Ecological Questions 35 (2024) 2: 117–128 http://dx.doi.org/10.12775/EQ.2024.021

Agricultural waste in Libya as a resource for biochar and methane production: An analytical study

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Received: 4 November 2023 / Accepted: 29 November 2023

Abstract. This study aims to analyse the possibility of exploiting agricultural waste in Libya to produce biochar and methane gas, and to evaluate the technical, economic and environmental aspects associated with this technology. In this study, the focus was on seven agricultural projects located in the Libyan desert, where these projects contain many varieties of Crops. A region with a total area of 5.36×10^6 ha was explored from Benghazi to Dernah eastward including the Green Mountain (Libya). For literary analysis, peer-reviewed scientific publications for 2018-2023 were selected from reliable bibliometric databases Scopus, Google Scholar, ScienceDirect, PubMed, since these databases have the greatest coverage of peer-reviewed publications. To study the biomass potential of the region, the Bioenergy Tool developed by IRENA was used. The study showed that agricultural residues available in Libya can be used Libya, such as grain straw, palm trees, and others, in the production of biochar and methane gas, using pyrolysis techniques to convert agricultural waste into biochar and methane gas. The study indicates that this technology can be cost-effective and environmentally effective, and that many environmental and economic benefits can be achieved, such as improving air quality, increasing agricultural land productivity, and providing new job opportunities.

Keywords: sustainable bioconversion, biochar, methane gas, agricultural waste, grain straw, palm trees, Libya.

1. Introduction

In recent decades, the environmental safety issues and the cyclical economy has occupied first positions in scientific research and practice (Khan et al., 2023; Sawicka et al., 2022; Vambol et al., 2016). This is justified by the fact that natural resources are limited and society strives for stable development. The most pressing issues are in the areas of natural water use (Sawicka et al., 2023; Hulai et al., 2022; Vambol et al., 2019), waste management (Ziarati et al., 2022; Husain Khan et al., 2023) and the creation of alternative energy (Constantinescu et al., 2018). Moreover, in these difficult and sometimes problematic issues there is a relationship, such as antibiotic-contaminated sewage sludge (Aly, 2016) and waste can be, in one way or another, converted into energy resources (Vambol et al., 2023). This achieves at least two goals: reducing waste and embracing a circular economy, which reduces the need for fossil fuels and the contribution to global warming.

Libya is an industrial country in which agriculture and horticulture do not occupy a dominant position, although this industry is developing to the best of its ability. The food culture in Libya involves the consumption of large quantities of cereal products, but domestic production is unable to meet demand, and the country meets the need for cereals (mainly wheat and barley) through imports. In the same time, in Libya agricultural land including permanent meadows, pasture and cultivated land covers a total of 15.35×10^6 ha constituting 9% of the total area of the country. The cultivated area which include arable land and area under permanent crops extends over 2.1×10^6 ha (FAO, 2020). Production of vegetables, roots and tubers in 2021 amounted to 953.8×10^6 t, which was 0.5% higher than the previous year. On average, this figure has increased annually by 0.6% since 2017. The basis of production is potatoes (328.9×10^6 t), tomatoes (219.5×10^6 t), as well as onions and dried shallots (189.5×10^6 t) [https://agrovesti.net/lib/advices/selskoe-khozyajstvo-livii-i-vozmozhnosti-dlya-eksporta-rossijskoj-produktsii.html]. Among crop products, a significant share of production is occupied by olives (173.3×10^6 t) and almonds in shell (34.6×10^6 t). Also, in Libya the available fruits are: apple, peach, date palm, figs, olives. In recent years, there has been great interest in Jojoba to be planted in South of Libya.

As a result of the development of this industry, waste is generated, which represents biomass suitable for use in a Circulation Economy (CE). For example, tree waste (trimmings) can be used as lignocellulosic raw materials. In addition to its contribution to the environment and spatial development of the Libyan desert, jojoba or *Simmondsia chinensis* can produce organic oil and liquid wax ester, which are extracted from its seeds. Residues from fields are also widely recognized as a potential resource for alternative energy.

To date, very limited work has been carried out to explore the current potential of agricultural biomass in Libya. All existing work has focused on the quantification and management of municipal solid waste (MSW). Hamad et. al. (2019) analysed the potential of methane production from organic waste to provide electricity and heat for the Omar Almukhtar University campus. Through anaerobic digestion of organic raw materials such as food waste, sewage, agricultural and livestock waste, which have been estimated at Al-Baida city could produce 674 m^3/h and 37 MJ/m^3 of methane and heat respectively. In another study, plastic waste from polyethylene and polypropylene was quantified throughout Libya and its conversion into fuels and chemicals was assessed (Alajail et al., 2014).

