Bioethanol from olive residues: prospects for a large scale production in the south of Algeria

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Abstract— *in the south-east of Algeria, olive cultivation and olive oil production know a remarkable development. But, the waste resulting from the olive oil industry represents a supplementary charge. Many ways used to valorize these residues such as livestock nutrition, solid fuel and ethanol extraction. In this context, the development of olive production in the southern regions (Ouargla and Ghardaia provinces) is examined. The geographical information system "ArcGIS" software is used to evaluate the natural potential of solar radiation, precipitation, groundwater reserves and large plains in these areas. The solar radiation lies between 5.3 and 6.5 KWh/m^2. By eliminating undesired zones which contain habitation and activity zones, sand and rocky soil, mountains, lacks and valleys, the available plain are evaluated at 15180 x10^3 hectares which present about 52 % of two provinces total area. The intersection of superposing maps (soil, precipitation and groundwater depth) gives the suitable areas for olive tree cultivation which can reach 5190 10^3 hectares. The obtained results show that the extension of olive cultivation is very promoting. In 2015, this agriculture covers 2471 hectares and releases 5500 x10^3 kg as residues. By using latest research rate of ethanol extraction, producing ethanol from olive residues is estimated at 1466 x10^3 liters. In 2040, the voluntary model shows that cultivated areas, olive residues and bio-ethanol production can reach 48800 hectares, 1086141 x10^3 kg and 22840 x10^3 liters respectively. For initial small scale bio-ethanol production, the cost evaluating shows that it remains relatively high (210.41 DZA (1.68 €) per litter.*

Index Terms—*Olive trees, ArcGIS, natural resources, olive residues, bio-ethanol.*

I. INTRODUCTION

World energy needs are constantly increasing, mainly for developing countries such as Algeria where the population grows rapidly [1]. The sustainable development of these countries requires the reinforcement of renewable energies production. Also, as interment sources, they need the amelioration of storage and conversion means. Among these conversion techniques, water electrolyser is commonly applied to generate hydrogen as alternative fuel. For producing gaseous fuels, many works are carried out. R. Boudries and R. Dizene [2] analyzed hydrogen production using solar energy.

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A. Gouareh et al. [3] studied the conversion of geothermal energy to produce hydrogen. M. Baik et al. [4] evaluated hydrogen production by hybrid system and its conversion by fuel cell. M. Douak et al. [5] treated hydrogen production using wind power. V. J. Veselovskaya et al. [6] and H. Kim et al. [7] carried out the transformation of CO_2 into methane. H. Siboukeur et al. [8] exploited anaerobic digestion to extract bio-methane from wastewater. Also, for producing liquid fuels, many processes and evaluations have been done. B. Recioui et al. [9] examined photo-catalytic reduction of captured CO_2 to produce methanol by using thermal solar energy. M. Oucif et al. [10] extracted ethanol from three date palm variety in ELoued (Algeria). B. Dokkar et al. [11] evaluated the long term ethanol production from low grade dates in south-eastern of Algeria. A. Akbi et al. [12] present an overview on bio-energy potential in Algeria and enclosing all residues for different sources which need more details for each industry. However, olives differ from all others drupes in their chemical composition by having relatively low concentration of sugars, and high oil content [13]. But, a lot of oil industry residues can be valorized. Currently, many researches [14-18] are carried out to develop this second generation under Mediterranean climate conditions.

The present work analyses ethanol extraction from the waste of olive industry in desert area. Normally, olive trees grow up in Mediterranean climate [19]. But, certain oil varieties such as (Chemlal) are mainly for the extraction of oil and it resists dry climate [20]. So, thank to these tree characteristics, the two provinces (Ouargla and Ghardaia) located in the South Eastern of Algeria are chosen. This hard climate imposes that olive agriculture can be expanded only by considering tree life conditions and area characteristics such as soil, rainfall, and groundwater which are treated numerically to show the suitable zone. In addition, an evaluation of bio-ethanol production cost is examined.

II. STUDIED REGION

Normally, olive trees grow up in Mediterranean climate region. But, thank to these trees have good resistance to hard climate, the two provinces (Ouargla and Ghardaia) located in the South Eastern of Algerian territory are chosen in this study. By using Google Earth, the borders of Ghardaia and Ouargla provinces are plotted as polygons in order to export these contours to ArcGIS software for converting them as geo-referenced surfaces. Figure 1 shows the map of northern Africa and the border of Ghardaia (red color) and Ouargla (bue color).

