomass for the production of biofuels, proximity to roads and power lines for economic standards, heights, slope and water bodies and land use for environmental standards, and the distance from residential areas and airports for social criteria.

Table 3.2: Description of the constraints defined in the suitability analysis

Constraints	Description	References
Distance to Roads	To exclude areas which contain or are less than 70 m away from motorways, regional roads, national roads and rail network.	[52] [59] [60]
Distance to Waterbodies	Area in distance from waterway < 500 m	[47] [51] [52] [60]
Distance to Power Lines	Area in distance from Power Lines < 200 m	[56] [59] [60]
Distance to Airports	Area in distance from Airports < 200 m	[59] [61]
Distance to Elevation	Area in distance from elevation < 2000 m	[43] [56]
Distance to Land use	Area in distance < 500 m.	[58] [60]
Distance to Residential Area	Area in distance from residential area < 200 m	[47] [59] [62]

The starting point for the analysis was to define the characteristics that make land suitable for developing a biofuel plant in Ouargla. For this analysis, the following factors were considered [63]:

1- Find areas with close proximity to maize farms and/or fields for easy access and availability of maize.

2- Close access to major roads and highways to promote ease of transportation to and from biofuel plant sites.

3- Availability and proximity to water resources (i.e., rivers and lakes).

4- Close proximity to developed areas where a range of services would be available to support consumers.

5- Availability of sufficient electric power supply to operate the biofuel processing plant.

6- Proximity to airports to serve as an additional means of transportation and access to other developed areas.

The criteria and limitations used in this study are not fixed factors as they can differ from one region to another and these criteria can be changed accordingly in the analysis process. The criteria factors were determined by going back to international experiences such as the Portuguese experience, which identified three basic criteria: environmental, economic, social and safety. [59]

A) Potential of biomass

Biomass is considered a major criterion in determining the suitable area for establishing a biofuel production project, because it is the only source of energy in such projects, and bio-energy is extracted from renewable sources such as agricultural waste, animal dung and municipal waste, and it is the most common source of biomass in the province of Ouargla. [64]

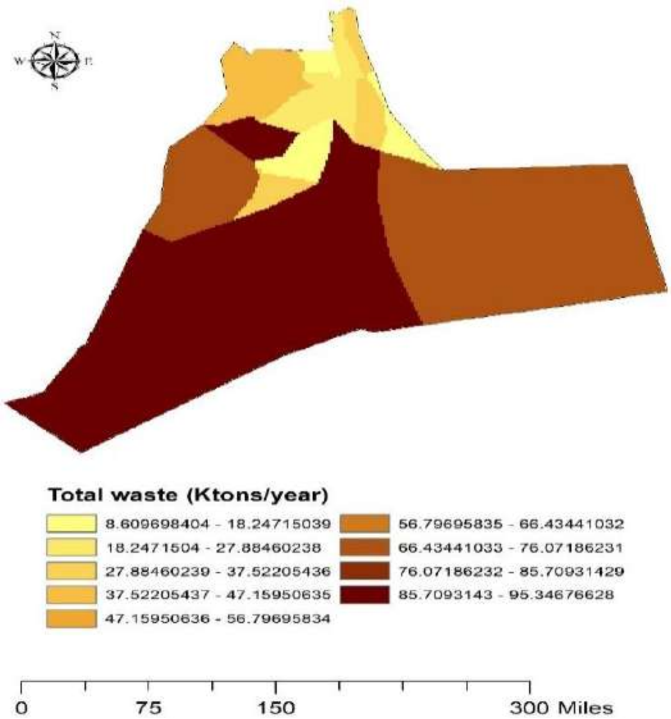
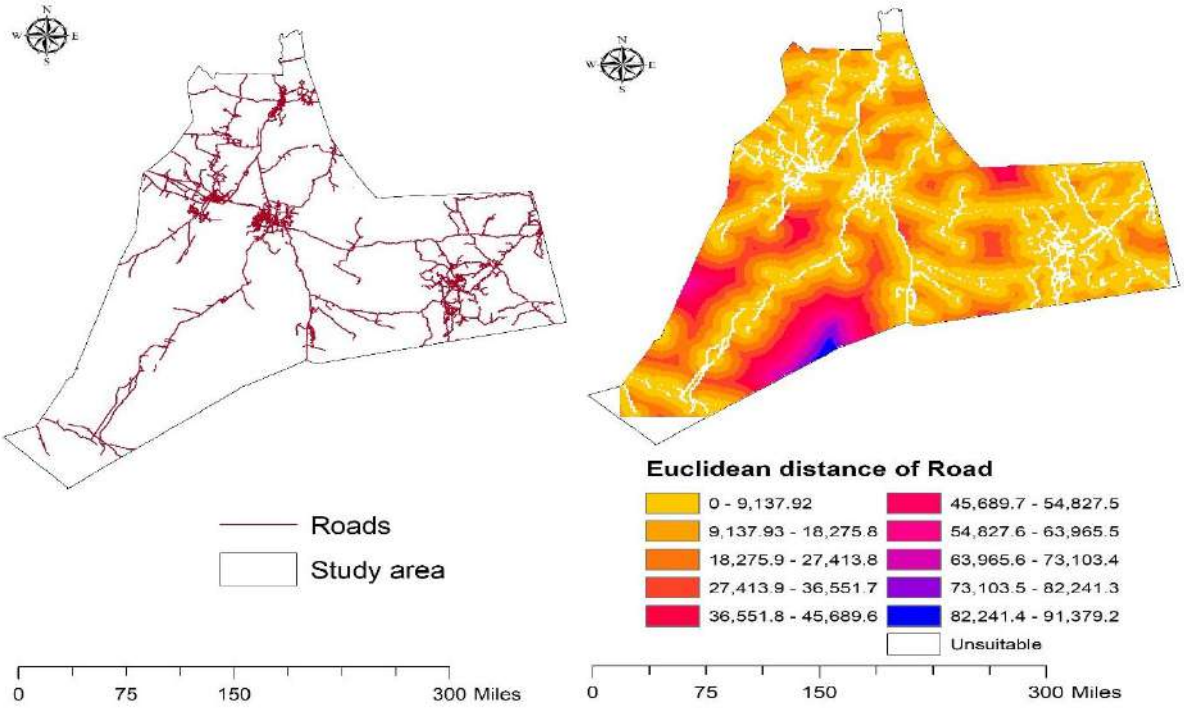


Figure 3.4: Potential of waste (ton).

The results showed that 831.621 kt of waste associated with municipal, animal and palm waste were annually produced in the province of Ouargla. It was determined that this quantity could generate 69085.895 m_3 of biogas per year.

B) Roads

The distance to the road is an important criterion in determining the appropriate location for establishing biofuel stations. Therefore, a distance of more than 70 m from main roads and highways should be avoided.On the other hand, the landfill site should not be placed too far away from existing road networks to avoid the expensive cost of constructing connecting roads. [65]



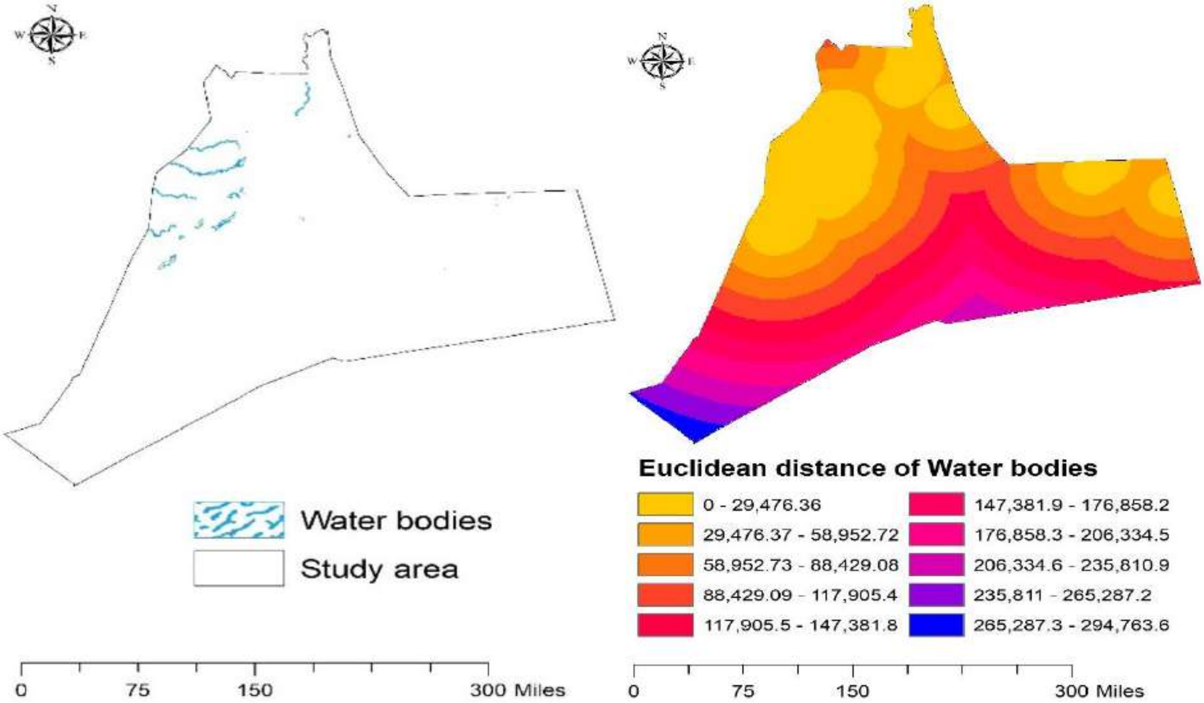
(a) **(b)**

Figure 3.5: (a) Roads in Ouargla. (b) Distance to roads in Ouargla.