Electricity production from biomass or bioenergy covers a wide range of technologies and feedstocks that range from low-cost, mature options such as combustion of agricultural and forestry residues (traditional biomass), to more expensive and/or less mature options such as biomass energy, including methane, biofuel oil, fuel ethanol, etc. While direct combustion of biomass has a lower efficiency of 5–15% and produces a large amount of greenhouse gas (GHG) emissions; Modern biomass, in contrast, has higher efficiency, typically 60–90%, with strict emissions controls (Kuang et al., 2016). For this reason, more and more countries are turning to modern methods of using biomass.

Bioenergy is an important source of energy that can be used for various purposes such as power generation, cooking and heating, transportation using biodiesel, etc. Although bioenergy has significant potential in Libya, it currently does not contribute any while waste continues to be generated.

In this regard, the study seeks to critically evaluate the current situation of agricultural waste in Libya and find progressive approaches to implement a circular economy in Libyan agriculture.

2. Research methodology

2.1. Study area

The study region extends from Benghazi to Dernah eastward including the Green Mountain. The total land area is 5.36×10^6 ha as shown in Figure 1. This area was chosen for the study due to its favourable rainfall, forests and vegetation diversity (Hegazy et al., 2011).

Figure 1. Study area for biomass potential assessment

2.1.1. The location of the study area

The study area is located between longitudes 7 and 95 degrees east and latitudes 17.45 and 97 degrees north (Elmnifi et al., 2019). It is bordered to the east by the Arab Republic of Egypt, to the south by the Republic of Sudan, Chad and Niger, and to the west by Algeria. The study area is a vast plateau interspersed with many mountains and valleys rising to the surface of the sea. This plateau rises gradually from north to south until it reaches its maximum height of 8433 m above sea level at the summit of Mount Amikossi in the Tibesti Mountains. In the study area, there is a group of mountains from its volcanic nation, the Tibesti Mountains, and to the northeast of the Tibesti Mountains, there is a mountain massif, the Iqi Mountains, which lies along the Tropic of Cancer (Elmnifi et al., 2023).To the northwest there are a number of volcanic cones, such as the Waw an-Namos volcano. As for the „Tammu" heights, an ancient plateau of sandy rocks extends to the west, which used to occupy this area of the Tibesti heights. It is a group of hills, of which a large branch extends towards the north, where it is known as the Acacus Mountains. At the southeastern end of the study area, there are Jabal Al-Awainat and Jabal Arkano, while in the north of the study area, Jabal Al-Harouj is located, which extends to the south from latitude 97 degrees north. It is a mountainous group that occupies a wide area and is divided into two main parts, one of which differs from the other in a clear difference in appearance and composition. And to the west of the Black Harouge Mountains lies the Souda Mountain, which extends to the west of it. The study area abounds with a group of depressions, the most famous of which is the Kufra depression, which includes a group of oases, namely Al-Jawf, Boma, Buima, Al-Zuwairq, Al-Tulalib, and Al-Talaba, in the middle of a large basin dug into the surface of the plateau. And the Fezzan Depression, which is located in the southwest of Libya and is crossed by a number of longitudinal depressions or valleys (Al-Kaf, 2019).

2.1.2. Climate of the study area

The study area as a whole is subject to a hot desert climate, but rather the hottest parts of the world, and the daily temperature range is large, which negatively affected plant life, as the amount of rain falling on the region is not enough for the growth of some seasonal grasses in the rainy season.

2.2. Procedure for selecting literary sources

Features of the literature selection procedure that was applied are presented in Table 1.

Bibliographic databases were selected for accessibility, widespread availability, and availability of peer-reviewed scientific publications.

Table 1. Selection of literary sources.

Bibliographic database	Scopus; Google Scholar; ScienceDirect; PubMed
Keywords for the search query (in various interpretations	agricultural waste; garden waste; Libya; biomass; methane; biochar; circular economy
Search within	Title, abstract, keywords
Document type	Any
Language	Any
Time interval	2018–2023

The keywords of the search query are justified by the purpose of the study.

The time interval was chosen based on the consideration that scientific knowledge is updated every 10-20 years. That is, what was published 10 years ago may not be relevant and innovative today. Due to the particularly rapid changes taking place in the world in all sectors of the economy, as well as in scientific discoveries, it was customary to study scientific publications over the past 5 years (considered a full calendar year) and for the current year (when the study was conducted), as the most relevant (not outdated) period of scientific development. At the same time, if the analysed articles contained cross-references that, in the opinion of the authors, were of interest for current study, then these sources were also taken into account.