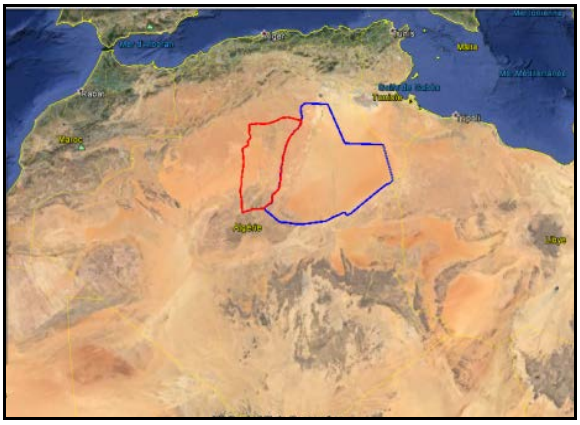

Figure 1: Studied region

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III. GROUNDWATER RESOURCES

A. *Different water reservoirs*

Ouargla and Ghardaia regions have desert climate, but they contain huge groundwater basin. The North-Western Sahara Aquifer covers more than 10^6 km^2, shared by Algeria, Libya and Tunisia [21]. Cross section of groundwater reservoirs [21] shows groundwater resources in the Sahara which are both renewable resources filled by rain-flows from Atlas Mountains, and as non-renewable aquifers: Continental Intercalary (CI) and Complexe Terminal (CT).

Continental Intercalary (Albian)**:** It is the most important Saharan aquifer ($3.5x10^9$ billion m^3 of water) with 700.000 km^2 and 250-1000 m thickness. Their deep start in GouraraTuat (West side) from ground surface and it dips gradually until reaching maximal depth (1000 m) in Oued Righ. It is loaded during the Quaternary period, currently; it receives low recharge from Saharan Atlas, and it debits 50 to 400 l/s at 25 to 70 °C [21].

Complex Terminal**:** The Complex Terminal aquifer is less extensive than the Continental Intercalary, but it is considered more renewable [21]. Nevertheless, it covers about 350,000 km^2 which present the major part of the basin of the north-western Sahara. Its depth varies between 100 and 500 m with 220 m as average thickness.

Phreatic zone**:** It is located below the water table at saturation zone (black color) where relatively all pores and fractures are saturated with water, it defines the lower edge of the Vadose zone [22]. It is characterized by its low depth (shallow aquifer) and high salinity, traditionally; it is used as supply wells and sanitary water sources.

B. *Maps of groundwater capacities*

For numerical simulation, geographic information system software (ArcGIS) [23] is used to interpret geographic data. In Ghardaia and Ouargla provinces, wells data (coordinates and depth) are gathered presented in geo-referenced form as groundwater depth contours (see figure 2). Ouargla province is divided in three different zones; the depth range of 64 to 84 meters is in the first zone (dark blue) due to population concentration (Touggourt and Ouargla cities). They contain the majority of agriculture surfaces due to the suitable depth in these zones. In the second zone (marine blue) the depth varies between 84 and 103 meters. Towards the west, this depth rises and the third zone (light blue) starts. Also, the depth rises towards the south due to the influence of Tassili Mountains.

For Ghardaia province, the area is divided into many zones according to the groundwater depth; it is generally rising from the western south where the range depth is 63-147 meters (light blue), to the eastern north of the province where the depth reach 1200 m as maximal value (dark blue). This distribution is due to altitude increase in the north-east (mountainous relief) and to Albian roof which getting deeper by going from south-west to north-east. The comparison between these provinces shows that generally the wells depth in Ouargla region is less than those in Ghardaia region, because Ouargla is located above the complex terminal groundwater which is less deep than the continental intercalary where Ghardaia province is located.

