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Determination of the Amount of Land Area Required for Alternative Second-generation Feedstock to Replace First-generation Feedstock in Biodiesel Production in Turkey

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Abstract

In this study, the amount of land area required for the replacement of sunflower and cottonseed plants, which are used as the first-generation feedstock source in the biodiesel production sector, which has the highest growing area as an oil plant in our country, with the second-generation vegetable oil feedstock was calculated. Safflower and rapeseed plants were selected as the second-generation vegetable oil feedstocks source. In this way, the required amount of land area and the amount of land saved to provide the same total potential biodiesel volume using second-generation feedstocks in the production sector has been determined. With the increase in the use of second-generation feedstock in biodiesel production, it is expected that land area use will be saved, our oil imports will decrease, and the pressure on the food sector will alleviation.

Keywords: Plantation area, biofuels, biodiesel, vegetable oil feedstocks, sustainability

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INTRODUCTION

In today's world, where conventional energy sources gradually decrease, energy is becoming one of the most expensive production inputs. Its importance is felt day by day with its polluting feature. Fossil fuels are unsustainable energy sources directly related to air pollution, soil pollution, water pollution, and climate changes. In this direction, governments, industrial organizations, non-governmental organizations, and agricultural unions struggling with global climate change always give privilege to the use of renewable energy sources, together with environmental awareness. Biofuels are seen as an attractive alternative to existing petroleum-based fuels. They can be used as transportation fuels with little change, are sustainable, provide energy security, and have significant potential to reduce greenhouse gas emissions (Ulukardeşler and Ulusoy, 2012; Göçer and Zaimoğlu, 2018). Biofuels are fuels of biological origin and are one of the energy sources that have come to the fore in recent years among renewable energy sources. Biofuels can be obtained from agricultural and forest products, animal and vegetable residues, and wastes, organic domestic, industrial, and urban wastes by thermochemical or biochemical methods. Biofuels can be in the form of solid, gas, or liquid. Solid biofuels include briquettes, pellets, biochar, and charcoal. Gaseous biofuels; consist of syngas, biogas, biohydrogen. Liquid biofuels include biodiesel, bioethanol, biomethanol, bio-dimethyl ether, and bio-oil (Avcıoğlu et al., 2011).

First-generation biofuels, whose production is commercial today, have a production of approximately 50 billion liters per year. First generation biofuels raise concerns in some scientists, especially on environmental and carbon balance issues. They argue that especially the increased production of first generation biofuels affects the food sector, which is the reason for the increase in food prices (Naik et al., 2010). Without the need for a design change in internal combustion engines biodiesel, defined as fatty acid methyl ester and bioethanol produced from sugary and starchy sources, constitute first-generation biofuels.

According to the International Energy Agency (IEA), second-generation biofuels are produced from cellulose, hemicellulose or lignin. Such biofuels can be blended with petroleum-based fuels or used in adapted vehicles (IEA, 2010). Navigant Research (2014) guess that global biofuel consumption in the road transportation sector will enlarge from more than 122.6 billion liters per year in 2013 to more than 193.41 billion liters per year in 2022, which will increase demand for advanced biofuels. In the last ten years, an increase in ethanol production capacity in the United States and Brazil, and biodiesel in Europe has resulted in biofuels gaining an important position in the global market for fuel. In the global liquid fuel market, biofuels have been particularly prominent in plenty countries and the production and consumption of biofuels like biodiesel and ethanol have been growing rapidly (UNCTAD, 2015).

Second-generation biofuel from locally available sources in each country can play a significant role in the economic development of that country's rural and developing regions. The production of 2nd generation biofuels is non-commercial, although pilot and demonstration facilities are being developed. Therefore it is anticipated that these 2nd generation biofuels could significantly reduce CO_2 production, do not compete with food crops, and some types can offer better engine performance. When commercialized, the cost of second-generation biofuels can be more comparable with standard petrol, diesel. It would be the most cost-effective route to renewable, low-carbon energy for road transport (Mofijur et al., 2021).