2.3. Research method

Analytical assessment is an important tool for gaining in-depth understanding and analysis of any phenomenon. This is a research method based on analysis of the characteristics and properties of a phenomenon in order to identify its essence and significance; is actively used in various fields where a systematic and objective analysis of the existing reality is required to make informed decisions and develop development strategies. The point of analytical assessment is that it provides a deeper understanding of a phenomenon and its impact on the environment. It helps to identify the causes and consequences of ongoing processes and makes it possible to make informed decisions.

The Bioenergy Tool developed by IRENA was used in this paper to explore the biomass potential of the region. IRENA collects and disseminates comprehensive data and statistics on renewable energy, including market trends, costs, and renewable energy potentials. This information is valuable for policymakers, investors, and researchers in making informed decisions and assessing the progress of renewable energy development at the global and regional levels. Libya lacks statistics and studies that support new research, therefore, data from the International Renewable Energy Agency were used.

This Bioenergy simulator [https://biosimulator.irena.org] is a user-friendly web-based application developed to help policy makers, practitioners, and business developers estimate potential bioenergy and plan bioenergy development taking into consideration combinations of area, biomass resource, technology, and end-use. This tool is used to estimate the study of specific sites and gives forecasts for cultivated areas of how much energy will be produced from these lands.

The potential of crops, agricultural residues, livestock waste and forest plantations was obtained using a bioenergy simulator. This work calculates the potential of bioenergy crops and agricultural residues.

Unfortunately, the bioenergy potential of animal waste has not been taken into account due to the lack of accurate data related to the number of animal heads. Also, due to the large number of plantations in the study area, which reaches more than 100 (Hegazy et al., 2011), the bioenergy potential of forest plantations was also not taken into account. Feedstock and biomass types are a key factor in determining bioenergy production productivity throughout the supply chain.

3. Results and discussions

3.1. Biofuel production from agricultural waste

Biofuel can be produced from agricultural waste in several ways, depending on the type of waste and the technology used. Here is some general information about it.

Biogas: Biogas can be produced from agricultural waste, which is natural gas extracted from the process of decomposing organic matter in the earth's atmosphere and converting it into gas. Biogas can be produced from plant and animal waste such as agricultural and organic waste, and it can be used as an alternative fuel to natural gas.

Ethanol: Ethanol can also be produced from agricultural residues such as corn, wheat, and other sugars. Ethanol is produced by fermenting the sugars in organic matter into ethanol. Ethanol can be used as a fuel for cars and trucks.

Biodiesel: Biodiesel can be produced from agricultural waste such as soybean oil, corn oil, palm oil, and mustard oil. Biodiesel is produced by converting vegetable oils into fuel through a process called biodiesel production. Biodiesel can be used as a fuel for cars, trucks, and agricultural equipment.

Bio hydrocarbons: Bio hydrocarbons can be produced from agricultural waste such as straw, vegetables and fruits. Bio hydrocarbons are produced by converting organic materials found in agricultural waste into hydrocarbons through a process called thermal depolymerization. Bio-hydrocarbons can be used as an alternative fuel to oil.

Biochar: Biochar can be produced from agricultural waste such as straw and other plant waste. Biochar is produced by heating plant waste without the presence of oxygen, and is used as a plant breeding material and to improve soil properties.

Bioethanol is an alcohol obtained by sugar fermentation or starch produced from certain crops (e.g. wheat, maize, sugarcane, sugar beet). The least complex technology for bioethanol production involves sugar feedstock, e.g. plants containing simple sugars, which can be fermented by yeast or other microorganisms directly into ethanol. The addition of a second enzyme is required for starchy plants to convert the starch to fermented glucose (saccharification process). An internal combustion engine (ICE), as well as can be fed with fossil fuels such as diesel, gasoline, or natural gas, can also be fed with renewable energy sources such as bioethanol, biomethane, biodiesel, and vegetable oils. Considering the rapeseed as the high potential crop for producing H&P, the harvested seeds produce 207.67 L/ha of biodiesel which in turn produces, using biodiesel CHP– engine technology, 3708 and 4768 GWh of a gross electricity and heat respectively. Figure 2 shows a scheme of methane production from crops. Biochar can be produced from agricultural waste such as straw and other plant waste. Biochar is produced by heating plant waste without the presence of oxygen and is used as a plant breeding material and to improve soil properties. Figure 3 shows a scheme of Biochar production from crops.