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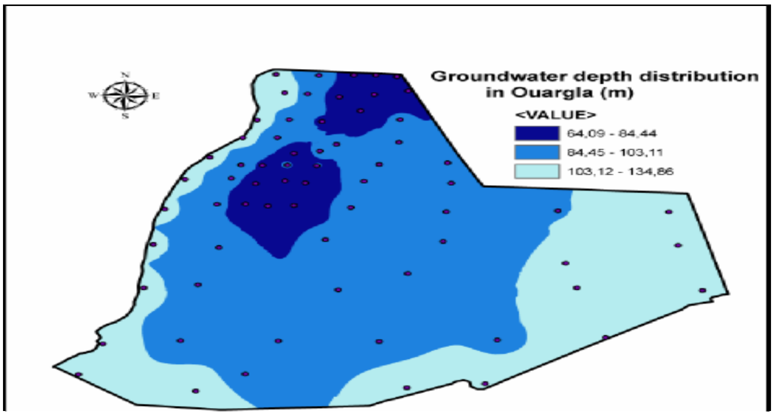

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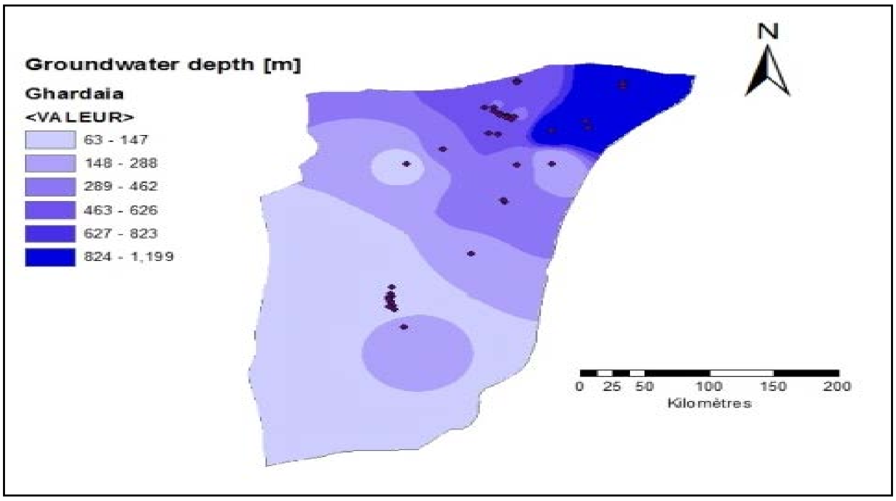

(b)

Figure 2: Groundwater depth: a) Ghardaia and b) Ouargla

C. Water precipitation

For presenting annual precipitation rate, the same steps are followed in ArcGIS software. The experimental precipitation data are gathered from the Algerian Mateo office (centre of Ouargla), also, province borders points (neighbors' cities) are taken from analytical climate model. All these data are interpolated; obtained results are presented as contours in figure 3. In Ouargla, the area is characterized by uneven rainfall, it vries between minimal value of 0,4 mm in July and it reach its maximal level in January with 19,9 mm. The average annual precipitation is about 70 mm/year. For Guardia, precipitation gets 2.2 mm as minimal value in July and reaches its maximum (22.4 mm) in September. The average annual precipitation is 92.5 mm/year. Generally, even its rarity, rainfall plays an important role in recharging the Miopliocene aquifer (CT) in Ouargla regions [24].

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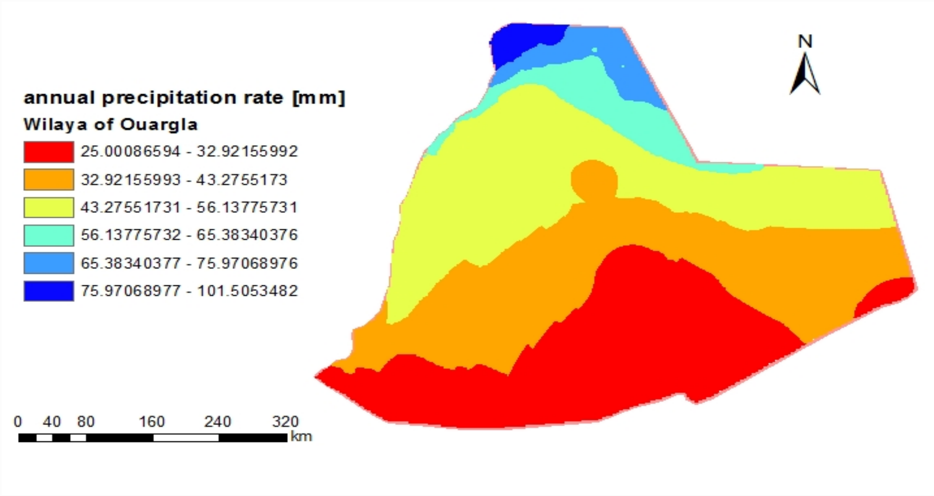