The two primary feedstocks for the production of second-generation biofuels are lignocellulosic and biodiesel feedstocks. Biodiesel, which has a biodegradable structure, is a second generation biofuel. . The main factor that creates the cost of biodiesel production is the oil feedstocks. Therefore, the way to reduce biodiesel production costs depends on the selection of the appropriate feedstock source. The main goal is to produce biodiesel at the lowest price and on a large scale. In general, oil raw materials used in biodiesel production can be classified into four groups. (i) edible vegetable oils (soybean, corn, sunflower, palm oil, etc.); (ii) inedible vegetable oils (camelina, karanja, mahua, jatropha, etc.); (iii) waste or recycled oils (cooking oils, vegetable oil soap stocks, etc.), (iv) animal fats (chicken fat, beef tallow, lard, fish oil, etc.).Inedible vegetable oils, waste or recycled oils, and animal fats are considered second-generation biodiesel raw materials. (Demirbaş, 2007; Lim and Teong, 2010; Balat 2011; Bhuiya et al., 2014; Silitonga et al., 2013).

Many countries in the world produce biodiesel from oil crops that are different and suitable for their ecological conditions. Figure 1 shows the most dominant biodiesel production feedstocks of different countries. Today, biodiesel has become more and more affordable due to the introduction of subsidies and tax exemptions (Mofijur et al., 2021).

Figure 1. Source of in different countries (Gardy et al, 2019)

According to the 1st Biodiesel Industry Report published in 2019, in the biodiesel sector in our country in 2018, as raw material sources, 32 000 tons of waste vegetable oil with a share of 30%, 35 000 tons of cotton oil with a share of 32%, 28 000 tons of canola with a share of 26%, 4200 tons of safflower oil with a share of 4%, and 8800 tons of other oils with a share of 8%. "Communique on Blending Biodiesel into Diesel Types" prepared by the Energy Market Regulatory Authority based on the Petroleum Market Law No. 5015 and the Regulation on Technical Criteria to be Applied in the Petroleum Market was published in the Official Gazette dated 16 June 2017 and numbered 30098 and entered into force. According to this communiqué, the blending ratio of biodiesel to diesel fuel was determined as 0.5%. In this way, it is aimed to reduce foreign dependency on energy, increase resource diversity, ensure efficient recovery of waste vegetable oils, reduce environmental pollution and adapt to the renewable energy policies of the European Union.

Considering our country's climate and soil characteristics, it has excellent potential for the production of oilseed plants. According to the data of the USDA report for the 2019-2020 growing season, total oilseed production in the world is approximately 577.15 million metric tons. Soybean ranks first with a production of 337.14 million metric tons, followed by rapeseed (canola) with 68.20 million metric tons and sunflower with 55.04 million metric tons (USDA, 2020).

Ranking first in oilseed production in Turkey in 2019, sunflower production is approximately 1.9 million tons, cotton production is 1.320 million tons, rapeseed production is 180 thousand tons, soybean production is 150 thousand tons, safflower production is 21.9 thousand tons, and sesame production is 16.9 thousand tons. The most cultivated area is a sunflower with 675.9 thousand ha, followed by cotton with 477.9 thousand ha, rapeseed with 52.5 thousand ha, soybean with 35.3 thousand ha, sesame with 24.9 thousand ha, and safflower with 15.9 thousand ha.

In our country, which has very different climate and soil characteristics ecologically, the production of oilseed plants cannot meet our consumption amount. The sustainability of biodiesel production, which has an important place among biofuels in providing energy diversity in our country, depends on the excellent display of vegetable oil raw materials. The production of oilseed plants will be brought to the desired levels, especially with the use of marginal and fallow areas in energy agriculture and specific agricultural regions.

According to the plant production data of the Ministry of Agriculture and Forestry in 2020, our total agricultural lands are 23 136 000 ha. While the area used for the cultivation of field crops is 15 615 000 ha, 3 173 000 ha has been left fallow. As a result of the increase in the population and the decrease in the total amount of agricultural land in Turkey, the amount of agricultural land per capita has decreased. In the 1990-2018 period, the population of Turkey increased by approximately 45.2%, and the shrinkage in agricultural areas per capita in the same period was 39.3%. The first generation feedstock in biodiesel production is edible oils used in the food industry. Second-generation feedstock, on the other hand, is non-preferred and inedible oils, especially in the food sector. The main alternative oil crops grown in our country are; rapeseed, safflower, camelina, sesame, and pelemir.

