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Exploitable Potential of Biomass Energy in Electrical Energy Production in the Mediterranean Region of Turkey

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ABSTRACT
Turkey is targeting to generate 30% of its total electricity production from renewable energy sources by 2023. The replacement of electrical energy in the Mediterranean Region of Turkey according to exploitable biomass data was determined in this study. Data from the Ministry of Energy and Natural Resources, the Ministry of Agriculture and Forestry, Turkish Statistical Institute, measurements and literature were used in the study. The technical potential of plant residues and animal-originated biomass in the region was analyzed. It is estimated that the existing plant and animal residues in Turkey correspond to 39% and 9%, respectively. These residues can meet 6.9% of the energy demand of the region, i.e. about 8.3 PJ/year. Employment can be established from the technologies to be used here. By generating electrical energy from biomass, 2 644 302 tons of CO_2/year can be reduced by generating electrical energy from biomass. The amount of biofertilizer that can be obtained after biogas production is 1 184 049 ton/year of biofertilizer can be obtained after biogas production. The calorific values measured to determine the energy values of agricultural residues were found to be between 13.0-20.7 MJ/kg.

Keywords: Renewable energy, Agricultural residues, Biomass potential, Energy substitution

1. Introduction

Although renewable energy sources (RES) have expanded rapidly in the last decade, it is pointed out that the share of fossil fuels in global energy demand is around 80% (GWEC 2018; IRENA 2018; Johnsson et al. 2018; REN21 2020; Afkari Sayyah et al. 2020). According to The Ministry of Energy and Natural Resources (MENR) in 2018, 85.5% of primary energy sources in Turkey were of fossil origin and 75.7% of them were imported. It is very important that to reduce foreign dependency by using domestic and renewable energy sources. Energy production technologies based on RES are environmentally friendly technologies that reduce foreign dependency.

The white document on RES prepared by the EU Commission in 1997 deems that achieving an increase of 8% between 2010-2020 and providing 20% of the electrical energy by RES as of 2020 is feasible (Brussels 2004). The main objective of the 2010-2014 strategic plan of the MENR is to achieve a level of 30% for RES energy generation in the total electricity supply as of 2023 in Turkey (MENR 2010).

Biomass is one of the promising alternatives in renewable energy sources to meet the future energy demand and reduce greenhouse gas emissions (Mao et al. 2015; Mao et al. 2018). Biomass includes all of the organic plant materials that are agricultural or forestry products and that can be used as fuel, in whole or in part, to recover energy (Atay & Ekinci 2020). Although Turkey has 78 million hectares of area, approximately 39.01 million hectares are used for agricultural applications. In addition, 5.8% of the national income is generated by agriculture (TURKSTAT 2019a). Approximately 50.01% of the total arable land in Turkey is used for agriculture, 10.7% is fallow land, fruit trees and vegetable fields cover 10.6% of the land while pastures and meadows comprise 37.9% of the total land (TURKSTAT 2019b). Turkey consists of seven geographical regions, each of which have different climate conditions as well as different agricultural activities, according to the geographical conditions and geographic area. The Mediterranean region enjoys a characteristically Mediterranean climate, with hot dry summers and moderately warm and rainy winters. Agriculture, tourism, animal husbandry, mining, industry, and forestry are the main economic activities in the Mediterranean Region. The economy of the region is looking for new energy sources to fill the energy deficit for the developing industry and expand. Biomass is the most important renewable energy source that can be used in the region. Direct burning of agricultural residues with the traditional method has negative effects on soil and air quality. In addition, it can be said that the biggest problems in agricultural residues are their high moisture content and low bulk density.

Biofuel, bioelectricity, and bioproducts can be generated from agricultural residues obtained from agricultural and livestock activities by using biomass energy technologies (NREL 2017). Biomass conversion technologies (combustion, co-firing, gasification, pyrolysis, CHP, Etherification/pressing, fermentation/hydrolysis, anaerobic digestion, etc.) were explained by Gokcol et al. (2009). Turkey meets about 37% of its total energy from primary domestic sources out of which 57% are biomass-based fuels (Demirbaş et al. 2001; Sürmen 2003; Balat 2004). The amount of agricultural residues is reported as 467-623 PJ/year and this value is equivalent to 22-27% of Turkey's energy consumption (Kar & Tekeli 2008).