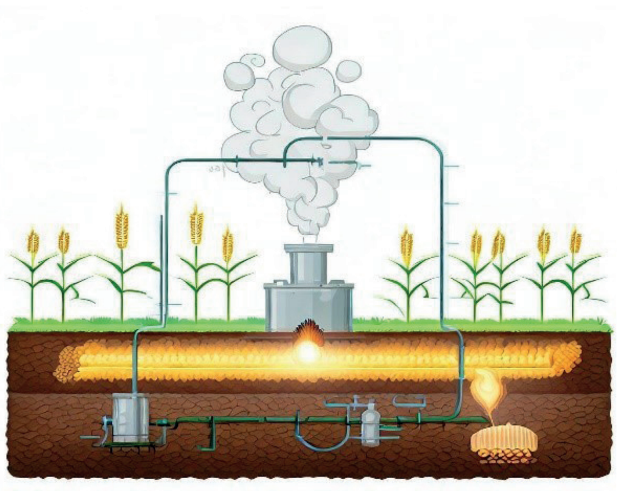

Figure 2. Scheme of methane production from crops

3.2. Bioenergy potential of agricultural waste in Libya

Table 2 shows the types and average yield of different crops within the confined area considering rain-fed condition. The solid biomass can exhibit a variety of characteristics depending on its origin (e.g. sawdust, wood, leaves, dried animal dung, agricultural residues) and on conditions during

Figure 3. Scheme of Biochar production from crops

the harvest and storage phases of the crop (e.g. growth status of the plant, temperature, humidity). Solid biomass should be treated with suitable technologies to ensure the desired characteristics for the bioenergy supply chain. Bioenergy potential from agricultural residues for the specified area was also obtained from the bioenergy simulator and the results are tabulated in Table 2. Energy yield is represented as minimum which resulted from maize husk and maximum value which obtained from wheat straw. The energy yield also depends on the conversion technology. For example, for electricity production using gasification steam turbine, the gross electricity production ranges from 108 GWh for maize husk feedstock to 7567 GWh when wheat straw feedstock is used.

The maximum electrical energy yield for wheat straw is gained when combustion steam turbine technology is involved where the gross electricity production is 10,926 GWh. For H&P or cogeneration utilization, biomethane-CHP-gas turbine is the suitable technology for maize husk which can produce 118 and 151 GWh of gross electricity and heat respectively. On the other hand, combustion-CHP-steam turbine is the most appropriate technology for wheat straw which can produce 10,926 and 27,314 GWh of gross electricity and heat respectively. Considering that the average annual electricity consumption in Libya is 3.9 MWh per capita [https://databank.worldbank.org/reports.aspx?source=2&series=EG.USE.ELEC.KH.PC&country], the estimated electricity production could supply 2,782,594 persons/year.

Table 2. Bioenergy crops and average yield

Crop	Harvested product	Average yield (t/ha)	Bioenergy end-use	Conversion technology
Maize	Grain	0.1	Transport	Ethanol-engine
Sugarbeet	Sugar	0.9		
Groundnut	Groundnut in shells	0.2	Heat & power Electricity Transport	Biodiesel CHP-engine Vegetable oil CHP-engine Biodiesel engine Vegetable oil engine Biodiesel engine
Rapeseed	Seed	0.5		
Soybean	Grain	0.2		
Sunflower	Seed	0.3		

As can be seen from Table 3, sugar, as a yield product from sugar beets, is the best raw material for the production of bioethanol.

Table 3. Bioenergy agricultural residues and average yield

Crop	Residue (feedstock)	Average yield (t/ha)	Bioenergy end-use	Conversion technology	Energy yield
Barley	Straw	0.4	Electricity	Biomethane-engine	from 101 (maize husk) to 6292 GWh/ha (wheat)
Groundnut	Husk, haulm	0.2		Biomethane- gas turbine	from 118 to 7340 GWh/ha
				Biomethane-steam turbine	from 67.4 to 4194 GWh/ha
				Combustion-steam turbine	from 21.8 to 10926 GWh/ha
Maize	Cob, husk, stover	0.1		Gasification-steam turbine	from 108 to 7567 GWh/ha
Oat	Straw	0.8			
Rye	Straw	0.9	Heat	Biomass- combustion boiler	from 98 to 49165 J
Soybean	Straw	0.2			
Sunflower	Husk, stover	0.3	Heat & power Transport	Biomethane-CHP engine	from 101 to 6292 GWh
				Biomethane-CHP- gas turbine	from 118 to 7340 GWh
Wheat	Straw	1.4		Biomethane-CHP-steam turbine	from 67 to 4194 GWh
Olive	Exhausted oil cake	0.2		Combustion-CHP-steam turbine	from 22 to 10926 GWh
				Gasification-CHP-steam turbine	from 108 to 7567 GWh
				Ethanol 2nd genengine	from 6.6 to 520 L/ha (ethanol)