In this study, the amount of land area required to replace oilseed plants, which are used as a first-generation feedstock source in biodiesel production in our country, with second-generation oil raw materials that are not used in the food sector, were determined. In the study, sunflower and cottonseed were selected as first-generation biodiesel feedstocks. Rapeseed, which is harmful to human and animal health due to the high content of erucic acid and glucosinolate in its oil, was chosen as the second generationfeedstock, and safflower which is not preferred as edible oil. Camelina and pelemir plants, which are very suitable for use as second-generation feedstocks in biodiesel production, could not be used as a vegetable oil raw material source in this study because they have not reached sufficient production amount commercially in our country.

MATERIAL and METHOD

Materials

In this study, sunflower and cottonseeds were selected as the first-generation feedstock sources in the biodiesel production sector, while safflower and rapeseed were chosen as the second-generation feedstock sources. Data were taken from the public, online sources. Food and Agriculture Organization (FAO) of the United Nations Statistics Division (FAOSTAT) was used as the source for 2019 year. The crop yield data of each first and second generation feedstock which is obtained from FAOSTAT for Turkey.

Second-generation biodiesel feedstocks - replacement

Non-edible second-generation biodiesel feedstocks can be grown on non-arable land, although they can save lands for food production can be held. The potentially carbon-neutral feedstocks also do not raise food prices as they do not directly compete with agricultural food products for space and water. Food security can be correlated to plowland (Irabien and Darton, 2016). The land can be seen as a central to store, convert and provide energy for food production. By adjusting the preference to meet the local food demand and using the extra land to produce biofuel feedstocks, there could be a net improvement in food and energy security. But it still requires more study for feasibility and productivity for second-generation biodiesel feedstocks (Hasan and Avami, 2018).

At present, the total global renewable energy is 72.12×10^{12} MJ. By introducing the total potential biodiesel volume from all countries into the energy market, the value can be increased to 74.90×10^{12} MJ. Figure 2 shows the most dominant feedstock used in second-generation biodiesel production for each country in the world. Jatropha is a superior feedstock as it is the potential dominant feedstock in 62 out of 130 countries. Camelina is also an ideal feedstock in all European countries (Chong et al., 2021).

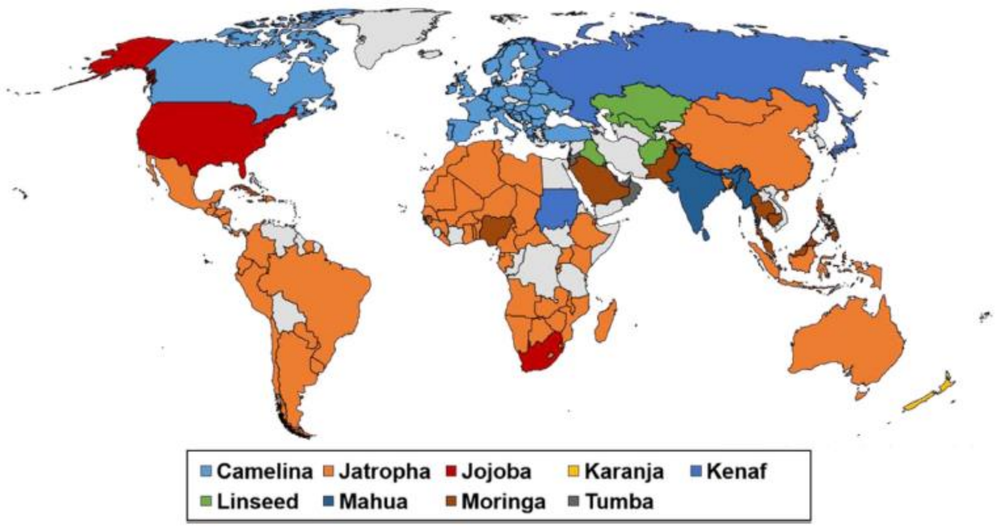

Figure 2. Potential dominant second-generation biodiesel feedstock of each country.