A potential waste map was prepared for all provinces in Turkey (Avcıoğlu & Türker 2012; Aybek et al. 2015). The number of cattle, small ruminants, and poultry, as well as the amount of biogas production based on various criteria were calculated. According to the 2009 agricultural information, Turkey's annual biogas energy potential was determined as 2.18 billion m^3. It is estimated that the biogas energy balance based on the total biogas potential obtained from 68% cattle, 5% small ruminants and 27% poultry was approximately 49 PJ (Bilgen et al. 2015; Yelmen & Çakir 2016), recent studies have outlined a perspective for the biomass potential and technologies in Turkey. The studies by Saka & Yılmaz (2017) on the biomass potential and the situation in Turkey showed that the current annual plant residue was $142.4x10^6$ ton. According to BP (2018), Turkey's total annual energy consumption for 2017 was 6 623 PJ. It was estimated that 995 PJ of this consumption took place in the Mediterranean Region. It is estimated that Turkey's potential amount of waste biomass was approximately 8.6 Mtoe and that the amount of producible biogas was 1.5-2 Mtoe (WEB1 2019). The total dry agricultural residues potential of Turkey in 2019 was approximately $256x10^6$ ton which is equal to 8.29 Mtoe of raw fuel in value (BEPA 2020).

In terms of the importance and the future of renewable energy in Turkey, the target of MENR for 2023 is to generate 34 000 MW of hydroelectric energy, 20 000 MW of wind energy, 5 000 MW of solar energy, 1 000 MW of geothermal energy and 1 000 MW of biomass energy. In short, it is predicted that approximately one third (1/3) of the total electricity consumed in 2023 will be generated from RES (MENR 2010).

This study aims to technically find out the agricultural biomass potential in the research area of the Eastern Mediterranean Agricultural Research Institute, Adana, Turkey. Subsequently, the obtained results were used to calculate electrical energy production from these wastes in the Mediterranean. Plant and animal biomass potentials, types and quantities for the provinces in the region and their use for energy purposes were evaluated using the data for the region. In addition to the technologies to be deployed in the region, the potential contribution of biomass to the regional energy consumption was determined. These technologies are expected to contribute the creation of new employment areas, reducing CO_2 emissions, and use of biofertilizers instead of chemical fertilizers in agricultural areas.

2. Material and Methods

The study area is in the south of Turkey, situated between the Taurus Mountains and the Mediterranean Sea (Figure 1). The coordinates of the location are between 36° 32′ 33″ - 34° 34′ 11″ North latitudes and 29° 57′ 38″-36° 54′ 59″ East longitudes, and the region covers eight provinces. The area covers around 89 493 km^2 which is approximately 14% of the total area of Turkey. About 10% of the area consists of agricultural land while the region is populated by 13% of the population. The average temperature for January in the region was 6.4 °C, while the average temperature for July which was the hottest month is 26.8 °C, the annual mean temperature is 16.3 °C and the annual mean relative humidity is 63.2%. While the mean annual total precipitation was 725.9 mm, the share of the summer precipitation was 5.7%. Therefore, summer drought dominants in the region (Sensoy et al. 2008).