In this study, the only national roads are considered. biofuels production installation system should be located as closely as possible to the existing roads network and a 70 m should be a buffer away from roads acceptable in term of infrastructure [59] [43]. The closer the distance to roads the higher the suitability score.

C) water bodies

The required buffer zone for waterbodies was determined to be 500 m. The layer of wetlands was classified as suitable or unsuitable. [43]

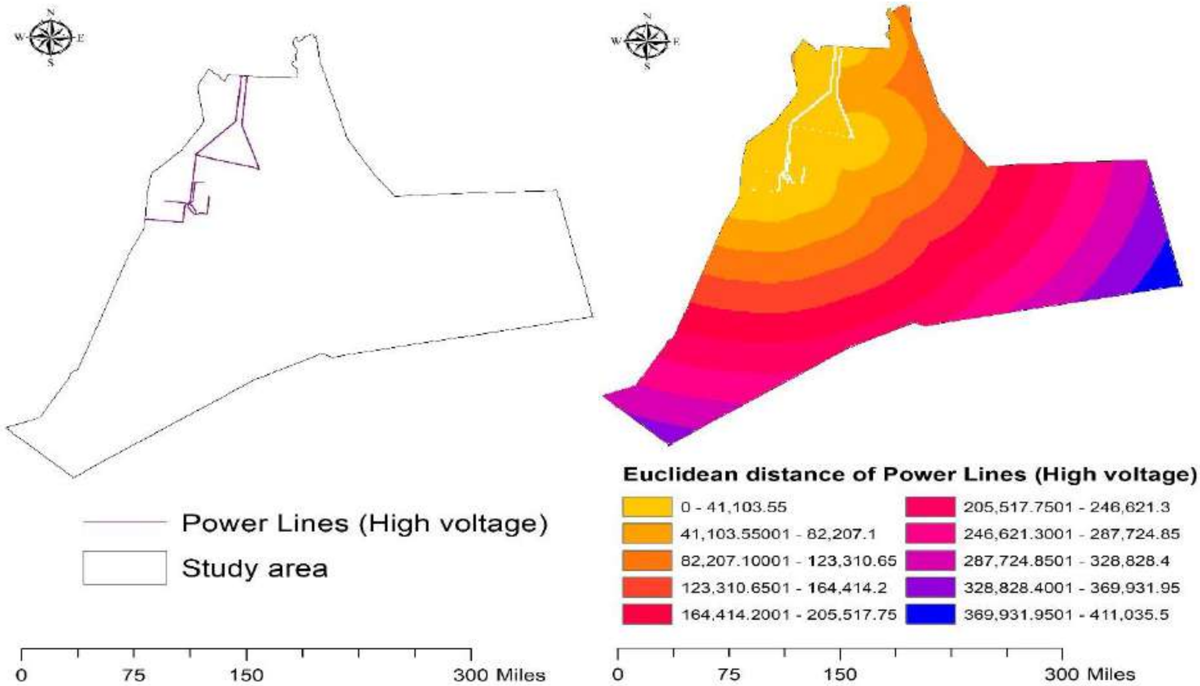


(a) (b)

Figure 3.6: (a) water bodies in Ouargla. (b) Euclidean distance of water bodies in Ouargla.

D) Power Lines (High voltage)

The necessary buffer zone distance should be considered so that it does not disturb the infrastructure and all high voltage power lines [65]. It should have a buffer of 200 m on both sides of the site. The buffer zones were created in the GIS environment.



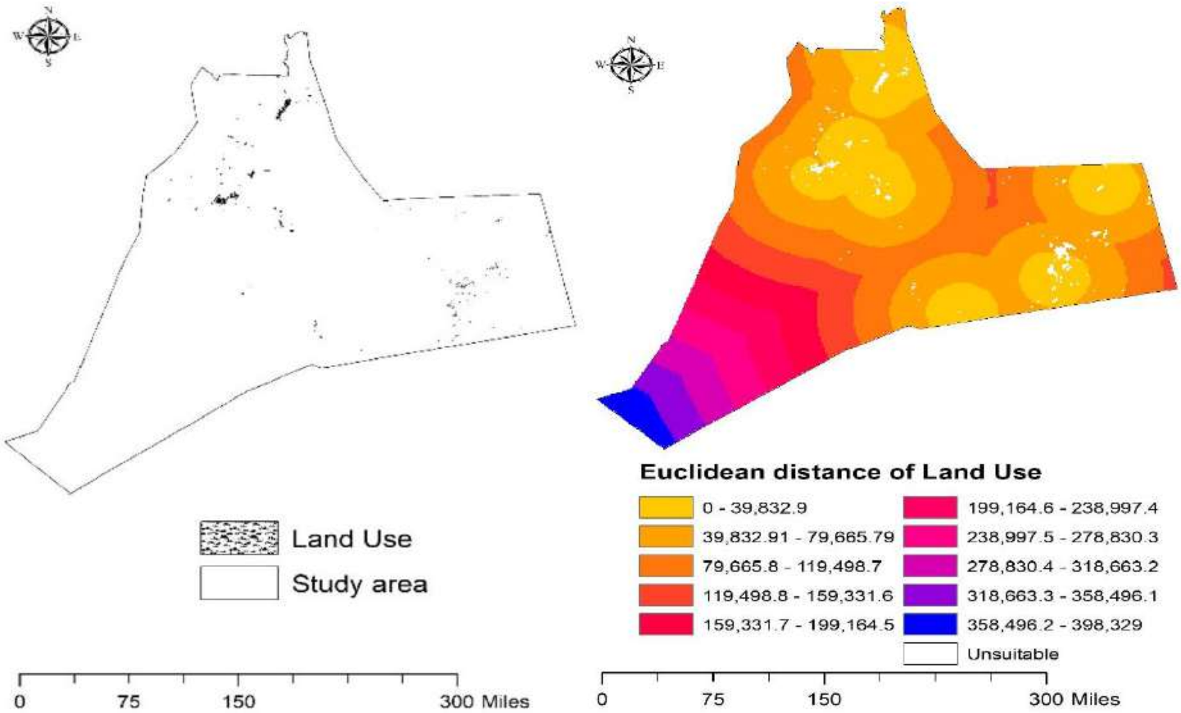
(a) (b)

Figure 3.7: (a) power lines in Ouargla. (b) Euclidean distance of power lines in Ouargla.

The proximity to power line connection is necessary to deliver power to electrical equipment in a biofuel production system. A buffer zone is needed at 200 meters from the power lines in terms of infrastructure. The closer the distance to grids the higher the suitability score.

E) Land use

In the study area, there are various land uses (see Fig. 3.8), for which types of land uses have been grouped. A distance of at least 500 meters from land use should be avoided.



(a) **(b)**

Figure 3.8: (a) Land use in Ouargla. (b) Distance to Land use in Ouargla.

F) Airports

There are different values related to safe distances from airports, such as 200 m. As Silva mentioned [59], the safe distance from the airport was defined as 200 meters.

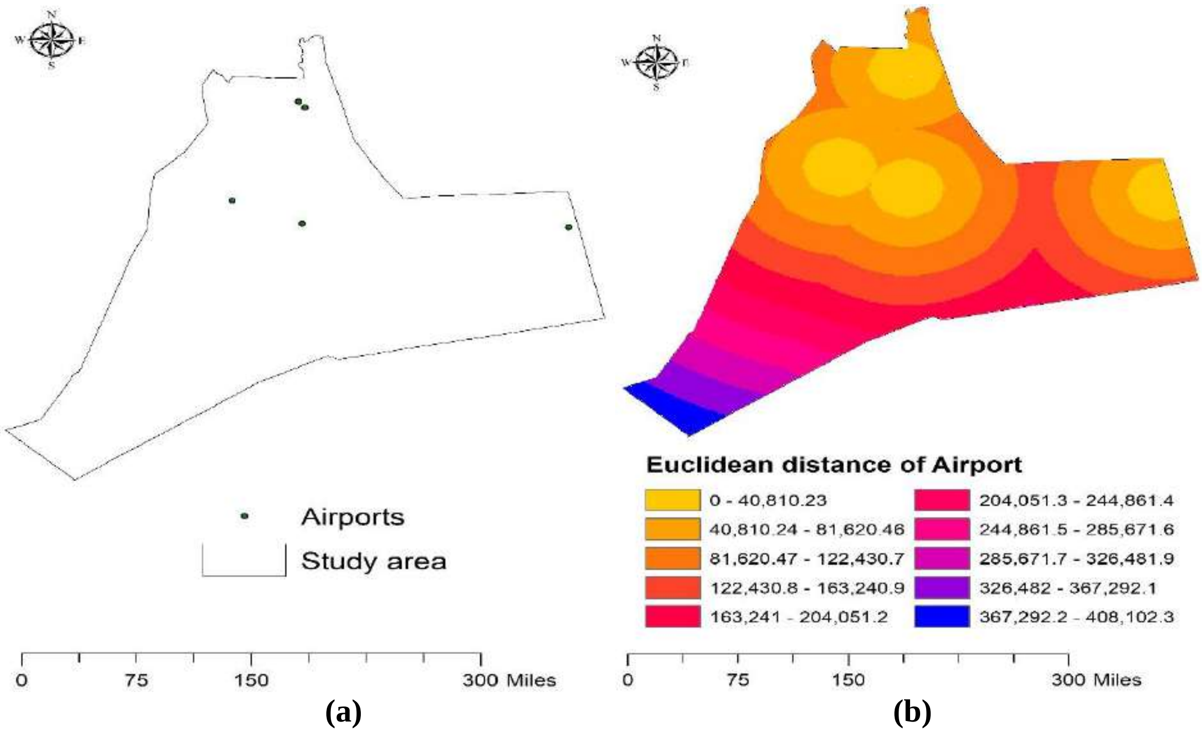


Figure 3.9: (a) Airports in Ouargla. (b) Distance to Airports in Ouargla.