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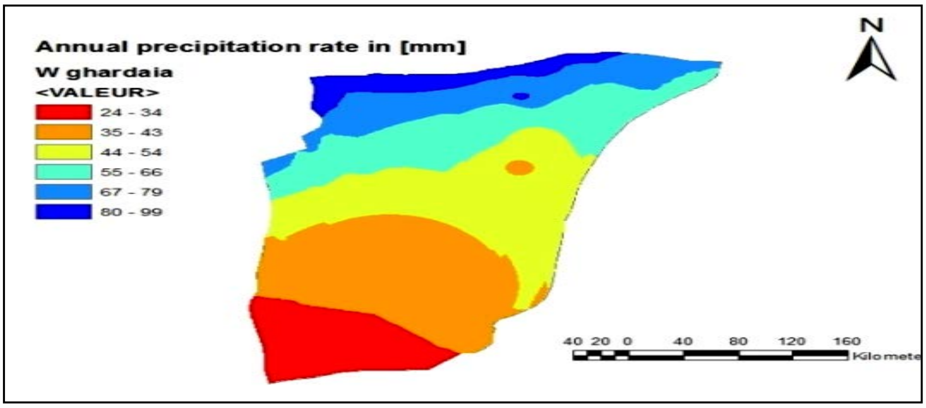

b)

Figure 3: Annual precipitation rate [mm]: a) Ghardaia – b) Ouargla

D. Soil quality

. By using Google Earth, in studied region, and consulting topographic maps, different type of soil surfaces are estimated and plotted as contours. All these contours are imported in ArcGIS and each type of soil has specific color. Then, exclusion step is carried out to eliminate sandy and rocky surfaces. It remains only the zones that containing cultivated area and plains which favorable for planting olive trees

Ghardaia soil types**:** Figure 4a shows soil types in Ghardaia which contains five main types of soils. Sand area (Erg) extends from the east borders (Grand Erg Occidental). Rock soil lies in the South; it is the extension of Tadmait plateau. Some mountainous areas are found in the north. They are Rock Mountains which are interspersed along seasonal Valleys. These valleys are observed in most of Ghardaia province cities, like Ghardaia, Guerrara, berriane, Metlili; Mensora, Sebseb. Remain areas are plains; they cover the east borders with the frontier of Ouargla.

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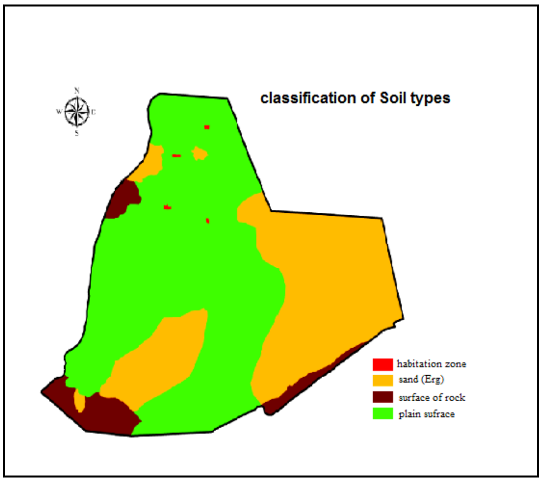
Ouargla soil types: Figure 4b shows main kinds of soils in Ouargla. In the east, there is the Grand Erg oriental; it is covered by sand (Erg) which has low consistence. This zone isn't favorable for planting olive trees. Rock lands coexist in the frontier of Ghardaia province. The zones near Illizi and Tamanraset provinces are excluded because of its hard consistence. Also, small areas are covered by habitations which contain the big cities (Touggourt, Ouargla, El-Hadjira, and Hassi Messaoud). For plain surface (able for cultivation), it contains some small areas of sand, chott and sebkha which are not suitable for olive tree agriculture. Shott and Sebkha have high salinity and they need water draining in order to reduce the effect of phreatic aquifer. For long term planning, these high salinity areas can be treated and explored as supplementary areas for olive tree agriculture.