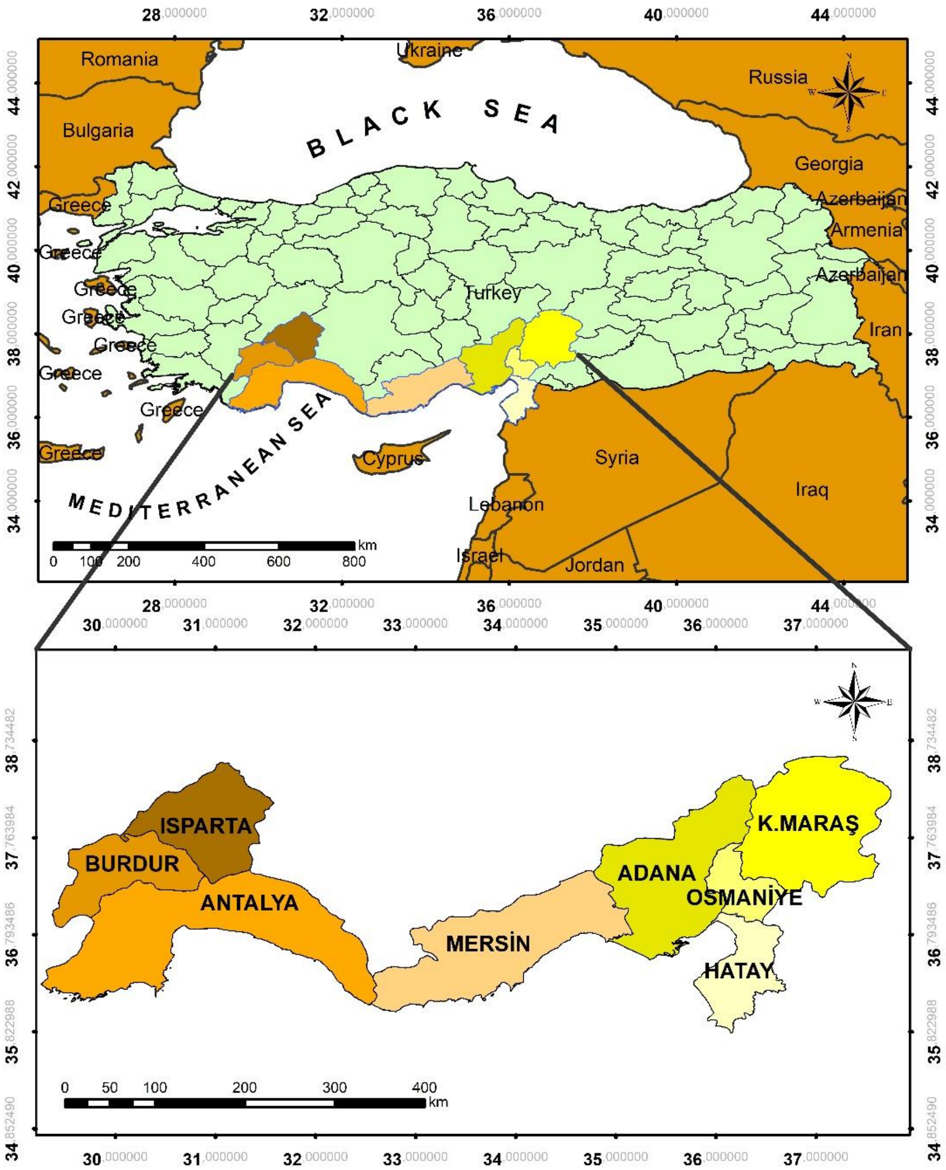

Figure 1- The Mediterranean Region

The region has an important agricultural economy and a share of more than 50% on a national basis in terms of arable land, vineyards-orchards, vegetable fields, and production. Greenhouse production is practiced the most in the Mediterranean Region in Turkey. The region also ranks first place in soybean, peanut, and corn production. In Turkey, 41% of cotton, 90% of peanut, 91% of soybean, 80% of sesame seeds, 100% of rose, 65% of anise seed, 29% of watermelon, 26% of vegetables, 22% of tomatoes, 90% of citrus fruits, 100% of banana, 18% of grapes and 16% of olives production are grown in the Mediterranean Region (TURKSTAT 2019b). A total of 34 different potential crops (trees, vegetables, and field crops) are grown in the region, but others are not grown in sufficient quantities for potential biomass energy.

The Mediterranean Region has significant potential in terms of animal husbandry. 7.9% of the country's cattle, 13.0% of sheep and goats and 9.3% of the poultry population are raised in the region (TURKSTAT 2019b).

According to TURKSTAT data for 2019, the population density of the region (person) and the amount of electrical energy consumed based on provinces (MWh/year) and agricultural areas (ha) are shown in Table 1 (TURKSTAT 2019b).

Table 1- Available biomass potential and status in the region according to 2019 data

Parameters	*Adana*	*Antalya*	*Burdur*	*Hatay*	*Isparta*	*K. Maraş*	*Mersin*	*Osmaniye*
Population (person)	2 237 940	2 511 700	270 796	1 628 894	444 914	1 154 102	1 840 425	538 759
Electricity consumption (MWh/yr)	6 754 795	8 608 939	793 877	4 390 056	1 007 211	3 902 864	4 605 510	3 709 730
Agricultural area (ha)	476 654	361 707	149 669	221 800	187 914	351 362	333 173	121 753
Number of animals								
Cattle	253 632	190 250	213 418	143 099	147 331	212 240	127 521	78 427
Small ruminant	833 027	1 273 635	410 055	414 512	537 493	925 327	1 695 174	229 174
Poultry	6 556 620	534 248	213 374	693 030	289 362	1 738 801	21 217 866	720 813
Manure amount Waste quantity (ton/yr)								
Cattle	114 562	85 934	96 398	64 636	66 548	95 866	57 600	35 424
Small ruminant	18 813	28 764	9 261	9 361	12 139	20 898	38 284	5 176
Poultry	87 051	7 093	2 833	9 201	3 842	23 086	281 707	9 570
The energy equivalent of animal waste (MWh/yr)								
Cattle	118 787	89 103	99 953	67 020	69 002	99 402	59 724	36 731
Small ruminant	3 200	4 893	1 575	1 593	2 065	3 555	6 513	880
Poultry	157 958	12 871	5 140	16 696	6 971	41 890	511 169	17 365
Annual vegetal production (ton/yr)								
Orchard (tree number)	27 782 884	25 997 154	5 425 826	34 117 471	18 577 757	27 020 858	65 438 725	5 415 963
Field crops	1 620 639	442 097	207 996	512 006	169 243	787 130	401 125	542 261
Vegetable	427 523	6 121 463	331 157	122 397	133 537	134 605	2 226 641	27 632
Biomass yield (kg/da) (kg/tree)								
Orchard (kg/tree)	3.76	3.47	2.14	3.32	2.79	2.18	2.59	3.21
Field crops (kg/da)	423.64	98.89	51.47	455.88	33.29	166.41	185.31	342.77
Vegetable (kg/da)	1124.95	2067.20	2017.38	579.26	1331.64	529.48	2218.83	600.74
Residues amount (ton/yr)								
Orchard	104 366	90 248	11 633	113 364	51 839	58 781	169 365	17 396
Field crops	1 211 740	147 948	38 024	494 768	28 712	337 498	213 901	341 562
Vegetable	193 145	26 943 421	149 109	55 087	67 820	54 619	1 328 945	12 245
The energy equivalent of vegetal residual (MWh/yr)								
Orchard	217 590	101 799	17 804	131 721	67 165	91 109	223 898	12 906
Field crops	3 620	434	110	1 463	83	999	637	1 023
Vegetable	364	48.429	268	103	122	100	2 479	23