In this study, sunflower and cottonseed were selected as first-generationfeedstocks. These plants are the first two oilseed plants with the most planting area in our country. As seen in Figure 2, the second-generation feedstock foreseen for our country is camelina. However, since the cultivation areas of this plant are minimal, the data to be used in the calculations could not be reached, and safflower and rapeseed, which are our alternative oil crops, were taken into consideration in this context.

The safflower plant is a potential oil plant planted in large areas in our country with its comprehensive climate demands, high drought and heat tolerance, availability in summer/winter forms, and suitability for mechanization. Although its importance has increased rapidly globally, there has not been a significant development in agriculture until today, since it is not sufficiently known and its importance is not adequately understood in our country. 86% of biodiesel production in the world is provided from the rapeseed plant. However, when the TUIK 2019 data were examined, rapeseed agriculture could not reach the desired levels in our country. The oil content of rapeseed seeds is between 40-45%. Since the high erucic acid and glucosinolate in its oil are harmful to human and animal health, it is one of the most suitable oil plants for energy agriculture (Yıldırım, 2005; Bayramin, 2006; Gizlenci et al., 2012; Yılmaz et al., 2021).

Calculation of total plantation area of first-generation feedstocks

The total plantation area of first-generation feedstock (TPA_j) to produce the total potential biodiesel volume is calculated using the following equation 1:

$$TPA_j = \sum_i \frac{EQ_{ij} \times 1000}{CY_{ij} \times OC_i} \qquad (1)$$

Equation 1 means CY_{ij} , OC_i and EQ_{ij} are the crop yield, oil content and export quantity of the feedstocks, respectively. The crop yield and export quantity of each first-generation feedstocks which is obtained from FAOSTAT varies for Turkey (FAO, 2014b). First-generation feedstocks with export quantity values below the threshold value of 10 000 tons are not considered in the calculation of potential biodiesel production (Chong et al., 2021).

Therefore, calculations were made by considering the data of sunflower and cotton seeds in the study since they have production values above the threshold value. Any export quantity of vegetable oils that is lower than the threshold is considered to be inadequate for the potential biodiesel production. The threshold value is based on a generic biodiesel plant with a capacity of 10 million litres per annum (USDA, 2017). The export quantity which reaches the threshold value is used in the calculation of the potential biodiesel production.

Calculation of total plantation area of second-generation feedstocks

The land area required by second-generation feedstocks (SPA_j) to produce the same volume of total potential biodiesel volume is calculated using the following equation 2:

$$\mathrm{SP}A_j = \frac{TPBV_j \times OD_i}{CY_i \times OC_i \times CR} \quad (2)$$

Equation 2 means total potential biodiesel volume, $TPBV_j$, OD is the oil density and CR (0.98) is the volumetric conversion ratio from oil to biodiesel. The land area saved by replacing first-generation feedstock with second-generation feedstock can be equated by deducting SPA from TPA (Chong et al., 2021; Johnston and Holloway, 2007).

RESULTS and DISCUSSION

Sunflower and cottonseed places as the first-generation dominant feedstocks sources in biodiesel production sector in our country. Table 1 contains the necessary data for calculating the plantation areas of first-generation biodiesel feedstocks. Table 1 shows the crop yield and export quantity information of sunflower, cotton seed, safflower and rapeseed oil crops for 2019 growing season according to FAOSTAT 2021 data.

Table 1. Properties of first and second generation vegetable oil feedstocks in Turkey

Feedstocks	Oil content (wt%)	Crop yield (kg/ha)	Export quantity (tons)	Reference
Sunflower	30	27937	544593	Altın et al. (2001), Karmakar et al. (2010)
Cottonseed	21.5	46044	9986	Agarwal (2007), Altın et al. (2001)
Rapeseed	42	34279	968	Agarwal (2007),
Safflower	40	13798	-	Altın et al. (2001)

Table 2 demonstrate the amount of plantation areas required for sunflower and cottonseeds, which are used as first-generation vegetable oil feedstocks in biodiesel production in our country. The TPBV value used in Equation 2 was calculated according to Chong et al. (2021).