G) Elevation

Flat ground is essential and is more suitable for biofuel plants. The height standard was evaluated using the DEM digital elevation model.

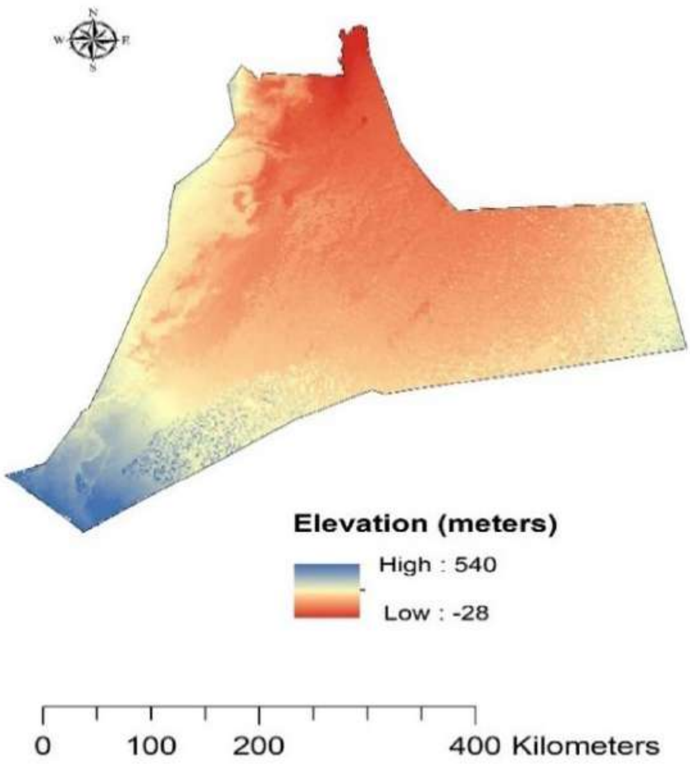


Figure 3.10: Elevation in Ouargla.

H) Population

Population and residential areas are an important criterion for locating biofuel stations, as areas less than 200 meters apart are not suitable for residence, and areas at distances of 200 meters or more are very suitable.

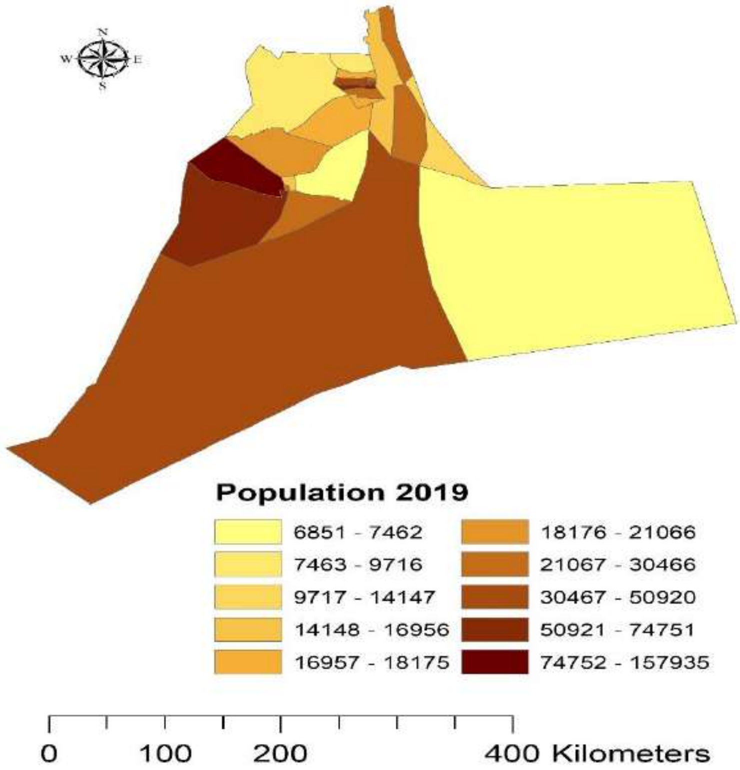


Figure 3.11: Population in Ouargla 2019.

According to the national office of statistics population census of 2019, the population of the province of Ouargla is 708463, with a population density of 4.34 persons living within every square kilometer.

I) Slope

The slope of the ground surface is a critical factor in construction costs, because steep slopes can reduce truck access and increase construction costs. As such, slopes of (0 ° - 0.5 °) are suitable areas for plant construction while slopes of other proportions are not suitable. [43]

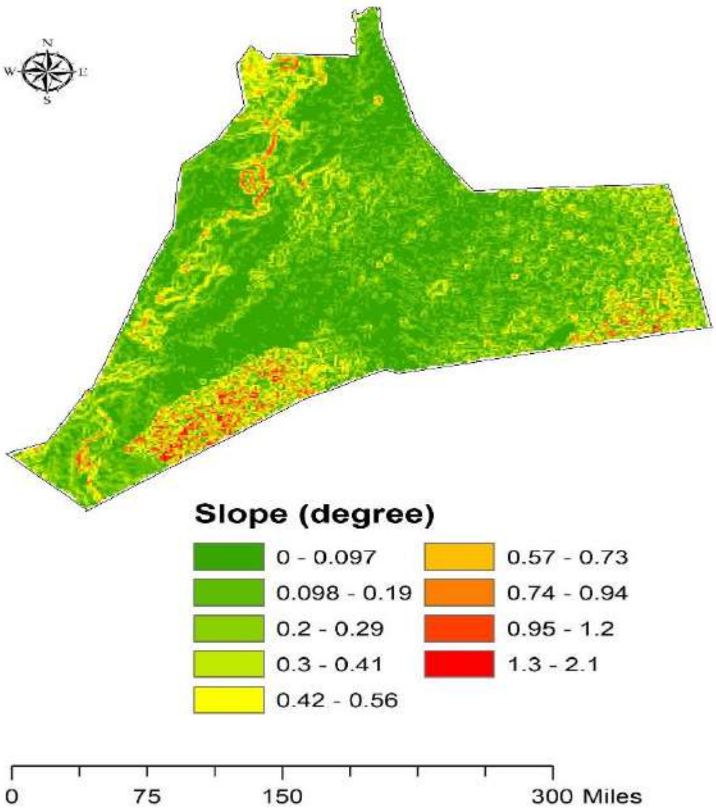


Figure 3.12: slope in Ouargla (degree).

3.4.2. Assigning Weights

Criterion weights are usually determined in the consultation process with choice or decision makers (DM), which results in ratio value assigned to every criterion map. They reflect the relative preference of one criterion more than another [44]:

$0 \leq Wi \leq 1$

Table 3.3: The significant weights of the main criteria and sub-criteria used in selection suitable sites for biofuel stations

Main Criteria	Weight	CR	Sub-Criteria	Weight	CR	Wi
Economic	0.544	0.02	**Biomass Potential**	0.662	0.03	0.36
			Roads	0.145		0.079
			Electricity grid	0.097		0.053
Environmental	0.25		**slope**	0.272	0.03	0.068
			Elevation	0.2		0.05
			water bodies	0.24		0.06
			Land use	0.66		0.165
Social	0.206		**Airports**	0.131	0	0.027
			Population	0.66		0.136

3.4.3. Selected sites

The most suitable areas for biofuel production are based on biomass as shown in (Figure 3.13). We note that South Ouargla has very suitable locations (from blue to yellow on the map) and some sites are scattered along the map according to the selected criteria.

The most suitable areas (blue on the map) are near roads, have close proximity to power lines, and have a higher potential for biofuel production, whereas the land has very few suitable LSI units (red on the map) due to depressions. The northwestern area of the study area shows low to moderate LSI (yellow on map), as it has a high biofuel production potential.