The outputs of the study were obtained in three consecutive steps in eight provinces in the Mediterranean Region.

In the first step, statistical data published by TURKSTAT (2019a, 2019b), the Ministry for Agriculture and Forestry, and MENR as well as data regarding biomass resources in Turkey, plant, and animal production values in the "Biomass Energy Potential Atlas" (BEPA 2020) and data from the regional project executed by the Eastern Mediterranean Agricultural Research Institute and other literature (Başçetinçelik et al. 2006; Tolay et al. 2008; Bilgili et al. 2008; Kayişoğlu & Diken 2019, etc.) were utilized and are presented in Table 1. These are I) Population (person) living in the region, electricity consumption (MWh/year), agricultural lands (ha), II) In the assessment, animal species (cattle, small ruminant, and poultry) numbers (number) and plant products (9 field crops, 3 vegetable crops and 22 different types of trees). The residue amounts (ton/year) according to the plant product quantities and animal numbers were determined, no significant residue potential was obtained from other than these.

In the second step, I) Plant and animal waste potentials of the region were calculated as technical potential (ton/year). II) The lower calorific value (MJ/kg) of the plant residues in the region were analyzed in the laboratory (Table 2), and the biogas calorific value (MJ/m^3) of animal biomass was calculated according to the equation given in a literature (Samah 2016; Ozcan et al. 2015).

In the third step, I) The substitution equivalence (MWh/year) of the electrical energy consumed in the region was calculated by converting the "technical potential" of the total biomass of the region into electrical energy. II) The amount of biofertilizer that can be produced from the residue of the production facility of the calculated biogas potential (ton/year) was also determined in the study. III) The CO_2 emissions (ton of CO_2/year) for the production of both "substitution electrical energy" that can be obtained from biomass in the region as well as "substitution biofertilizer" to replace chemical fertilizer that can be obtained after biogas production were calculated.

Table 2- Average calorific values (Avg. CV) (MJ/kg) and standard deviations (Std. dev) of agricultural residues.

Crops	*Agricultural residue*	*Avg. CV (MJ/kg)*	*Std. dev. (MJ/kg)*
Orchard	Apricots	19.3	0.64
	Olives	18.1	0.48
	Figs, Almonds	18.4	0.51
	Sourcherries, Plums, Pistachios, Walnuts	19.0	0.54
	Grapefruit, Lemons, Oranges, Mandarins, Apples, Pears, Quinces, Armeniaca Vulgaris, Cherries, Peaches, Nectarines, Loquats, Pomegranates, Persimmons.	17.6	0.86
Field crops	Wheat	17.9	0.88
	Maize	18.4	0.34
	Barley, Rye	17.5	0.72
	Oats	17.4	0.67
	Soybeans	19.4	0.66
	Peanuts	20.7	0.64
	Paddy	13.0	0.07
	Cotton	18.2	0.33
Vegetable	Peppers	17.5	0.67
	Aubergines	17.4	1.09
	Tomatoes	15.4	0.93

The technical potential quantities (kg/da, kg/tree) of annual usable residues from crop production were calculated based on 4 replicate measurements and observations on a dry basis during each crop's harvest or pruning period during the study conducted in the region. Field crops and vegetable residue, annual yield, and residue rates per hectare were determined. The annual amount of residue for vineyard and orchard production was calculated as the total residue left after the pruning of each tree (Bilgili et al. 2008). The thermal production method was preferred as a suitable method for direct burning energy generation for plant residues (Tezçakar & Can 2010; Ozcan et al. 2012; Yılmaz & Saka 2017).