3.3. Possibility of biofuel production in Libya

Biogas is a mixture of primarily biomethane (CH_4) and carbon dioxide (CO_2). It is produced by bacteria through anaerobic digestion of organic wastes while the remaining non-digestible solids are collected as sludge which can be valuable as fertilizer in agriculture. The biogas can be purified and treated to become natural gas or biomethane. Synthesis gas (Syngas), on the other hand, is a fuel gas mixture consisting mainly of hydrogen, carbon monoxide, and carbon dioxide produced through gasification of feedstock. The syngas can be used as a fuel to generate electricity and/ or heat. Solid biofuels had the largest share of total global cumulative biomass energy by 2018 with 84 GW, followed by biogas with about 18GW of total installations, renewable municipal waste with 12.63 GW, and 3.24 GW came from liquid biofuels. In 2017 electricity generation from different biomass sources amounted to 500 TWh (IREA).

Waste to Energy (WTE) technologies could contribute substantially to the RE production as well as alleviating the cost of landfilling and its associated socio-economic and environmental impacts (Fazeli et al., 2016). Principally, WTE utilizes three routes: biochemical, thermochemical, and physicochemical processes. Biochemical process, including bio methanation (anaerobic digestion) and fermentation technologies, convert organic wastes to energy in the form of gaseous or liquid fuels in presence of biological agents (Korai et al., 2016). Thermochemical technologies, through either pyrolysis, gasification and incineration, use high temperatures to convert waste feedstocks to energy in the form of heat and power and value-added products (Tozlu et al., 2016). Using chemical agents, physicochemical processes convert organic wastes to energy, commonly in the form of liquid fuels. Transesterification is the most widely adopted physicochemical conversion technology (Münster & Lund, 2009; Ouda et al., 2016).

Biomass potential in Libya is estimated at 2 TWh/year and is thought to be suitable for domestic consumption only [https://www.rcreee.org/content/libya]. The use of biomass offers competition for agricultural lands that is interfering with food production. However, the major concern is the large amount of water necessary to grow energy crops. Biomass plants are on the increase around the globe to realize the concept of low carbon societies. The proportion of biomass of total energy in Libya is negligible. Besides the forestry biomass, we should also stress the importance of non-forestry biomasses, such as biomass from municipal waste, agricultural and animals' residues and industrial biomass which can represent an undreamed-of capacity for energy production

Majority of the research work related to the biomass energy in Libya was discussed in the perspective of solid waste and its management at the level of municipalities. Wastes are usually considered a sustainable energy source in the sense that it is convertible to useful energy forms like biogas, bio alcohol, hydrogen (biohydrogen), etc., through waste-to-energy technologies (Kothari et al., 2010).

Municipal solid waste (MSW) management in Libya is inefficient and sanitary landfills is not existing. Urban solid waste is often dumped and burned in specified empty plots within urban limits, resulted in serious health problems and environmental degradation.

Libya suffers from very poor collection and disposal services of solid waste. All types of waste are dumped together unprocessed thus without any type of segregation, treatment or recycling. The waste discard is still a tremendous issue in all Libyan cities. Libyan youth represents more than 50% of the current population (Hamad et al., 2014). This situation poses a great pressure on energy demands, food supplies, and the environment by increasing the generation of waste and residues. Share of modern biomass and liquid biofuels in total final energy consumption in Libya was reported at 0% in 2012, according to the World Bank collection of development indicators, compiled from officially recognized sources. Biofuels are liquid fuels and blending components produced from biomass feedstocks, used primarily for transportation.

MSW is a type of biomass that mainly consists of waste and residue of food, plastics, glass, metals, wood, paper, yard, rubber, leather, and textiles. Generally, incineration (combustion), gasification, and pyrolysis are the three thermochemical conversion processes of MSW (Sipra et al., 2018). Libya has huge agricultural areas of date palm and olive trees. Products amount to (statistics). Residues are yet unspecified thus their potential as biofuels needs further investigation. Residues of date palm and olive trees along with other biomass residues have the potential to drive the biofuel industry in the country. A qualitative analysis study conducted in the third largest city in Libya, Misrata, indicated that the yearly generated MSW in the city amounts to 0.155 Mt of which organics were identified as the major component (56%), followed by plastics (26.5%), and the paper had the third highest percentage of solid waste (8%). While only 10% of the collected MSW, as a current practice, ends up with organic fertilizer plants while the rest is either buried or combusted in open landfills; the study proposed an incineration plant that could generate about 36 GWh/year using 70% of the waste input (Badi et al., 2016).The quantity of solid waste generated in Benghazi is estimated to be 750 tons per day of which 28-30% was found in bio-degradable materials (Baba et al., 2018). The bio-degradable materials include food and kitchen waste, green waste, and recycled paper (Hamad et al., 2014).