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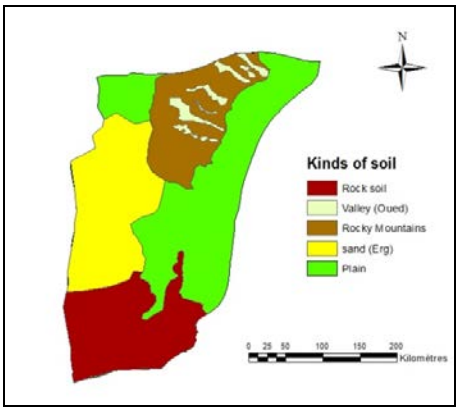

b)

Figure 4: Soil types: a) Ghardaia and b) Ouargla

E. Plain land

After the exclusion step concerning no suitable areas, the map of wide plain lands able for cultivation is obtained. In Ghardaia, the plain land reaches 2881800 hectares (see figure 5a); it represents about 37% of total province surface. According to the Data from DSA (direction of agriculture service), in 2015, the cultivated surface is about 32745 hectares. Among this surface, only 1269 hectares (4%) are cultivated by olive trees. In

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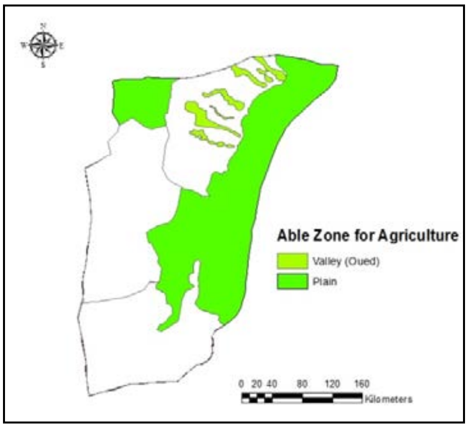
Ouargla region, the plain land reaches 12297800 hectares (see figure 5b); it represents about 58 % of total province surface. According to the Data from DSA, the cultivated surface is about 39737 hectares. Among this surface, only 1206 hectares (3%) are occupied by olive tree cultivation.

a)



b)

Figure 5: Plain soil: a) Ghardaia and b) Ouargla

F. Suitable areas for olive trees

Suitable areas are obtained by superposing the three maps (soil, precipitation and groundwater depth). The intersection between the three maps gives the suitable areas for olive tree cultivation (see figure 6), where they must insure olive conditions life (plain, Soil, low groundwater depth) at first level and high precipitation rate at second level. The suitable surfaces are evaluated at 3 250 000 hectares for Ouargla province, and 1 940 000 hectares for Ghardaia province.

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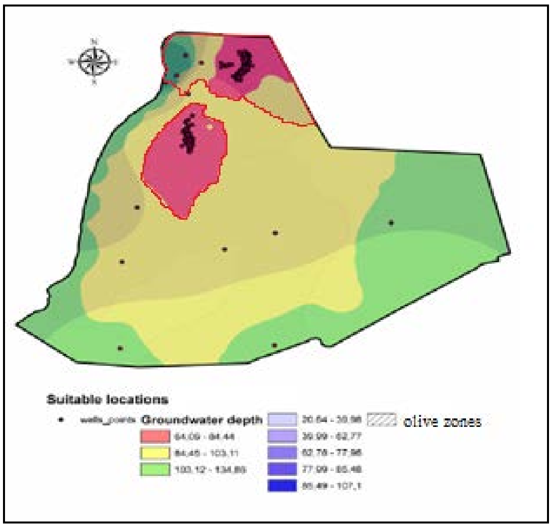

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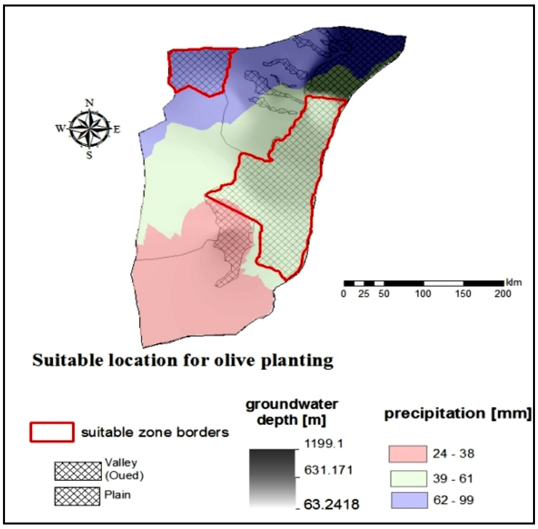

b)