The total annual manure production in each province was calculated based on types and number of animals and the total manure production per one animal was calculated with the equations found in the literature (Gonzalez-Salazar et al. 2014), Equation (1-3), and in Table 1. Yılmaz & Saka (2017) proposed an anaerobic system to increase the use of energy obtained from animal manure. Biogas (methane (55-75% CH_4), carbon dioxide (25-45% CO_2), 1-10% hydrogen (H_2), 0-0.3% nitrogen (N_2) and 0-3% hydrogen sulfide (H_2S)) is formed as result of anaerobic digestion (Weiland 2010).

The calorific values were generally determined according to the methane content in biogas (Öztürk et al. 2015). The calorific value of 65% methane gas (6.1 kWh/m^3) in the biogas was converted (Samah 2016) and subsequently calculated as MWh in this study.

Daily livestock activities affect the amount of manure and the cumulative biogas potential. Animal species, diet, body weight, total solids ratio, volatile matter ratio in solids, waste availability, and biogas efficiency have a high impact on the waste potential of animals. While the availability of poultry manure is very high, bovine manure can be collected in less amount and the availability of manure is much lower for small ruminant animals due to the limited time in the shelter.

The next procedure was followed to calculate the amount of biogas production: the amount of annual manure of three animal species in 8 provinces was calculated with Equation (1, 2 and 3), and the amount of total annual manure was estimated with Eq. (4) (Gonzalez-Salazar et al. 2014). The number of each species was determined according to the data of BEPA (2020).

$$\sum_{i}^{8} AB_{c}=\sum NA_{c}.(M.(0.365)).SC.WA \quad (1)$$
$$\sum_{i}^{8} AB_{s}=\sum NAs.(M.(0.365)).SC.WA \quad (2)$$
$$\sum_{i}^{8} AB_{p}=\sum NAp.(M.(0.365)).SC.WA \quad (3)$$
$$\sum_{i,j}^{8,3} TAB=\sum ABc+\sum ABs+\sum ABp \quad (4)$$

Where TAB is total animal biomass (ton/year), j is animal species (3 species),

Where: í, Number of provinces; c, s and p: cattle, small ruminants and poultry, AB: the amount of animal manure (ton/year), NA: Number of animals (number), M: the amount of daily produced animal manure (kg/day), k: coefficient (0.365 year/ton), SC: solid content (%), WA: Waste availability (%).

The amount of manure was determined based on the daily feeding and manure accumulation habits of the animal species. In other words, the amount of manure produced (M) by cattle, small ruminants, and poultry was estimated as 15, 3, and 0.074 kg/day, respectively (Hart 1960). Table 3 shows that the characterization of waste varies.

Table 3- Physical properties of animal manure (Hart 1960)

Animal species	*Body weight (kg)*	*Wet waste amount*		*Solid content (%)*	*Waste data (kg/day)*
		% of weight	*(kg/day)*		
Poultry	1.5-2.3	3-5	0.08-1.6	10-90	0.074
Small ruminants	30-75	4-5	2-3	23-30	3
Cattle	135-800	5-6	10-30	5-25	15

Waste availability (WA) was selected as 55% for cattle, 13% for small ruminants, and 99% for poultry, taking into account the time the animals remain in shelters (Avcıoğlu & Türker 2012). Availability is a measure of a collectible manure fraction that varies with livestock conditions (Ekinci et al. 2010, Yılmaz & Saka 2017).

The total biomass obtained from animal manure was determined by multiplying the total number of animals, the total amount of dry manure, the availability value, and solids content of the manure (Equations 1-3). The solids content (SC) factors were taken as 25%, 23%, and 11.5% for poultry, small ruminants, and cattle, respectively (Ekinci et al. 2010). Annual total biomass amount according to animal species in eight provinces is given in the Eqs. (1-3):

The total annual biomass amount of 3 animal species in eight provinces was calculated with Equation 4. The total energy from animal manure (MWh/year) was determined by multiplying the total amount of animal manure (ton/year), the thermal value of biogas (MJ/m^3) and the coefficient of gas engine efficiency (%) (Özcan et al. 2012). The amount of biogas production was accepted as approximately 200 m^3 per ton of dry manure, the calorific value of biogas was taken into account as 22.7 MJ/m^3 (6.1 kWh/m^3) (Özcan et al. 2015; Samah 2016; Görmüş 2018; Yılmaz & Saka, 2017). The gas engine efficiency used in converting biogas to electrical energy was taken as 44% (Horlock 1997; Özcan et al. 2012). The total amount of electrical energy that can be obtained depending on the animal species for each province is given in Eqs. (5- 7):

$$\sum_{i}^{8} AEc = \sum ABc.v.e \quad (5)$$
$$\sum_{i}^{8} AEs = \sum ABs.v.e \quad (6)$$
$$\sum_{i}^{8} AEp = \sum ABp.v.e \quad (7)$$

Where: AE is the amount of energy produced (MWh), v is Energy value of biogas (MWh/m^3), e is electrical efficiency of gas engine (%).