4. Productive agricultural projects

It includes all productive agricultural projects established and managed by the state and aimed at self-sufficiency. The fields of these projects are mostly in the form of circles and the irrigation system used is the center pivot irrigation system. Al-Kufra agricultural project, Al-Sarir project, Al-Ariel project, and others to 43 ha, and some to 53 ha, as in the Maknousa and Barjouj projects. Emphasis is placed on cultivating wheat as the main crop, in addition to cultivating some other crops such as barley, beans, alfalfa, cane, sorghum, maize and alfalfa (Al-Kaf, 2019).

4.1. Kufra Agricultural Production Project

The project is located to the southeast of the city of Kufra. The area of the project is 10,000 ha, and it has a pivot irrigation system, whereby the area of each circle is 133 ha. Emphasis is placed on cultivating wheat as a main crop, in addition to cultivating some other crops such as barley, beans, and alfalfa during the winter seasons. In the summer seasons, crops are cultivated: cane, sorghum, maize, and alfalfa (Fig. 4) (Al-Kaf, 2019).

4.2. Productive agricultural bed project

It is one of the largest productive agricultural projects in the study area, as it is located to the north of the Kufra region, and includes the northern bed project and the southern bed project. The total area of the project is about 1733 ha, and the irrigation system used for the project is the centre pivot irrigation system, where the area of each circle is 73 ha. Other fields are less than 43 ha, and the most important crops grown are grains and legumes (Al-Kaf, 2019).

4.3. The Ariel Agricultural Productive Project

It is located in the northeastern region of the city of Sebha, with a total area estimated at about 9133 ha, and its irrigation system is pivotal in the form of circles, each circle covering an area of 133 ha. The most important crops grown in it are grains and legumes (Fig. 5).

Figure 4. Kufra Agricultural Production Project (Al-Kaf, 2019)

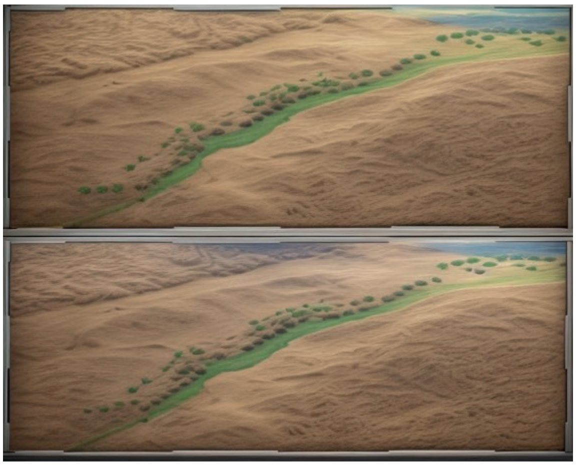

Figure 5. The Ariel Agricultural Productive Project

4.4. Maknousa Agricultural Production Project

It is located to the south of the Wadi Al-Hayat region, between the Tsawa region and the Al-Fujij region. The total area of the project is about 8783 ha, and the irrigation system is pivotal in the form of circles. The area of each circle ranges from 53 to 133 ha for wheat, barley and oats. Summer season, planting is in this season. Most fields are cultivated during the winter season, when agriculture is limited to cane and sorghum.

4.5. Tawasawa agricultural productive project

It is located to the south of the Maknoussa Agricultural Production Project. It is one of the productive projects affiliated to the Agricultural Research Center. It has a pivot irrigation system. The total area of the project is about 1533 ha, and the area of each circle is about 53 ha.

4.6. Borgoj agricultural productive project

It is located to the south of the city of Ubari and to the east of the Tsawa region along the Berjoj Valley. The total area of the project is about 8153 ha. It has a pivot irrigation system. The area of each circle is 53 ha. The most important agricultural crops grown in this project are grains and legumes.

4.7. Eraun agricultural productive project

It is located to the west of the city of Ubari. The total area of the project is 1853 ha. Roho has a pivot irrigation system. The area of each circle is 53 ha. The most important crops grown are alfalfa in the summer season, and wheat and barley in the winter season (Fig. 6) (Al-Kaf, 2019).