Figure 6: Suitable areas for olive tree agriculture

A. Solar radiations

The solar energy is the most important renewable energy resources in the world. Ouargla and Ghardaia regions are known among the shiniest areas in the world, where solar shine duration reaches an average of 3340 h/year, this radiation can gives an energy potential of 2900 KW/m^2/year [25]. Olive trees have good living in shiny zones. The studied area has high radiation potential, its distribution is almost similar from the East to the West, but, it has small increase from the North toward the South. The daily radiation lies between 5.3 and 6.5 KWh/m^2 [26]. According to the high solar energy in Ouargla and Ghardaia regions, the usage of photovoltaic pumping for olive tree cultivation against conventional electric supply can be the best solution to reduce olive agriculture cost. B. Dokkar et al. [11] found that there is high electricity consumption for the irrigation in these regions. So, it is better to drill water wells and opt to irrigate by using solar pumping. It doesn't need batteries for energy storage. Indeed, it has a profitable payback on the long term [11].

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IV. BIO-ETHANOL PRODUCTION

A. Biomass of olive

The oil residues obtained from the various extraction systems has to undergo some operation to completely separate the oil from the vegetable water. For immiscible liquids with different densities can be separated by natural settling or centrifugation [27]. In Algeria, olive Oil industry rejects big amount of residues which affect the environment. So, it requires special care to treat this important discharge [28]. For better exploitation of olives biomass residues the flowing resources are included: olive tree pruning (OTP) (leaves, thin and thick branches) performed every two years after fruit harvesting, olive stones (OS) after oil separation and from table olive industry, olive oil pomace including vegetation and process waters, all substances coming from the fruit except olive oil, olive mill wastewater (OMWW) from olive fruits cleaning and horizontal centrifuge (decanter), and olive leaves found in lower machine at the early steps of olive cleaning [29].

In Ouargla region, olive oil yield is about 12%, therefore the residues represent 88% of total olive production. For Ghardaia, according to its oil yield, this percentage is about 10% of total olive (see table 1). The pomace oil is extracted from this mixture and destined for consumption as olive oil of second level or mixed with virgin oil [30].

Table 1: Olive residues in Ghardaia and Ouargla (2015 year)

Province \ Olive residues	Olive stones	Pomace oil	Pomace dry residues	Waste-water
Ghardaia(Kg)	569250	56925	370012	1850063
Ouargla (Kg)	530640	53064	344916	1724580

B. Bio-ethanol extraction

For producing ethanol (C_2H_5OH) biomass fermentation [31] is adopted by choosing second generation process which is generally produced from olive lingo-cellulosic biomasses and others by-products residual. Pretreatment is carried out after collecting and comminuting, the first stage of lingo-cellulose-based bio-refinery. It aids in the ready fractionation of the biomass into its key constituents, cellulose, hemicelluloses and lignin, while facilitating its subsequent conversion into fuels and high value co-products in high yield. Also, enzymatic hydrolysis is proceeded in order to depolymerize the polysaccharides contained in the pretreated lingo-cellulosic substrates [32]. Then, to get ethanol, sugars fermentation by enzymatic hydrolysis of cellulose or hemi-cellulosic-derived sugars from prehydrolysates is carried out by using yeast. For ethanol feedback each residues needs a special process to be converted into ethanol, so ethanol feedback varies from a substance to another [29]. These fractions are: 0.26 g/g olive stone (OS), 0.26 g/g pomace dry residues (PDR), 0.0142 g/ g Wastewater (OWW), and 0.171 g/g olive tree pruning (OTP). For ethanol extraction, it is proved by experience that 1 ha of olive trees can gives an average of 1500 kg of tree pruning and 2500 kg of olive [29]. The main source of ethanol is tree pruning and Pomace as shown in figure 6 which presents olive residues and Ethanol extraction 2015.