The amount of electrical energy from animal biomass (MWh/year) is given in Equation 8:

$$\sum_{i,j}^{8,3} AEh = \sum AEc + \sum AEs + \sum AEp \quad (8)$$

Where; AEh is the amount of electrical energy from animal biomass (MWh/year).

The amount of plant residue in eight provinces was determined by Equations 9-11:

$$\sum_{i,h}^{8,22} VOP = \sum_{h}^{22} NT\ .\ AA.\ WA.\ k \quad (9)$$
$$\sum_{i,f}^{8,9} FCP = \sum_{f}^{9} FC\ .AA.\ WA.\ k \quad (10)$$
$$\sum_{i,s}^{8,3} VP = \sum_{s}^{5} VP\ .AA.\ WA.\ k \quad (11)$$

Where; VOP is Vineyard-orchard tree potential (ton/year), NT is Number of trees (units), AA is Actual amount (kg/tree), WA is Waste availability (%), k is the residue coefficient for the plant species.

The amount of available waste was first calculated by multiplying the residual amounts with the Equation (9- 11) and some reference coefficients and plant production values for the estimation of the amount of energy that can be obtained from plant residues (Hart, 1960). Subsequently, the energy content of the residues was calculated by using Equation (12-14). The electrical energy values of plant products in the region were calculated as:

$$\sum_{i,h}^{8,22} AE_{VOP} = \sum_{h}^{22} VOP\ .v.e.Hu \quad (12)$$
$$\sum_{i,f}^{8,9} AE_{FCP} = \sum_{i,f}^{8,9} FCP\ \ .v.e.Hu \quad (13)$$
$$\sum_{i,s}^{8,3} AE_{VP} = \sum_{i,s}^{8,3} VP\ \ .v.e.Hu \quad (14)$$

Where; FC is Field crops (kg/da); FCP: Field crops potential (ton), f: Field crops group (9 items), VP: the amount of total vegetable (ton/year), vg: vegetable group (3 items), v: Biomass energy value (MWh/ton), e: used engine efficiency (40%). Hu: lower calorific value (MJ/kg).

The calorific values (MJ/kg) of agricultural residue types were determined with a stoichiometric analysis method (Bilgili et al. 2008). The calorific values of each vegetable residue were measured using a bomb calorimeter (Bilgili 2015). The calorimeter method was based on a TS ISO 1928 standard. At least 4 measurements (by calorimeter) were made to calculate the calorific values and the arithmetic average and standard deviation of the determinations were taken to obtain the calorific values of the relevant pruning/vegetable/plant residues are shown in Table 2.

Electrical energy in total crop production was calculated with Equation 15:

$$\sum_{i,b}^{8,3} AEb = \sum AEvop + \sum AEfcp + \sum AEvp \quad (15)$$

Where; b is 3 plant groups (Field crops, Vegetable and Vineyard-orchard).

The total amount of electrical energy that can be obtained from biomass in the region was calculated with Equation 16:

$$\sum_{i,x}^{8,2} AE_{total} = \sum_{i,b}^{8,3} AEb + \sum_{i,j}^{8,3} AE\,h \quad (16)$$

Where; x is the energy group that can be obtained from plant and animal biomass.

In conclusion, the analyzes carried out revealed the potential biomass for each province in the region, the supply of waste from animal and plant production, and the annual amounts of electrical energy that they corresponded to (Yılmaz & Saka 2017). Equation 17 was used to calculate the remaining solids by taking approximately 15% for separator and other losses for 3 animal species in the study to determine the amount of biofertilizer after biogas production (Bilgili et al. 2018):

$$\sum OF_{BiO} = (\sum TAB)\ 0.85 \quad (17)$$

Where; OF is the amount of biofertilizer (ton/year), TAB the amount of animal manure (ton/year). 0.85 is the availability coefficient.

CO_2 emissions were calculated according to 2019 electricity energy consumption data and its replacement in the Mediterranean Region. According to the Development Bank of Turkey (DBT) (2018), electricity generation from fossil fuels in Turkey was 512 tonCO_2/GWh, and electricity generation from biomass was 26 ton CO_2/GWh in Turkey (Bilgili 2020). The CO_2 emission was calculated with Equations 18 and 19:

Fossil: CO_2 =512 (ton CO_2/GWh). current energy consumption (GWh) (DBT 2018) (18)

Biomass: $\sum CO_2 = (\sum AEh + \sum AEFC).26$ ton (ton CO_2/GWh) (Bilgili 2020) (19)

Where; AEh + AE_{FC} is energy production from Biomass (GWh).