LSI: land suitability index

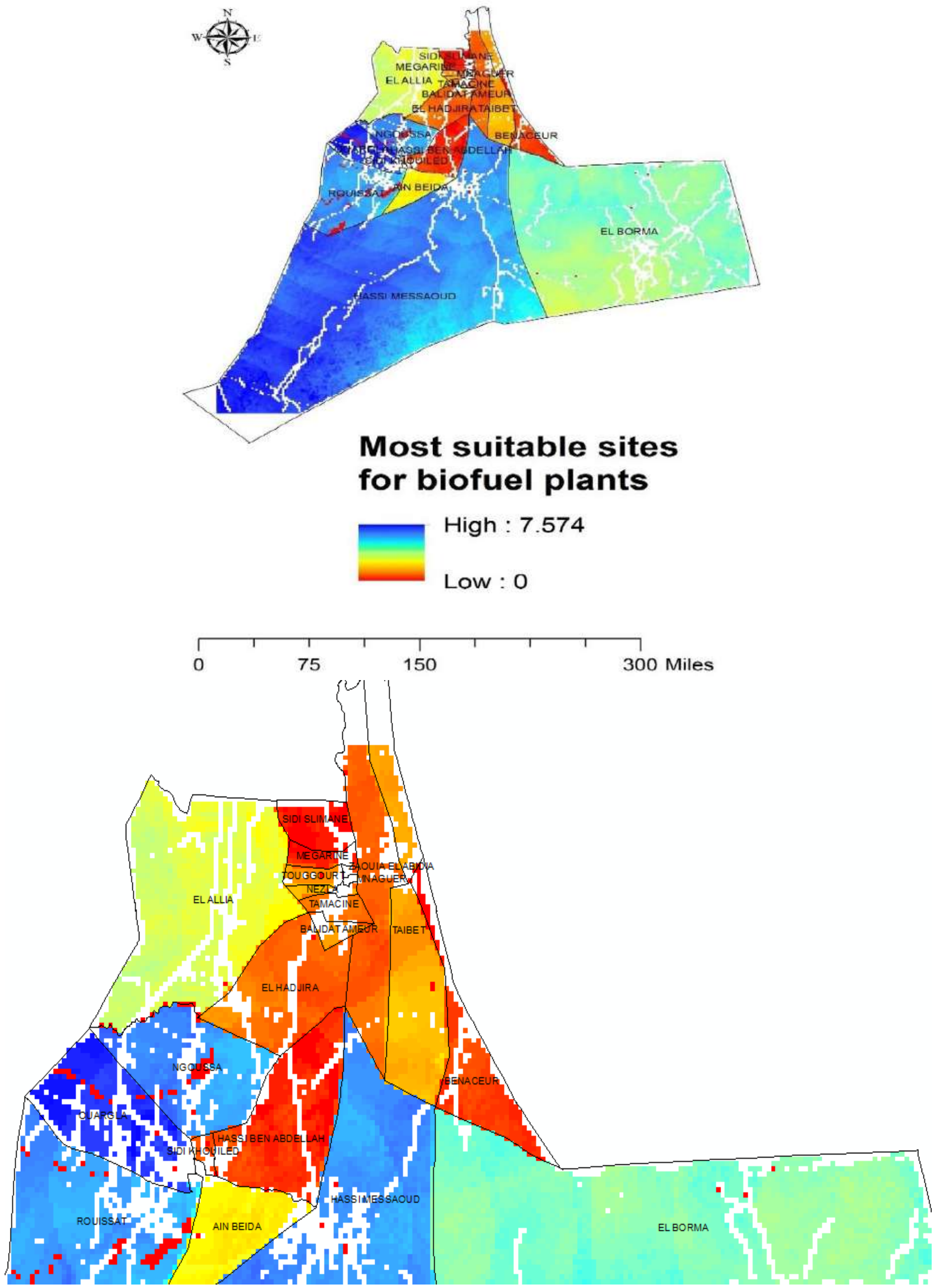


Figure 3.13: The most suitable sites for biofuel production from biomass

As a result, suitable and unsuitable areas were identified for receiving the biofuel production plant project, where the total suitable area is estimated as 79.83% (130,303.527 Km^2), and the inappropriate area is 20.17% (32,929.4734 Km^2).

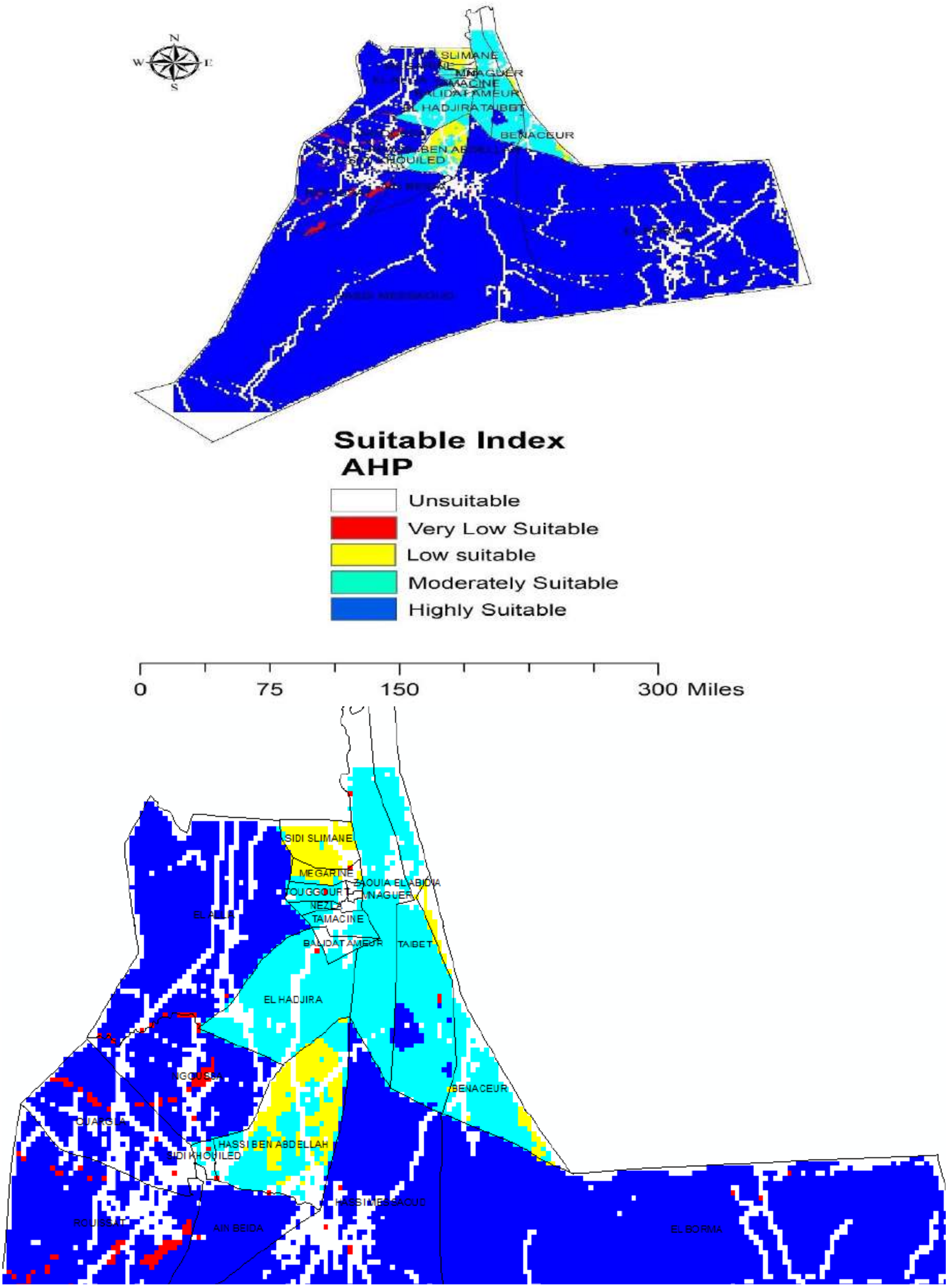


Figure 3.14: Site suitability map for a biomass-based biofuel production installation system

Table 3.4: land suitability index (LSI)

<table>
<tr><th colspan="2">Suitability</th><th>Scale values</th><th colspan="2">Percentage (%)</th></tr>
<tr><td colspan="2">Unsuitable</td><td>0</td><td colspan="2">20.17</td></tr>
<tr><td rowspan="4">Suitable sites</td><td>Very Low Suitable</td><td>0 - 2</td><td>0.59</td><td rowspan="4">79.826</td></tr>
<tr><td>Low Suitable</td><td>2.01 - 3</td><td>1.53</td></tr>
<tr><td>Moderately Suitable</td><td>3.01 - 4</td><td>7.34</td></tr>
<tr><td>Highly Suitable</td><td>4.01 – 7.574</td><td>90.55</td></tr>
</table>

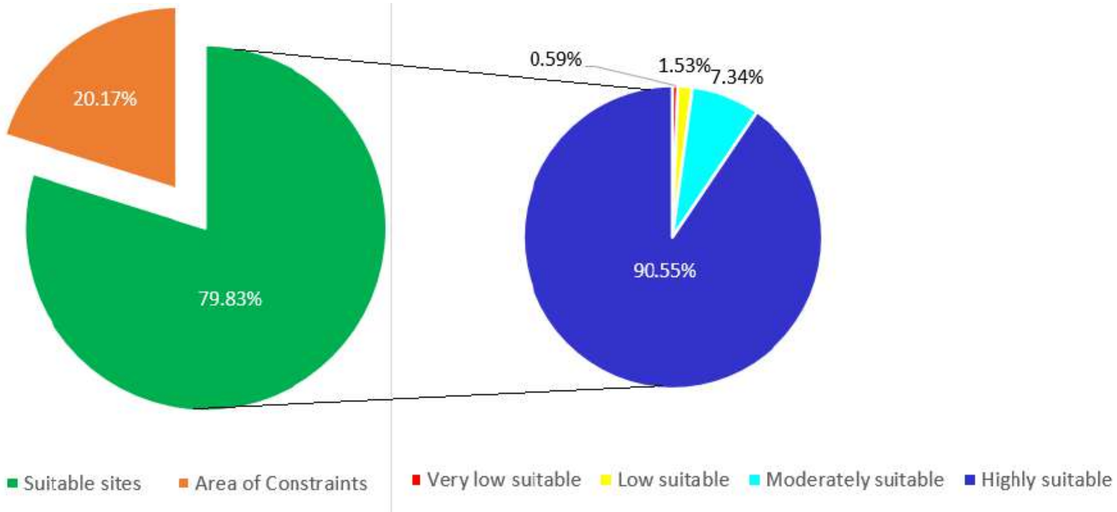


Figure 3.15: Land suitability distribution.