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C. Long term ethanol production

The investigation using ArcGIS software shows that able surface for olive cultivation is 3250000 ha in Ouargla, and 1940000 ha in Ghardaia; this surface can be cultivated in long term investment program; by dividing the entire surface on equal sub-surfaces distributed every year. In this study, an investment of 25 years is considered, and ethanol production is calculated adopting a period of 5 years for olive tree production by using trend and voluntary models. Trend model (25%) is considered as reality, by investigation of real data where only 25% of given surfaces are real fruit production. Voluntary model (75%) is estimated as optimistic objective to improve this agriculture. During all period, this rate is taken as constant because olive agriculture is new activity and its performance is not well known in the region**.** Noting that every year total surface attributed to farmers is 1200 ha in Ouargla and 1265 ha in Ghardaia. By applying the average of olive tree per hectare and the fractions of ethanol feedback, the ethanol production is estimated for long term period (see figure 7). Figure 8 shows the progression of ethanol production in the period 2015- 2040 for Trend and voluntary models.

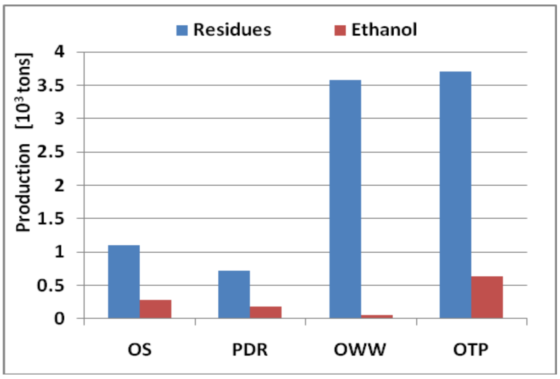

Figure 7: Olive residues and ethanol extraction in 2015

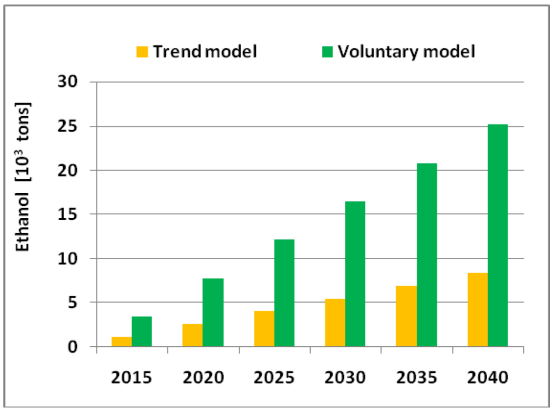

Figure 8: Evolution of ethanol production

A. Bio-ethanol production cost

The introduction of all dispenses is need for evaluating bio-ethanol cost. This cost includes both olive residues as raw materials and production cost (conversion, electricity, reagents and Enzymes and labour).

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Raw material prices are low because nowadays these residues are free, only the cost of transportation is taken into account. So, in 2016, these prices are estimated as: 0.1 DA per 1 kg of Olive tree pruning and 0.5 DA per 1 kg of pomace residues. Total cost of converting raw materials into Ethanol is equivalent to 210.41 DZA (1.68 €) for producing 1 litter of ethanol. The obtained cost is high compared to the Europe market price (1.485€/l) because the present extraction process is for small scale production, this cost can decrease when using big scale production.

V. CONCLUSION

The multi-components of olive biomass residues such as tree pruning, olive stones, pomace oil, pomace residues and wastewater presents important raw materials for bio-ethanol refinery. Also, natural conditions for olive cultivation such as soil nature, rainfall, and groundwater are important factors to intersect between them for finding the maximal suitable areas for olive tree cultivation. These huge areas are evaluated at 3250000 ha for Ouargla province and 1940000 ha for Ghardaia province. In addition, the big amount of solar radiation gives high opportunity for using photovoltaic pumping instead of conventional supply for olive tree irrigation in order to reduce the production cost for long term planning.

The comparison between bio-ethanol cost produced from olive residues in the south of Algeria (1.68 €/liter) and average price applied in world markets (around 1.485€/liter) shows this bio-ethanol is more expensive. But, as this product is clean fuel the level price is acceptable. Noting, that in foreign markets (especially European market), the governments are supporting bio-fuels use by grant subsidies for encouraging people to consume bio-fuels rather than conventional fuels. So, local authorities can opt for these subsidies to make beneficial activity for producers. Also, the application of solar water pumping will contribute to reduce the production cost for long term investment.

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