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Determining and Spatial Analysis Biogas Energy Potentials from Agricultural - Animal Wastes in Isparta, Türkiye

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Abstract
Increasing energy need poses various problems in terms of energy supply security and environmental aspects for many countries. Therefore, energy policies are an important part of sustainable development plans, especially in developing countries. Türkiye is one of the developing countries and its need for energy is increasing day by day. In Türkiye, which generally meets its energy needs from fossil fuels, it is very important both economically and environmentally to reduce the use of these fuels, which are harmful to the environment and depend on foreign sources, and to use renewable energy sources. Considering Türkiye's potential in renewable energy resources, the energy production efficiency to be obtained from the investments to be made is quite high. In this study, a numerical map was created by determining the biogas and energy potentials that can be obtained depending on the agricultural and animal wastes of the province of Isparta, Türkiye. In determining the energy potential, 2018 agricultural and animal statistics of the Turkish Statistical Institute were used. In the calculation made for the province of Isparta, a total of 25831264.2 m^3/year of biogas can be obtained from animal wastes and the thermal value of this value is 586369.70 GJ/year and the total energy potential that can be obtained from some agricultural wastes is calculated as 3549790.42 GJ/year.

1. Introduction

Energy is one of the most important inputs of daily life and industry that determine the development levels of countries. Energy is obtained from renewable energy sources such as solar and wind as well as fossil-based resources. Biomass energy is also an important renewable energy source and is being developed day by day in terms of technology and use [1, 2, 3]. Population growth and industrialization in the world cause an increased need for energy. Biomass energy is one of the most important energy resources that are environmentally friendly and can meet energy needs sustainably. Accordingly, the European Commission sets some targets for the use of renewable energy to reduce fossil fuel consumption [4,5]. In Europe, it is aimed to increase renewable energy consumption from 5% to 20% by 2020. Türkiye is increasing rapidly in developing countries and is one of the priority objectives in the strategic plan, giving priority to local resources by ensuring the diversification of sources and the share of renewable energy sources in the energy supply. In this context, to reduce the external dependency ratio, the share of renewable energy sources in electricity generation is aimed to be at least 30% in 2023 [6,7]. Türkiye has different climate types, topographic structure, soil structure, and depth and due to these characteristics has rich plant diversity. When these characteristics are taken into consideration, a large number of cereals, industrial plants, fruit trees, and forest trees are grown in Türkiye in terms of biomass energy sources. Although there are large amounts of agricultural and vegetable residues in the country every year, the usage rates of these residues are very low. Agricultural residues constitute an important potential for fuel production. The main agricultural residues are

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sunflower, corn, cotton and grain straws, and pruning residues that occur in orchards If this potential is evaluated, an economic input can be provided in terms of energy, and rural development can be realized as a result of ensuring a sustainable quality environment by reducing harmful wastes in terms of the environment [8,9,10,11]. Türkiye can only produce an average of one-third of the energy it has consumed in recent years. This situation reveals the need for countries with high agricultural potential, such as Türkiye, to convert vegetable and animal waste into energy by using it more efficiently. Currently, these plant wastes are usually buried under the soil or burned, using them most inefficiently, leading to environmental pollution. The waste assessment is very important in terms of environmental pollution and energy needs [12]. Onurbaş and Türker (2012) calculated the total biogas energy potential of Türkiye as 2.18 Gm^3 using the numbers of cattle, small ruminants, and poultry for 2009. The study also stated that 68% of this potential is caused by cattle, 5% by small ruminants, and 27% by poultry, and found that Türkiye's biogas energy equivalent potential is about 49PJ (1170.4 ktoe) [13]. Akçay (2014) identified the biomass potential and energy value of paddy stalk in the Thrace region, Türkiye. For paddy stalk samples, the minimum thermal value was 3.4 cal/G, the power production was 39.39 GWh/year and the power production potential was 5.29 MWe. It is stated that this calculated amount corresponds to 0.019% of the total electricity consumption of Türkiye and 0.7% of the total electricity consumption of Tekirdag province [14]. Aybek et al (2015) determined and mapped the potential values of biogas and energy that can be obtained from total animal and grain waste based on agricultural regions of Türkiye for 2014. In the study, the amount of volatile dry matter that can be obtained from animal fertilizers is 33210.844 billion tons/year, the amount of volatile dry matter that can be obtained from grain waste is 7.17 billion tons/year and the biogas energy potential is approximately 331.87 PJ / year [15]. Aybek et al. (2015) calculated the biogas potential of animal and some plant wastes in Kahramanmaraş, Türkiye. In the calculation, it was determined that the annual total biogas energy potential that can be obtained from agricultural waste is 2.18 TJ/year [16]. Özsoy and Alibaş (2015) determined the biogas potential that can be obtained from animal waste in Bursa, Türkiye. The potential amount of biogas to be obtained from animal waste and the potential bio-electrical energy per capita were examined. It has been stated that if the biogas potential is utilized, 1.12% of the electricity consumption in Bursa can be met by transforming it into electricity from animal waste [17]. Demir et all. (2016) determined the equivalent potential of agricultural biomass energy in Erzincan, Türkiye between 2006 and 2015 and compared it proportionally with the data obtained for Türkiye and the eastern Anatolia region. Using the cultivated area values of sugar beets, cereals, fruits, vegetables, dry legumes, and forage crops, they calculated the energy potentials of average agricultural biomass in MW. They found that the 9.23 MW value obtained for Erzincan province is equal to 0.59% of the biomass energy potential of Türkiye and 5.76% of the Eastern Anatolia Region [18]. Salihoglu et all. (2019) determined the amount of biogas production that can be obtained from cattle and small ruminant wastes in Balıkesir, Türkiye for 2017 and calculated the energy potential. Different calculation approaches were used according to the amount of waste accepted per animal, and it was stated that 82815.60 m^3 of biogas and 1879914.12 MJ of energy can be produced from 5955.32 tons of waste annually in Balıkesir [19]. Akbaş (2019) calculated the energy equivalent potential of agricultural biomass for Aydın, Türkiye in MW using fruit, vegetable, grain, oilseeds, and dry legumes data between 2009-2018. It has been determined that a total of 40.59 MW of agricultural biomass energy can be obtained [20]. Avcioglu et all. (2019) developed a mathematical model for calculating the energy potential of agricultural biomass residues in Türkiye. The total amount of biomass residues obtained from field crops and garden plants in Türkiye was 59432 kilotons and 15652 kilotons, respectively. Energy potentials from agricultural biomass residues were found to be 298955 TJ for agricultural field crops and 65491 TJ for garden plants [21]. Türkiye has a high potential in terms of animal and vegetable production. However, wastes are buried in the soil for fertilizer purposes, collected around the production area, and directly burned or left to rot or stored to provide grass for animals [22]. In this study, the biomass potential of Isparta from animal and agricultural production was determined by using the data of the Turkish Statistical Institute (TUIK) in 2018 [23]. Different animal species were used in determining the potential of animal biomass. Agricultural biomass resources were evaluated