The final indicator model for areas that can receive a biofuel plant project was grouped into four categories as “very low suitability”, “low suitability”, “moderate suitability” and “high suitability” with a manual interval classification method. The results indicate that 0.59% (765.234 km^2) has very low suitability, 1.53% (1,992.591 km^2) has low suitability, 7.34% (8,704.2756 km^2) has moderate suitability and 90.55% (117,985.24 km^2) has high suitability for biomass powered biofuel production installation system.

3.4.4. Sensitivity analysis

In a multi-criteria decision making a “what if” [43], sensitivity analysis is recommended as a means of checking the stability of results against the subjectivity of expert judgments. In doing so, a different scenario of criteria weight was considered and its overall impact on the land suitability index was assessed. In this way, the scenario of equal weights was examined in this study as shown in **(Figure 3.16**).

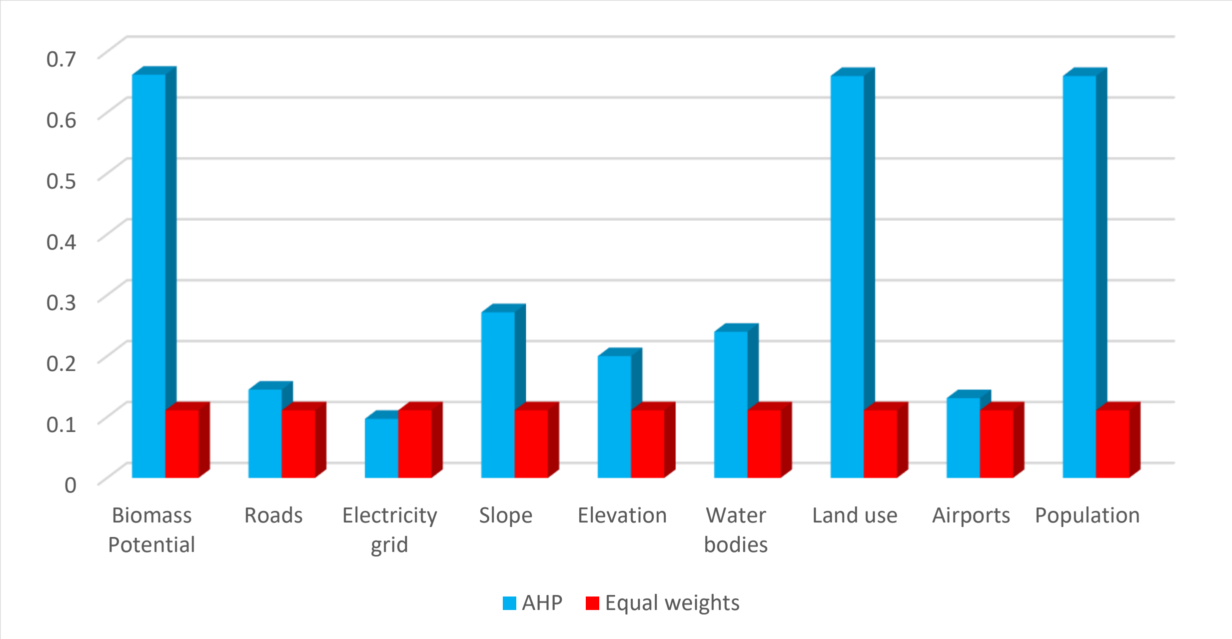


Figure 3.16: Weights of decision criteria considering different scenarios.

In the second scenario all criteria have the same weights, the weight is (0.111) for each criteria as shown in **(Table 3.5)**.

Table 3.5: Weights of the main criteria and sub-criteria used in the Equal Weights scenario

Main Criteria	Weight	CR	Sub-Criteria	Weight	CR	Wi
Economic	0.333	00	**Biomass Potential**	0.111	00	0.37
			Roads	0.111		0.37
			Electricity grid	0.111		0.37
Environmental	0.333		**slope**	0.111	00	0.37
			Elevation	0.111		0.37
			water bodies	0.111		0.37
			Land use	0.111		0.37
Social	0.333		**Airports**	0.111	00	0.37
			Population	0.111		0.37

The results obtained indicate a comparative distribution of fit across the study area **(see Figure 3.17)**, where most areas are characterized by a good fit (blue color in the map) with a value of 99.40% of the permitted area. However, there are significant shifts across the different value scores and relevance categories. Compared with the AHP methodology, the very low suitable areas (red color in the map) decreased from 0.59% to 0.59% and the low suitable areas (yellow color in the map) from 1.53% to 0% of the allowable area, and the high suitable area (blue color in the map) showed map) an increase from 90.55% to 99.40% of the permitted area **(see Table 3.6)**.

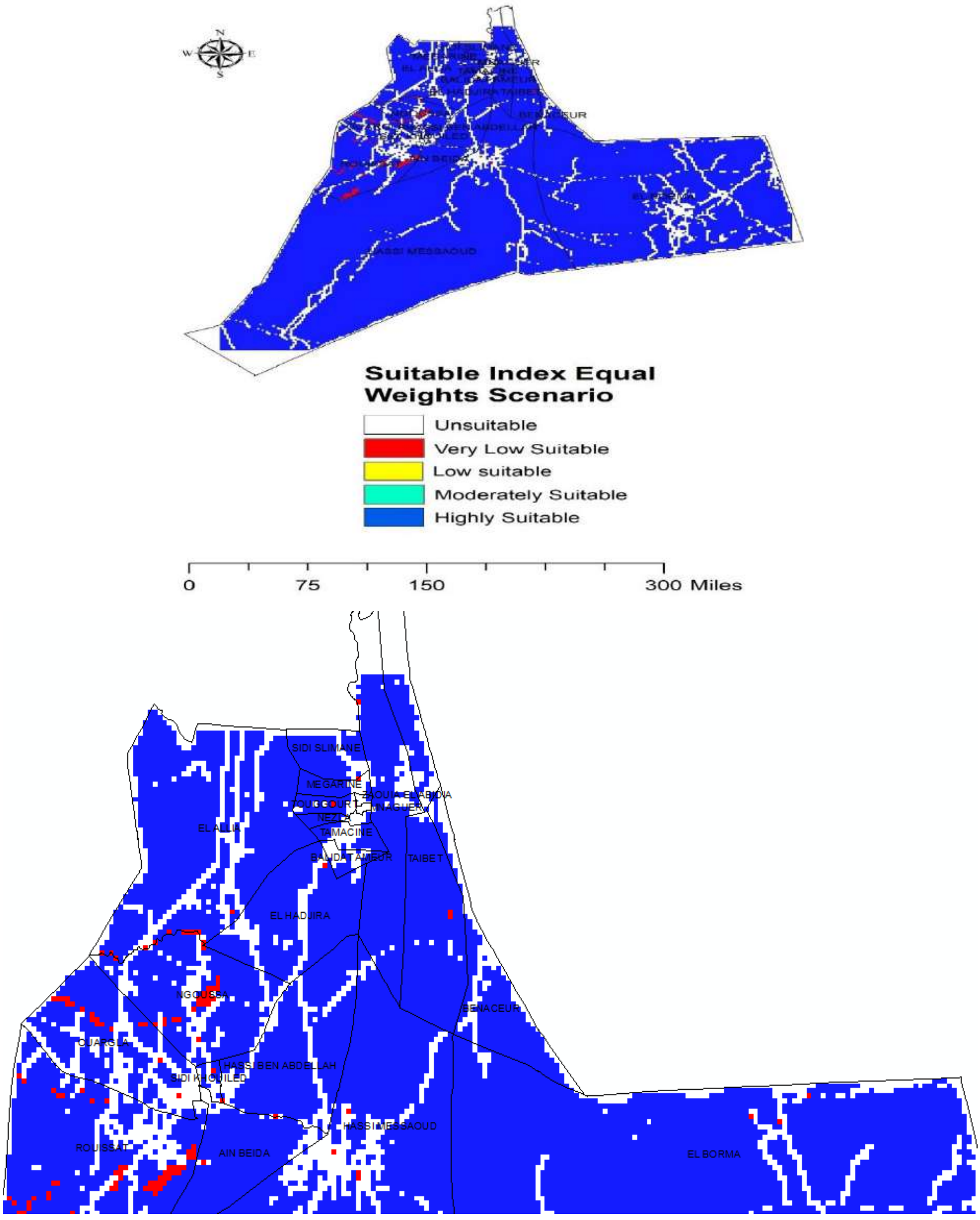


Figure 3.17: The most suitable sites for biofuel production from biomass (equal weights criteria)

Table 3.6: Land suitability distribution considering different scenarios with respect to study area.