The amount of CO_2 that can be obtained from the total replaced electrical energy is given in Equation 20.

$$\sum CO_2 = (\sum AEtotal).26 \text{ ton} \quad (20)$$

The amount of CO_2 emission that can be provided by biofertilizer that can be used to replace chemical fertilizer was calculated according to Sturm (2011) and Gellings & Parmenter (2016).

3. Results and Discussion

The status of the provinces in the region and the available biomass potential in the study are shown in Table 1. According to the data obtained as a result of the calculation using TURKSTAT (2019b), While average electricity consumption in Turkey was 2 761 kWh/year/person, the electricity consumption in the Mediterranean Region was calculated as 3 178 kWh/year/person. The total number of animals in Turkey was 408 433 823, out of which 84% were poultry, 12% were small ruminants and 4% were cattle.

The Mediterranean Region's contribution to total animal production in Turkey was calculated as 10%. The total amount of animal waste in the corresponding region of Turkey was 1 184 049 ton/year which corresponds to 9%. The animal waste potential of the region, as seen in Table 1, is not directly proportional to the number of animals and the amount of waste. Table 3 shows that the characterization of waste potential varies according to the animal species. As the size of the animal increased, the amount of waste per animal naturally increased. Yılmaz & Saka (2017), animal manure properties varied according to many factors. The physical properties of animal manure can vary depending on weight, eating habits, and the season.

Although Table 1 indicates that Mersin had a higher number of animals compared to Burdur, the proportional waste potential according to the highest animal number in the region was calculated for Burdur with approximately 91% and Mersin with 6%. This is due to the difference in animal species (Burdur has mainly cattle while poultry is dominant in Mersin). Estimates indicated that 104 238 MJ thermal energy can be produced annually from animal wastes. This is significant in determining the locations where new energy technologies will be installed in the region.

According to the results of the research, it is possible to obtain approximately 221 million m^3 of methane gas per year from animal residues and approximately $1.4x10^6$ MWh of electrical energy per year from this gas. When the results obtained are examined, it is similar to the studies performed by Aktas et al. (2015), calculated that approximately 30 million m^3 of methane gas per year and approximately 119 million kWh electrical energy can be obtained from this methane gas from the total animal fecal waste of Tekirdağ Province.

At this stage, it is important to evaluate biomass technology to be applied. Thermal or chemical processes can be used to convert biomass into a usable form. Combustion of biogas is the most common method of thermal conversion (Özcan et al. 2012). IEA (2017) data revealed that 2000 biogas plants in Turkey that can operate only with animal manure (WEB2 2017). There are 100 licensed biogas plants in Turkey, 82 biomass, waste heat, and pyrolytic oil energy power plants with a total installed capacity of 467.37 MWe were active. 19 of these plants with an installed capacity of 79.36 MWe were in the Mediterranean Region. There were 5 of them in Mersin province, 4 in Adana, 3 each in Antalya and Kahramanmaraş, 2 in Hatay, 1 each in Osmaniye and Isparta, respectively. Burdur was the only province in the region without such a plant (WEB3 2017). The amount of annual plant residues in Turkey was $163.30x10^6$ ton, 77% of this residue was from croplands, the remaining 23% was from the production of plant residues (WEB4 2019). The Mediterranean Region contributed 13% to plant production.

According to Table 1, since orchard and vegetable crops are produced on less land than field crops, their residue amounts are also less. The highest amount of residue in the region was obtained from field crops. Yields are shown in Table 1. Adana had the highest yield of $1.9x10^6$ ton/year and 95.9% of the waste and the most residues were collected from cultivated plants. The percentages for residue amount generated by wheat, corn, sunflower, cotton, and soybean were 32.1%, 47.3%, 8.9%, 7.7%, and 4.0%, respectively. According to estimates, 5.97 Mtoe can be used every year if plant residues are used as specified. Bilgili (2020), despite its high potential availability, agricultural residues in the region have generally been directly incinerated and used for thermal purposes for the last 20 years, biomass thermal conversion facilities were not available. However, a few businesses were working with new technologies intending to generate electrical energy. Furthermore, many new facilities were in the design or commissioning phase.

Although the existing energy potential for the provinces in the region seems high, the supply chain (logistics) problem limits the capacities of potential power plants in the absence of large volumes in the field crops. Similar results were observed in several other studies (Yılmaz & Saka 2017; Bilgili 2020). However, the most suitable conditions for thermal conversion-based energy generation are to establish a medium or large-scale plant to achieve an efficient cycle (WEB5 2017). Investment and operating costs for small-scale plants are high compared to large-scale power generation (Yılmaz & Saka 2017). The central facility concept, which is as economical as the transport distance between stations (Salleh et al. 2019) and the amount of dry matter in the manure requires a solution. For example, dry matter content should be 70%, the economic distance should be around 40 km. If the dry matter content drops to 10%, the distance should be 10 km (Tafdrup 1994).