Table 2. First-generation feedstocks plantation areas

Feedstocks	**TPA (ha)**
Sunflower	649787
Cottonseed	10087
Total	659874

Table 3 shows the amount of land area required by second-generation biodiesel feedstocks to produce the same of total potential biodiesel volume.

Table 3. The amount of land area required for second-generation vegetable oil feedstocks

Feedstocks	**SPA (ha)**
Rapeseed	383.525
Safflower	1002.643

The total potential biodiesel volume obtained by using all sunflower and cottonseeds grown in our country in the 2019 sowing period as a first-generation feedstock has been calculated as 593338554 liters. To achieve this production volume, the sunflower was grown in 649787 ha area, cottonseed was grown in 10087 ha area, and 659874 ha of land area was used for this cultivation in total. As can be seen from these results, if the rapeseed plant, which is not used in the food sector, were used as a feedstock biodiesel production, 383.525 ha would be needed to provide the same potential biodiesel volume, and 1002.643 ha would be required if safflower plant was used. In this way, 659490.4 hectares of land would be saved using rapeseed and 658871.3 hectares with the use of safflower.

CONCLUSION

As the population of Turkey increases, the amount of agricultural land area per capita decreases as a result of the decrease in the total amount of agricultural land. While the population increased by 45.2% between 1990 and 2018, there was a 39.3% contraction of farming areas. As a result of this shrinkage in agricultural regions, our energy resources, whose raw materials are based on agriculture and the food sector, are adversely affected by this situation. In this study, both the required land sizes and the saved land sizes were determined if the second-generation feedstocks are used instead of the first generation feedstocks in the biodiesel production sector. 659490.4 and 658871.3 hectares of plantation area can be saved in Turkey, by replacing sunflower and cottonseed as a first-generation feedstocks with rapeseed and safflower, recspectively. Second-generation biodiesel feedstocks can be planted in non-arable lands and do not compete for lands with food crops, making them good candidates to replace first-generation feedstocks. In 2020, 3173000 hectares of agricultural land was left fallow in our country. It is essential to use these areas and the areas we save thanks to using second-generation vegetable oil feedstock in energy agriculture. Ensuring energy security and the production of biodiesel, which is one of our renewable energy sources, depends on the sector throughout the year. To achieve it is crucial to evaluate these areas primarily for planting the necessary oilseed plants. There could be a net improvement in food and energy security by arranging the local food demand and using the extra land to produce biofuel feedstocks.

REFERENCES

Ulukardeşler A.H. & Ulusoy Y. 2012. 3. Nesil Biyoyakıt Teknolojisi olan Alglerin Türkiye de Üretilebilirlik Potansiyeli, *Onuncu Ulusal Kimya Mühendisliği Kongresi*, 3-6 Eylül 2012, Koç Üniversitesi, İstanbul.

Göçer S. & Zaimoğlu Z. 2018. Üçüncü ve dördüncü nesil biyoyakıtların araştırılması. *Uluslararası GAP Yenilenebilir Enerji Ve Enerji Verimliliği Kongresi*, 10-12 Mayıs 2018, pp: 71-75, Şanlıurfa, Türkiye. (Conference paper), GAP Yenilenebilir Enerji ve Enerji Verimliliği Merkezi (GAPYENEV-2018).

Avcıoğlu A.O., Türker U., Atasoy Z.D.& Koçtürk D. 2011. Tarımsal Kökenli Yenilenebilir Enerjiler-Biyoyakıtlar, *Nobel Yayıncılık*, Ankara.

Naik S.N., Goud V.V., Rout P.K. & Dalai A.K. 2010. Production of first and second generation biofuels: A comprehensive review, *Renewable and Sustainable Energy Reviews*, 14, 578-597.

IEA, (2010). Sustainable Production of second-generation Biofuels: Potential and perspectives in major economies and developing countries. https://www.iea.org/publications/freepublications/publication/second_generation_biofuels.pdf / (accessed 20 September 2021)

Navigant Research (2014) Biofuels demand for road transportation will surpass 51 billion gallons annually by 2022. https://www.navigantresearch.com/newsroom/ biofuels-demand-for-road-transportation-will-surpass-51-billion-gallons-annually-by-2022/ (accessed 15 September 2021)

UNCTAD, 2015. Second generation biofuel markets: State of play, trade and developing country perspectives. *United Nations Conference on Trade and Development (UNCTAD*). UNCTAD/DITC/TED/2015/8, United Nations Publication.