Based on the data of the engineers and farmers in these seven projects, the total area of the project (41,188 ha) can be divided according to the different type of crops as follows:

1 – Wheat and barley: 20% of the total area (about 8238 ha)
2 – Maize: 15% of the total area (about 6178 ha)
3 – Beans: 10% of the total area (about 4119 ha)
4 – Safsafa: 25% of the total area (about 10,297 ha)
5 – Date palms: 10% of the total area (about 4119 ha)
6 – Other miscellaneous crops: 20% of the total area (about 8238 ha).

As for the expected production of biochar and bladder gas, it depends on the conditions surrounding the project and the technologies used in production, and therefore it is difficult to determine with great accuracy. However, the expected proportion of biochar can be expected to be between 10% and 20% of the dry weight of the crop used in production, and the expected proportion of methane gas can be expected to be between 30% and 50% of the biochar production. It should be noted that these projections depend on Several factors, such as the type of crops used in production, the technologies used in production, and the climatic, environmental and economic conditions in the area where biochar and bladder gas are produced. Agricultural engineers and researchers in the field can set forecasts more accurately based on actual conditions in the target area.

5. Average production of biochar and methane gas for the seven agricultural projects

The expected amount of biochar and methane gas production from the seven targeted projects can be calculated based on the expected proportion of each type of crop, and the expected efficiency of the biochar and methane gas production process.

The following mathematical formulas can be used to produce biochar and methane from different crops:

Biochar production:

Biochar production = Raw material quantity x Carbonization rate x Biochar yield

Figure 6. Eraun agricultural productive project

This formula can be represented by mathematical symbols as follows (Lehmann, 2019):

$$Bp = Q \times Cr \times By \quad (1)$$

where:

Bp: amount of biochar produced (tonnes)

Q: The amount of raw materials used (in tons)

Cr: Refining percentage (in percentage)

By: Proportion of biochar production from raw materials (in percent)

Methane production:

Methane gas production = Raw material quantity x Methane yield x Methane content x Correction factor

This formula can be represented by mathematical symbols as follows (Shen et al., 2019):

$$Mgp = Q \times My \times Mc \times Cf \quad (2)$$

where:

Mgp: Amount of Methane Produced (in 10^6 m^3)

Q: The amount of raw materials used (in tons)

My: Percentage of methane production from raw materials (in %)

Mc: Percentage of methane in the gas produced (in %)

Cf: correction factor (reflects losses in the production process)

if we assume that the efficiency of biochar and methane gas production from willows is about 20%, then it can be expected to produce about 1.6 tons of biochar and about 4800 m^3 of methane per hectare of this crop.

For other crops, available data on biochar and methane gas production efficiency from different crops can be used and determined accordingly. The following data can be used as a model for projections:

- Wheat: It can be expected to produce about 0.5 tons of biochar and about 1500 m^3 of methane per hectare of crop.
- Barley: It can be expected to produce about 0.4 tons of biochar and about 1200 m^3 of methane per hectare of crop.
- Maize: It can be expected to produce about 0.8 tons of biochar and about 2400 m^3 of methane per hectare of crop.
- Beans: It can be expected to produce about 0.3 tons of biochar and about 900 m^3 of methane per hectare of crop.
- Palms: It can be expected to produce about 2 tons of biochar and about 6000 m^3 of methane per hectare of crop.

It should be noted that these expectations depend on the circumstances surrounding the project and the technologies used in production, and therefore can vary significantly depending on local conditions. The expected actual production must be determined based on the circumstances surrounding the project and the technologies used in production, after a comprehensive evaluation of the project.

The cost of biochar and methane production can be calculated based on expected costs for each production process, such as the costs needed to grow and allocate crops, the costs of processing raw materials into biochar and methane, and the costs of labour, energy, maintenance, management and marketing.

The cost of production can be estimated based on the following data (Ravindranath et al., 2019):

Crop cultivation cost: This depends on the type of crops and farming practices used, but the cost of planting can be estimated at around 1500 US$/ha.

The cost of converting raw materials into biochar and methane: This depends on the technologies used and the production scale of the project. The cost can be estimated at about 1000 US$/ton of biochar and about 3000 US$/$10^6$ m^3 of methane.

Labour, energy, maintenance, management and marketing costs: These costs can be estimated based on production scale, technologies used and local conditions, but can be estimated at about 500 US$/ton of biochar and about 1500 US$/$10^6$ m^3 of methane.