Scenario	Main Criteria Weights	Suitable sites (%)				Unsuitable (%)
		High Suitable	Moderate Suitable	Low Suitable	Very Low Suitable	
AHP	Eco = 0.544 Env = 0.25 Soc = 0.662	90.55	7.34	1.53	0.59	20.17
Equal weights	Eco = 0.333 Env = 0.333 Soc = 0.333	99.40	0.01	0	0.59	20.17

3.4.5. Discussion

This study has direct and indirect benefits for the city of Ouargla. The findings will directly assist the authorities in identifying suitable sites for the stabilization system for biofuel production and to help promote the implementation of biomass energy in Ouargla. The results not only indicate where suitable sites are located, but also show that not all of Ouargla land territory is suitable to locate biofuel production installation systems based on biomass energy. The main limitation of this work is that the size and amount of biofuel production installation system were not taken into account. This can be addressed by facility location optimization models that are able to consider the size and amount of biofuel needed to be produced on each installation system. The work developed in this study allows such a location model to be much easier to solve and also it can be applied to investigate other types of similar projects in Ouargla.

3.5. Conclusion

With the aim of selecting a site for a biofuel station relying on biomass as the primary source for biogas production, an MCDA methodology combined with a geographic information system (GIS) was used and an AHP technology was implemented with the help of the Expert Choice program, which is used as a decision-making software. The potential sites for establishing a biofuel station were chosen based on three basic criteria (economic, environmental and social). Each of the mentioned criteria contains a number of sub-criteria:

the potential of biomass for the production of biofuels, proximity to roads, railways and power lines for economic criteria, and heights, slope, water bodies and land uses according to environmental standards, distance from residential areas and airports from the social criteria, appropriate areas, high and very low and inappropriate, have been identified. Whereas the appropriate red region was very low and was excluded as possible candidate locations. On the other hand, pixels with values were considered 7.574 is more appropriate and it is colored blue. The approach presented is easy to understand and can clarify the best or least suitable areas for selecting a biofuel station location. The criteria used in this study are not fixed factors as they can differ from one region to another and these criteria can be changed accordingly in the analysis process.

General Conclusion

General Conclusion

The siting of biofuel plants is a complex process due to the various security, economic, environmental, technical and social requirements that must be taken into account. It is not always possible to determine which sites have the greatest potential or demand for biofuel production, and many other criteria play important roles in selecting suitable sites. Therefore, the use of MCDA models has become essential.

This research presents an application for combining MCDA and GIS for selecting biofuel stations in Ouargla. The aim of the study was to find suitable sites to host a biofuel station from sources of organic waste (municipal, animal and palm waste), taking into account a number of different criteria. AHP technology was implemented with the help of Expert Choice, which is used as a decision-making software, to assign the relative weights of the assessment criteria, while the GIS generated and placed the spatial dimension of the constraints and evaluation criteria in order to produce the overall fitness map. Moreover, by incorporating relevant criteria into the decision-making process, it makes suitable sites for a biofuel station construction project more economically and technically feasible.

The criteria that were taken into consideration in this study are economic, environmental and social. Each of the aforementioned criteria contains a number of criteria and sub-restrictions: the potential of biomass for the production of biofuels, proximity to roads and power lines for economic standards, heights, slope and water bodies and land use for environmental standards, and the distance from residential areas and airports for social criteria. The criteria and limitations used in this study are not fixed factors as they can differ from one region to another and these criteria can be changed accordingly in the analysis process.

As a result, suitable and unsuitable areas were identified for receiving the biofuel production plant project, where the total suitable area is estimated as 79.83% (130,303.527 Km^2), and the inappropriate area is 20.17% (32,929.4734 Km^2). The final indicator model for areas that can receive a biofuel plant project was grouped into four categories as “very low suitability”, “low suitability”, “moderate suitability” and “high suitability” with a manual interval classification method. The results indicate that 0.59% (765.234 km^2) has very low suitability, 1.53% (1,992.591 km^2) has low suitability, 7.34% (8,704.2756 km^2) has moderate suitability and 90.55% (117,985.24 km^2) has high suitability for biomass powered biofuel production installation system.

In a multi-criteria decision making a “what if”, sensitivity analysis is recommended as a way to check the stability of results versus subjectivity of expert judgments. In this study, two scenarios were examined to observe the sensitivity of the criteria and their impact on the results. The process analysis shows that the appropriate locations of a biofuel plant depend on the weights of the parameters that influence the decision. The main advantage of this work is the utilization of existing resources and infrastructure to provide viable sites for the construction of a biofuel station. However, for the first time, our results describe suitable sites for the production of biofuels (biogas) from municipal and animal wastes and palm residues using MCDA methods combined with a geographic information system in Ouargla, where the MCDA methodology combined with GIS is a powerful tool for effective evaluation of the selection of production sites. Biofuels.

The presented methodology can clearly and directly explain the analysis and results in an easy-to-understand format. As a result, when the approach and results of a suitability map can be clearly understood, it can assist in obtaining full support, especially from the public. In this study, biogas potential was estimated from agricultural waste resources. In the future, the biogas potential can be estimated more accurately by combining various wastes with actual research data.

Recommendations and perspectives:

This study and this research is a first step to invest in the field of energy from biomass, and in order for the vision to be well clear and the study to be comprehensive in all respects, we recommend some important points for that.

- Determining of accurate statistics for all types of biomass in the wilaya of Ouargla particularly and Algeria in general.
- Adding an economic feasibility study for this project.
- Calculate the percentage of GHG that will be reduced due to the consumption of biofuels instead of fossil fuels.
- Calculating the amount of energy produced from biomass and giving an estimate of the extent to which, this energy covers the electricity generation and transportation

sector, for example, or other sectors, and the extent to which it is substituted for fossil fuels.

- Administrative challenges facing such projects in the wilaya of Ouargla.
- Determine points to collect biomass potentials at the municipal level instead of giving the same value to all points in the municipality, that is, if an area of the municipality contains a certain biomass potential, this area is determined by a point and not the entire municipality, in order to determine the appropriate areas for the establishment of gas stations The bio-energy is accurately compared to the distribution of potentials over the entire municipal soil, as was done in this study.

In the end, we hope that such projects related to renewable energies will be implemented in reality and exploit the available capabilities, which are considered a huge wealth and a precious treasure if they are optimally exploited.

Annex

Annex chapter II:

Table A1.1: Production of biomass and biogas from municipal waste

Municipal	Population 2019	Waste (kt/year)	Organic waste (kt/year)	Biogas (m^3)
Ouargla	157,935	46.11702	31.22122	6,244.245
Rouissat	74,751	21.82729	14.77708	2,955.415
Sidi-Khouiled	16,956	4.95115	3.35193	670.386
Ain-Beida	25,797	7.53272	5.09965	1,019.931
Hassi-B-Abdallah	6,851	2.00049	1.35433	270.867
N'Goussa	21,066	6.15127	4.16441	832.882
El-Hadjira	18,175	5.30710	3.59291	718.581
EL-Alia	9,667	2.82276	1.91101	382.202
Temacine	26,048	7.60602	5.14927	1,029.855
Blidet-Amor	17,884	5.22213	3.53538	707.076
Touggourt	50,749	14.81871	10.03227	2,006.453
Nezla	67,800	19.79760	13.40298	2,680.595
Tebesbest	41,715	12.18078	8.24639	1,649.278
Zaouia	26,799	7.82531	5.29773	1,059.547
Meggarine	17,659	5.15643	3.49090	698.180
Sidi-Slimane	9,716	2.83707	1.92070	384.140
Taibet	30,466	8.89607	6.02264	1,204.528
Bennaceur	14,147	4.13092	2.79664	559.327
M'Nagueur	15,900	4.64280	3.14318	628.635
Hassi-Messaoud	50,920	14.86864	10.06607	2,013.214
El-Borma	7,462	2.17890	1.47512	295.024
TOTAL WILAYA	708,463	206.87120	140.05180	28,010.360

Table A1.2: Production of biomass and biogas from animal manure (cow and calf)

Municipal	Cow and calf (head)	Mature (kt/year)	Biogas (m3)
Ouargla	144	01.183	88.695000
Rouissat	04	00.033	02.463750
Sidi-Khouiled	07	00.057	04.311563
Ain-Beida	07	00.057	04.311563
Hassi-B-Abdallah	45	00.370	27.717188
N'Goussa	14	00.115	08.623125
Hassi-Messaoud	140	01.150	86.231250
El-Borma	00	00.000	00.000000
El-Hadjira	00	00.000	00.000000
El-Alia	00	00.000	00.000000