While the yield status of potential plant residue is 14.63 ton/ha-year depending on the agricultural areas in the region, the overall potential in Turkey has been calculated as 2.40 ton/ha-year (Table 1). Similar results were observed in several other studies, Bilgili et al. (2008); Yılmaz & Saka (2017); Bilgili (2020), the lowest and highest calorific values of plant residues varied between 10.3 and 21.8 MJ/kg.

Biomass waste potential in the Mediterranean Region was estimated to be around 8.3 PJ. According to the results, 6.9% of the region's energy demand can be countered by this potential. The inclusion of biomass in energy technologies investments in the region is highly recommended. These are in agreement with the results were observed in several other studies (Yılmaz & Saka 2017; BP 2018; WEB1 2019).

According to the results of this study, 1 184 049 tons/year of biofertilizer, which can be obtained after biogas production in agricultural areas can be used in the region. This is in agreement with the results of a research involving biomass-energy performed by Bilgili (2020). The literature has reported that the pure nitrogen ratio of the biogas slurry to the chemical fertilizer best improves the soil nitrogen and organic matter content. The liquid-solid part remaining after biogas production is used as fertilizer (Tolay et al. 1999; Türker 2008). For the use of this biofertilizer, the optimum digestion time is recommended as 21 days in agricultural applications (Okoroigwe 2007). If 40 t/ha biofertilizer can be applied instead of 0.5-5 t/ha conventional compost application, the need for mineral fertilizers can be reduced by 20-75% (Sidorchuk 2017).

If the animal waste in the region is used for energy replacement, it is estimated that a total of 1 461 116 ton of CO_2 in emissions will be reduced per year with the production of biofertilizers. This is in agreement with the results of an experiment involving biofertilizers application in agriculture performed by Havukainen et al. (2018), carbon footprints are 0.8 $kgCO_2$/kg for N and 1.8 $kgCO_2$/kg for P, whereas carbon footprints for mineral fertilizers are 1.9–7.8 $kgCO_2$/kg for N. and 2.3–4.5 $kgCO_2$/kg for P. Compared to the emission from mineral fertilizer production, the reduction of GHG emission in organic fertilizer production is 78% for N and 41% for P on average.

4. Conclusions

The usable biomass potential of the provinces in the Mediterranean Region was emphasized in this study. The amounts of waste of animal and plant biomass and the energy equivalency of potential of biomass were analyzed according to the statistical data of the Mediterranean Region for 2019 and the project was carried out to represent the region. A comparison of the biomass potential with literature studies showed that the estimate seems reasonable. The current biomass potential was determined and the amount of energy to be generated with biogas from animal waste and burning plant residues were calculated basis on waste. The electrical energy value of the total biomass waste in the region was calculated as 2 313 965 MWh/year in 2019. The following results can be evaluated in this context:

- ✓ The provinces with the highest plant and animal biomass potential in the region were Mersin and Adana.
- ✓ The region's total biomass potential was calculated as approximately 8.3 PJ/year and this energy can meet 6.9% of the regional demand.
- ✓ The animal waste potential was lower than plant residue potential, therefore it is likely that animal energy production-based biomass can be generated with relatively small-scale energy technologies, hybrid applications are needed.
- ✓ 1 184 049 ton/year of biofertilizer that can be obtained after biogas production can be used in agricultural areas in the region. Accordingly, approximately 537 kg of biofertilizer per hectare can be applied to all agricultural land in the region. This can benefit areas that are poor in organic matter.
- ✓ If the agricultural residues in the region are used for energy replacement, it is estimated that a total of 2 644 302 ton of CO_2 emissions are reduced with the production of approximately 1 183 186 ton of CO_2 and biofertilizers per year.
- ✓ The fact that the region's electricity consumption per capita (3 178 kWh/year/per person) is above Turkey's average (2 761 kWh/year/per person) can be expressed as an indicator of development. In this study, the per capita electricity requirement of the region (218 kWh/year/per person) may be beneficial. Alternative energy sources are important at this point.
- ✓ The approach to making useful biomass without damaging the environment and reducing CO_2 emissions on a global scale realized with this study will also contribute to the energy targets of Turkey's "Vision 2023".

In conclusion, some of the expected differences in energy production from biomass compared to other energy sources in this study can be listed as follows: 1) Strategically important energy can provide economic and political advantages to the state. 2) It is considered a reliable potential in soil protection, water, creating landscape value, energy and food production. 3) It can provide permanent job opportunities by creating new technologies and employment. 4) It is an energy source that slows down climate change by reducing greenhouse gas emissions.

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