For the expected value of production, the following previously mentioned data can be used:

- Willow: It can be expected to produce about 1.6 tons of biochar and about 4800 m^3 of methane per hectare of this crop.
- Wheat: It can be expected to produce about 0.5 tons of biochar and about 1500 m^3 of methane per hectare of crop.
- Barley: It can be expected to produce about 0.4 tons of biochar and about 1200 m^3 of methane per hectare of crop.
- Maize: It can be expected to produce about 0.8 tons of biochar and about 2400 m^3 of methane per hectare of crop.
- Beans: It can be expected to produce about 0.3 tons of biochar and about 900 m^3 of methane per hectare of crop.
- Palms: It can be expected to produce about 2 tons of biochar and about 6000 m^3 of methane per hectare of crop.

Based on this data, the expected value of production, cost and profits can be estimated as follows:

Biochar production (calculated per 1 ha):

- Willow: 1.6 tons x 1500 US$/ton = 2400 US$
- Wheat: 0.5 tons x 1500 US$/ton = 750 US$
- Barley: 0.4 tons x 1500 US$/ton = 600 US$
- Maize: 0.8 tons x 1500 US$/ton = 1200 US$
- Beans: 0.3 tons x 1500 US$/ton = 450 US$

- Palm trees: 2 tons x 1500 US$/ton = 3000 US$
- Methane production (calculated per 1 ha):
- Willow: 4800 m^3 x 3000 US$/$10^6$ m^3 = 14,400 US$
- Wheat: 1500 m^3 x 3,000 US$/$10^6$ m^3 = 4500 US$
- Barley: 1200 m^3 x 3000 US$/$10^6$ m^3 = 3600 US$
- Maize: 2400 m^3 x 3000 US$/$10^6$ m^3 = 7200 US$
- Beans: 900 m^3 x 3000 US$/$10^6$ m^3 = 2700 US$
- Palm trees: 6000 m^3 x 3000 US$/$10^6$ m^3 = 18000 US$

It should be noted that these estimates are only projections and estimates and actual values may vary based on the circumstances surrounding the project, the technologies used in production and actual market prices. It must ensure the market availability of the produced products and determine the actual prices based on supply and demand in the market.

6. Conclusion

In Libya, renewable energy is an important issue as Libya is heavily dependent on fossil fuels as its main source of energy, making it vulnerable to fluctuations in oil and gas prices and increasing greenhouse gas emissions. Therefore, bioconversion technology for biochar and methane production could be a good option to promote renewable energy in Libya and achieve environmental sustainability. Accordingly, a study was conducted to analysed the feasibility of a project to convert palm waste into biochar and methane in Libya. energy resources. Through this study, we will try to shed light on the benefits and challenges of this technology in Libya, as well as the possibility of achieving environmental and economic sustainability through the application of this project. We will also analysed the technical and economic aspects of the project, the challenges that may be encountered during its implementation in Libya, and ways to enhance the positive aspects of this technology and overcome potential problems. We hope that this research will contribute to finding new solutions to achieve environmental and economic sustainability in Libya and promote the use of renewable energy as the main source of energy in the future.

It can be said that a sustainable agricultural project that uses bioconversion technology to produce biochar and methane from agricultural waste represents one of the promising solutions to reduce greenhouse gas emissions and generate clean and sustainable energy. Bioconversion technology uses bacteria and fungi to convert agricultural waste into biochar and methane gas. It is an environmentally friendly technology that reduces the use of fossil fuels and reduces agricultural waste. By determining the appropriate yields and ratios for each type of agricultural waste, this technology can be effectively used to produce biochar and methane. It was found that the highest production of biochar and methane gas was for the date palm crop, where about 2 tons of biochar and about 6000 m^3 of methane gas are produced per hectare of the crop. For the total crop area, it is projected that up to 60% of crop residues can be converted into biochar and methane using bioconversion technology, which means that about 67 ha of agricultural crops can be produced into clean and sustainable energy sources. This technology can be used to produce large quantities of biochar and methane at a lower cost than fossil fuels, making it an attractive alternative to the energy available today. In the end, it can be said that bioconversion technology to produce biochar and methane from agricultural waste represents a promising option for generating clean and sustainable energy, and can be used to achieve sustainable development, reduce the negative environmental impacts of agricultural waste, and achieve a green economy. Due to the growing interest in renewable energy and sustainable development, this technology may receive great attention in the future. This technology can contribute to achieving the 2030 Sustainable Development Goals, in particular Goal 7, which is related to ensuring access to affordable and clean energy for all.

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