Temacine	33	00.271	20.325938
Blidet-Amor	19	00.156	11.702813
Touggourt	00	00.000	00.000000
Nezla	00	00.000	00.000000
Tebesbest	01	00.008	00.615938
Zaouia	31	00.255	19.094063
Meggarine	00	00.000	00.000000
Sidi-Slimane	00	00.000	00.000000
Taibet	417	03.425	256.845938
Bennaceur	84	00.690	51.738750
M'Nagueur	53	00.435	32.644688
TOTAL	999	08.204	615.321563

Table A1.3: Production of biomass and biogas from animal manure (camels)

Municipal	Camels (head)	Mature (kt/year)	Biogas (m3)
Ouargla	734	06.028	452.098
Rouissat	5,288	43.428	3257.078
Sidi-Khouiled	232	01.905	142.898
Ain-Beida	2,651	21.771	1632.850
Hassi-B-Abdallah	988	08.114	608.546
N'Goussa	7,113	58.416	4381.163
Hassi-Messaoud	7,502	61.610	4620.763
El-Borma	7,317	60.091	4506.815
El-Hadjira	832	06.833	512.460
El-Alia	2,003	16.450	1233.723
Temacine	00	00.000	00.000
Blidet-Amor	1,534	12.598	944.848
Touggourt	1,122	09.214	691.082
Nezla	00	00.000	00.000
Tebesbest	00	00.000	00.000
Zaouia	00	00.000	00.000
Meggarine	342	02.809	210.651
Sidi-Slimane	250	02.053	153.984
Taibet	1,712	14.060	1054.485
Bennaceur	751	06.168	462.569
M'Nagueur	1,132	09.297	697.241
TOTAL	41,503	340.843	25563.254

Table A1.4: Production of biomass and biogas from animal manure (sheep)

Municipal	Sheep (head)	Mature (kt/year)	Biogas (m3)
Ouargla	18,565	10.842	140.945
Rouissat	13,814	08.067	104.876
Sidi-Khouiled	1,555	00.908	11.806
Ain-Beida	3,554	02.076	26.982
Hassi-B-Abdallah	1,917	01.120	14.554
N'Goussa	16,876	09.856	128.123
Hassi-Messaoud	16,991	09.923	128.996
El-Borma	7,308	04.268	55.482
El-Hadjira	9,580	05.595	72.731
El-Alia	15,860	09.262	120.409
Temacine	3,883	02.268	29.480
Blidet-Amor	2,568	01.500	19.496
Touggourt	2,299	01.343	17.454
Nezla	3,267	01.908	24.803
Tebesbest	1,867	01.090	14.174
Zaouia	7,889	04.607	59.893
Meggarine	2,676	01.563	20.316
Sidi-Slimane	1,963	01.146	14.903
Taibet	6,686	03.905	50.760
Bennaceur	2,242	01.309	17.021
M'Nagueur	4,517	02.638	34.293
TOTAL	145,877	85.192	1107.498

Table A1.5: Production of biomass and biogas from animal manure (Goats)

Municipal	Goats (head)	Mature (kt/year)	Biogas (m3)
Ouargla	31,445	18.364	238.730
Rouissat	10,329	06.032	78.418
Sidi-Khouiled	1,754	01.024	13.316
Ain-Beida	2,962	01.730	22.488
Hassi-B-Abdallah	2,335	01.364	17.727
N'Goussa	26,281	15.348	199.525
Hassi-Messaoud	18,942	11.062	143.808
El-Borma	10,477	06.119	79.541
El-Hadjira	11,969	06.990	90.869
El-Alia	27,373	15.986	207.816

Temacine	13,840	08.083	105.073
Blidet-Amor	9,264	05.410	70.332
Touggourt	3,550	02.073	26.952
Nezla	6,910	04.035	52.461
Tebesbest	3,688	02.154	27.999
Zaouia	3,404	01.988	25.843
Meggarine	4,934	02.881	37.459
Sidi-Slimane	3,332	01.946	25.297
Taibet	10,361	06.051	78.661
Bennaceur	3,488	02.037	26.481
M'Nagueur	7,042	04.113	53.463
TOTAL	213,680	124.789	1622.259

Table A1.6: Production of biomass and biogas from palm waste

Municipal	number of palms	Palm waste (kt/year)	Biogas (m3)
Ouargla	304,919	7.623	1411.287
Rouissat	127,102	3.178	588.279
Sidi-Khouiled	54,501	1.363	252.252
Ain-Beida	218,086	5.452	1009.389
Hassi-B-Abdallah	180,817	4.520	836.893
N'Goussa	184,977	4.624	856.148
Hassi-Messaoud	61,436	1.536	284.350
El-Borma	00	0.000	0.000
El-Hadjira	111,043	2.776	513.951
El-Alia	64,035	1.601	296.380
Temacine	214,184	5.355	991.329
Blidet-Amor	183,213	4.580	847.983
Touggourt	13,820	0.346	63.964
Nezla	176,339	4.408	816.167
Tebesbest	136,000	3.400	629.462
Zaouia	117,624	2.941	544.411
Meggarine	195,621	4.891	905.412
Sidi-Slimane	164,506	4.113	761.400
Taibet	34,390	0.860	159.171
Bennaceur	24,711	0.618	114.372
M'Nagueur	61,490	1.537	284.600
TOTAL	2,628,814	65.720	12167.203

Annex chapter III:

Table A3.1: MCDA based software [66] [67] [68] [69] [70]

Software	About	Uses
Expert Choice	Developed by Thomas Saaty and Ernest Forman 1983, is currently one of the leading companies in providing cutting-edge decision-making solutions globally. Software is based on AHP and comes in two different version know as Expert Choice Comparison and Expert Choice Riskion	Riskion is widely used in all type of industries such as aerospace, asset management, automotive, banking, Energy, government, health care and many more for risk management processes. Comparison is being used in project management, capital budgeting, strategic planning, vendor source management's, trade studies etc.
BENSOLVE	Implement Benson's algorithm and its extensions	To solve linear vector optimization problems a subclass of multiple objective linear programs (MOLP)
Bubble Chart Pro OPTIMAL	A powerful all-in-one project prioritization and real optimization system in an easy-to-use application	A linear programming optimizer and prioritize based on SMART (Simple Multi-Attribute Ranking Technique).
ChemDecide	A software package based on AHP, ELECTRE III and MARE	Used to aid route selection, chemical storage, equipment selection and sourcing decisions
DECISIONARIUM	The website provides multicriteria decision tools for individual and group decision making.	Used for purposes like decision support, global participation, voting, surveys, group decisions, robust portfolio modelling, preference programming, etc.
DEXi	A computer program for multi-attribute decision making	For supporting complex decision-making tasks based on Multi Attribute decision making
D-SIGHT	Based on PROMETHEE methods, MAUT and AHP	Used in corporate for taking various decision
ElectioVis	A decision-aiding software tool	It lets one to fill all the data and then simulate results
FLO	It is a project for development of a MATLAB-based software tool.	Used for solving location problems.
GUIMOO	GUI (Graphical User Interface) based mainly used for Multi-Objective Optimization.	Mostly used to design of efficient metaheuristics.
IDS	An IDS (Intelligent Decision System) used for MCDA under conditions of uncertainty	It can be used for total quality management (TQM) in corporate an also for business excellence
Interalg	A solver for multi-objective optimization with specifiable accuracy, with general logical constraints and categorical variables.	It can be used for the purpose of solving Multi Objective optimization problem where we have user defined accuracy.
IND-NIMBUS	Aimed at solving nonlinear multi-objective optimization problems and it can be applicable for solving real-world problems.	Suitable for both differentiable and non-differentiable multi-objective and single objective optimization problems.
Triptych	Basically, it is a Microsoft Excel based adding	Currently used in industries such as

	providing not only decision support but also helping to understand the voice of customers, generation and selection of design alternatives. It incorporates many methods such as Quality Function Deployment methods, affinity diagram, AHP, Theory of Inventive Problem Solving TRIZ, TOPSIS etc.	aerospace, biomedical, mining & $2 oil, automotive, equipment developers and also in academic research.
IRIS and VIP and Decision	-IRIS - Interactive Robustness analysis and parameters' Inference software for multicriteria Sorting problems. - VIP - Variable Interdependent Parameters: uses aggregation of multicriteria performances by means of an additive value function under imprecise information. - Decision Deck is a project aimed to collaboratively develop Open-Source software tools implementing Multiple Criteria Decision Aid (MCDA)	Can be used for sorting, risk analysis specially risk assessment and remediation risk management.
MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique)	An interactive approach that requires only qualitative judgments about differences. It helps a decision maker or advising group to quantify the relative importance of options.	1. Strategic plan development 2. Resource allocation 3. Participative evaluation of social, economic and environmental impacts for major infrastructures 4. Public policy planning. 5. Feasibility of projects and plans 6. Performance evaluation for employees, suppliers, tender evaluation
MakeItRational	An AHP based platform	Project Management
modeFRONTIER	multi-objective optimization and multidisciplinary design tool, which provides an easy interface to many Computers Aided Engineering (CAE) tool	For optimization and multi objective decision making
Decision Explorer	A Windows based mapping tool of ideas.	Used to develop feasible, practical and acceptable solutions by considering opinions for different people and negotiating for a shared understanding.
Criterium Decision Plus	A visual decision tool that helps you make decisions by communicating and inculcating recommendations effectively.	Used for decision support for environmental, aerospace, engineering, defense and space
Winpre	Workbench for Interactive Preference Programming.	Decision support, Spontaneous decision conferencing in parliamentary negotiations, Traffic planning
SANEX	University of Queensland, Australia in collaboration with Swiss Development Cooperation (SDC)	Applicable in sanitation system designs for rural communities in developing nations.
1000Minds	Based on PAPRIKA (Potentially All Pairwise rankings of all possible Alternatives) method.	MCDM, prioritization and resource allocation

IDSS	It is based on a team including top-level scholars and consultants with specialization in decision support based on varios methodologies of operational research and artificial intelligence.	- Preference Modelling, ranking and sorting. - Multi objective programming in fuzzy environment, interactive procedures for multicriteria choice. - System programming for water supply, regional planning, agriculture, software engineering, surgery, environment

Table A3.2: Summary of MCDA Methods.