Mofijur M., Siddiki Y.A., Shuvho B.A., Djavanroodi F., Rizwanul Fattah I.M., Ong H.C., Chowdhury M.A. & Mahlia, T.M.I. 2021. Effect of nanocatalysts on the transesterification reaction of first, second and third generation biodiesel sources- A mini-review, *Chemosphere* 270, 128642.

Gardy J., Rehan M., Hassanpour A., Lai X. & Nizami, A.S. 2019. Advances in nanocatalysts based biodiesel production from non-food feedstocks, *J. Environ. Manag*. 249, 109316.

USDA (2020). Statistical data of USDA. Retrieved from: https://usda.library. cornell.edu/concern/publications/ tx31qh68h? locale=en./ (accessed 2 October 2021)

TÜİK (2019). Statistical data of TUIK. Retrieved from: https://biruni.tuik.gov.tr/ medas/?kn=104&locale=tr./ (accessed 2 October 2021)

TÜİK (2020). Statistical data of FAO. Retrieved from:https://biruni.tuik.gov.tr/ medas/?kn=92&locale=tr./ (accessed 2 October 2021)

Irabien A. & Darton R.C. 2016. Energy–water–food nexus in the spanish greenhouse tomato production, *Clean Technol. Environ. Policy* 18 (5), 1307–1316.

Hasan A.H. & Avami A. 2018. Water and emissions nexus for biodiesel in Iran. *Renew. Sustain. Energy Rev*. 93 (5), 354–363.

Yılmaz A., Yılmaz H., Arslan Y., Çiftçi V. & Baloch F.S. 2021. Ülkemizde Alternatif Yağ Bitkilerinin Durumu, *Avrupa Bilim ve Teknoloji Dergisi*, Özel Sayı 22, 93-100.

Gizlenci Ş., Acar M. & Şahin M. 2012. Türkiye'de yenilenebilir enerji kaynaklarının (Biyodizel, biyoetanol ve biyokütle) projeksiyonu, *Tarım Makinaları Bilimi Dergisi*, 8(3), 337-344.

Bayramin S. 2006. Aspir (*Carthamus tinctorius*L.) / Kolza (*Brassica napus*spp. oleifera L.) Tarımı ve Islahı, *Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi*,15(1-2), 74-85.

Yıldırım M. 2005. *Seçilmiş alternatif keten (Linum usitatissimumL.) hatlarının verimve verim öğeleri bakımından karşılaştırılması.* Doktora Tezi, Ankara Üniversitesi Fen Bilimleri Enstitüsü, Ankara.

FAO 2014b. Crop Yield. FAOSTAT, http://www.fao.org/faostat/en/#data./ (accessed 25 September 2021).

Chong C.T., Loe T.Y., Wong K.Y., Ashokkumar V., Lam S.S, Chong W.T., Borrion A., Tian B. & Han N.G.J. 2021. Biodiesel sustainability: The global impact of potential biodiesel production on the energy–water–food (EWF) nexus, *Environmental Technology & Innovation*, 22, 101408.

USDA 2017. Foreign Agricultural Service, U.S. Department of Agriculture Gain Report. https://apps.fas.usda.gov/newgainapi/api/report/ (accessed 22 September 2021)

Johnston M. & Holloway T. 2007. Policy analysis a global comparison of national biodiesel production potentials, *Environ. Sci. Technol*, 41 (23), 7967–7973.

Agarwal A.K. 2007. Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines, *Prog. Energy Combust. Sci*, 33(3), 233–271.

Altın R., Cetinkaya S. & Yücesu H. 2001. Potential of using vegetable oil fuels as fuel for diesel engines, *Energy Convers. Manage*, 42, 529–538.

Karmakar A., Karmakar S. & Mukherjee S. 2010. Properties of various plants and animals feedstocks for biodiesel productio, *Bioresour. Technol*, 101(19), 7201-7210.