Method	Advantages	Disadvantages	References
Analytic Hierarchy Process (AHP)	• Can be easily applied to solve different problems • The computation process is quite simple compared with other methods • Results are obtained quite quickly compared to other methods • The method has a comprehensible logic • The method is based on a hierarchical structure; therefore, it has a better focus on each criterion used in the calculations	• Interdependence between alternatives and objectives can lead an inaccurate/wrong result • Additional analysis is required to verify the results • The more decision-makers that are involved, the more complex the assigning weights are • Requires data collected based on experience	**[71]**
ELECTRE	• Takes uncertainty and vagueness into account.	• Its process and outcome can be difficult to explain in layman's terms; • outranking causes the strengths and weaknesses of the alternatives to not be directly identified.	**[72]**
PROMETHEE	• The method is especially useful when there are alternatives that are difficult to harmonize • The method works with qualitative and quantitative information • Uncertain and fuzzy information can be incorporated into calculations	• The computation process is quite long compared with other methods • Calculations are very complicated • therefore, the method is only suitable for experts	**[69]**
Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS)	• Works with a fundamental ranking • The method completely uses allocated information • The information need not be independent • The method has a rational and	• In principle, the method works based on Euclidean distance and negative and positive values do not influence calculations • A strong deviation of one indicator from the ideal solution	**[73]**

	comprehensible logic, and the concept is in a quite simple mathematical form • The computation process is quite simple compared with other methods • Results are obtained quite quickly compared to other methods	strongly influences the results • The method is suitable when the indicators of alternatives do not vary very strongly	
Multi-Attribute Utility Theory (MAUT)	• Takes uncertainty into account • can incorporate preferences.	• Needs a lot of input. • preferences need to be precise.	**[72]**
Case-Based Reasoning (CBR)	• Not data intensive. • requires little maintenance • can improve over time. • can adapt to changes in environment.	• Sensitive to inconsistent data. • requires many cases.	**[72]**
Data Envelopment Analysi (DEA)	• Capable of handling multiple inputs and outputs. • Efficiency can be analyzed and quantified.	• Does not deal with imprecise data. • assumes that all input and output are exactly known.	**[72]**
Simple Multi-Attribute Rating Technique (SMART)	• Simple. • allows for any type of weight assignment technique. • less effort by decision makers.	• Procedure may not be convenient considering the framework.	**[72]**
Fuzzy Set Theory	• Allows for imprecise input. • takes into account insufficient information.	• Difficult to develop. • can require numerous simulations before use.	
CRITIC	• One of the most objective methods, where there is no need for decision-makers intervention • The method involves basic statistical operations • The method has simple calculations	• Does not express the relative importance of achieving decision-makers' goals • The method shows only some properties of the initial data • The method does not consider the type of criteria	**[74]**
EDAS	• Very practical method in conditions with contradictory attributes • The method characterized as a highly efficient method • Calculations are quite simple • Popular when used for various fuzzy cases	• The method is limited by its hypothesis that the evaluation criteria are compensatory • The method has the same disadvantages as the TOPSIS method. • rank reversals not stable	**[75]**
WASPAS	• The method has shorter calculation stages • The method weights the beneficial and nonbeneficial criteria in the problem	• The method takes into consideration only minimum (for non-beneficial attributes) and maximum (for beneficial attributes) values, and does not consider all the performance values	**[76]**

	separately • The method is useful for the complete ranking of alternatives • Seeks to reach the highest accuracy		
WSM	• Very simple computation process • Suitable for managing single-dimension problems	• There is no possibility to integrate multiple preferences • Evaluates only one dimension	**[77] [78]**
Goal Programming (GP)	• Capable of handling large-scale problems. • Can produce infinite alternatives.	• It's ability to weight coefficients. • typically needs to be used in combination with other MCDM methods to weight coefficients.	**[72]**
Simple Additive Weighting (SAW)	• Ability to compensate among criteria. • intuitive to decision makers • Calculation is simple does not require complex computer programs.	• Estimates revealed do not always reflect the real situation. • result obtained may not be logical.	**[72]**

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Abstract

This research addresses the problem of determining the most suitable sites for locating biogas plants using biomass (municipal waste, animal manure and palm waste) as a feedstock in the province of Ouargla (Algeria). A Multicriteria Spatial Decision Support System is developed to tackle this complex multicriteria decision-making problem, involving constraints and criteria such as environmental, economic, safety, and social. The approach followed combines the use of a Geographic Information System (GIS) to manage and process spatial information with the flexibility of Multi-criteria Decision Aid (MCDA) to assess factual information (e.g. slope, Roads and population) with more subjective information (e.g., expert opinion). The MCDA method used in this work is AHP, an outranking-type method that yields a classification of the possible alternatives. As a result, suitable and unsuitable areas were identified for receiving the biofuel production plant project, where the total suitable area is estimated as 79.82 % (130,303.527 km^2), and the inappropriate area is 20.17 % (32,929.4734 km^2). The final indicator model for areas that can receive a biofuel plant project was grouped into four categories as "very low suitability", "low suitability", "moderate suitability" and "high suitability" with a manual interval classification method. The results indicated that 0.58 % (765.234 km^2) has very low suitability, 1.52 % (1,992.591 km^2) has low suitability, 7.34% (8,704.2756 km^2) has moderate suitability and 90.54 % (117,985.24 km^2) has high suitability for biomass powered biofuel production installation system.

Keywords: Biofuel, Geographic Information System (GIS), Multi-criteria Decision Aid (MCDA), Site Selection, Analytical Hierarch Process (AHP), Ouargla

ملخص

يعالج هذا البحث مشكلة تحديد أنسب المواقع لتحديد مواقع مصانع الغاز الحيوي باستخدام الكتلة الحيوية (نفايات البلدية، روث الحيوانات ومخلفات النخيل) كمادة وسيطة في مدينة ورقلة (الجزائر). تم تطوير نظام دعم القرار المكاني متعدد المعايير لمعالجة مشكلة صنع القرار المعقدة متعددة المعايير هذه، والتي تتضمن قيودًا ومعايير مثل البيئية والاقتصادية والسلامة والاجتماعية. يجمع النهج المتبع بين استخدام نظام المعلومات الجغرافية (GIS) لإدارة ومعالجة المعلومات المكانية مع مرونة تطبيق القرار متعدد المعايير (MCDA) لتقييم المعلومات الواقعية (مثل المنحدرات والطرق والسكان) مع المزيد من المعلومات الذاتية (على سبيل المثال، رأي الخبراء). طريقة MCDA المستخدمة في هذا العمل هي AHP، وهي طريقة من النوع الذي يعطي تصنيفًا للبدائل الممكنة. ونتيجة لذلك، تم تحديد المناطق المناسبة وغير المناسبة لاستلام مشروع مصنع إنتاج الوقود الحيوي، حيث تقدر المساحة الإجمالية المناسبة بـ 79.82% (130303.527 km^2)، والمساحة غير الملائمة 20.17 % (32929.4734 km^2). تم تجميع نموذج المؤشر النهائي للمناطق التي يمكن أن تتلقى مشروعًا لمصنع الوقود الحيوي إلى أربع فئات على أنها "ملائمة منخفضة جدًا" و "ملائمة منخفضة" و "ملاءمة معتدلة" و "ملاءمة عالية" باستخدام طريقة التصنيف اليدوي للفاصل الزمني. أشارت النتائج إلى أن 0.58% (765.234 km^2) ذات ملاءمة منخفضة للغاية، و1.52 % (1992.591 km^2) ذات ملاءمة منخفضة، و7.34% (8,704.2756 km^2) ملائمة بشكل معتدل و 90.54 % (117985.2km^2) لديها ملاءمة عالية لتركيب نظام إنتاج الوقود الحيوي الذي يعمل بالطاقة الحيوية.

الكلمات المفتاحية: الوقود الحيوي، نظم المعلومات الجغرافية (GIS)، المساعدة في اتخاذ القرار متعدد المعايير (MCDA)، عملية التسلسل الهرمي التحليلي (AHP)، تحديد أفضل موقع، ورقلة.