into four groups: field crops, vegetables, fruits, and ornamental crops. By determining the amount of production area belonging to product groups, the average annual amount of dry biogas and the energy equivalent of the biogas potential were calculated over these areas. In the light of the calculated data, the energy potentials of the province based on livestock and agricultural products were also created.

2. Material and Method

Isparta province is located between longitudes 30°01' and 31°33' east and latitudes 37°18' and 38°30' North. Its area is 8933 km^2 and its average altitude is 1050 m, located in the Mediterranean region. Isparta has twelve districts: Aksu, Atabey, Eğridir, Gelendost, Gönen, Keçiborlu, Senirkent, Sütçüler, Şarkikaraağaç, Uluborlu, Yalvaç and Yenişarbademli. The effects of the Mediterranean climate are observed in Sütçüler, Eğirdir, and partially Aksu and Merkez districts that form the southern part of Isparta lands. In these parts, winters are rainy and milder, while summers are hot and humid. Again, the same geography shows the geographical features of the Mediterranean Region [24]. The distribution sizes of agriculture, forest, meadow-pasture forest, and non-agricultural land of Isparta province and their % ratio are given in Table 1. Paragraphs following the first paragraph should begin with the paragraph indentation.

Table 1 Land distribution of Isparta [20]

Land type	Area size (ha)	Percentage (%)
Agricultural land	210078	28.13
Meadow - pasture land	17747	1.87
Forest land	386048	43.22
Other lands	279434	26.78
Total	893307	100

The number of animals in the districts is given in Table 2. The total number of animals in Isparta province is 1084621. Of the total number of animals, 45.32% consist of sheep-goats, 39.16% of chickens, 7.74% of dairy cattle, 5.63% of meat cattle, 1.91% of turkey-goose-duck, 0.24% of horse-donkey-mule. Considering the distribution of animals by district, the number of chickens and turkey-goose-duck are the most in the central district, while other animal species are located in the Yalvaç district. The formulas and parameters given in Figure 1 were used in the theoretical calculation of the biogas potential resulting from animal waste [24, 26]. The calorific value of animal wastes has been accepted as 22.7 MJ /m^3 [26]. The coefficients used in the calculation method have been obtained from various studies and are given in Table 3.

Table 2. Number of animals in Isparta [23]

District	Dairy Cattle	Meat Cattle	Horse-Donkey-Mule	Small ruminant	Turkey-Goose-Duck	Chicken
Aksu	3589	2532	273	6829	302	1950
Atabey	3462	2985	22	18389	200	3907
Eğirdir	8780	4720	180	59765	264	27000
Gelendost	3865	2824	75	28036	475	16500
Gönen	3303	2234	19	19982	785	7300
Keçiborlu	5201	4865	70	20947	92	9300
City center	11574	7628	224	84564	10042	294359
Senirkent	2566	1371	36	32013	83	775
Sütçüler	6253	4186	194	39770	265	10400
Uluborlu	600	1227	50	15013	82	1100
Yalvaç	17860	13177	893	98349	1700	45000
Yenişarbademli	864	420	28	2653	133	1750
Şarkikaraağaç	16070	12856	421	65240	6310	5500

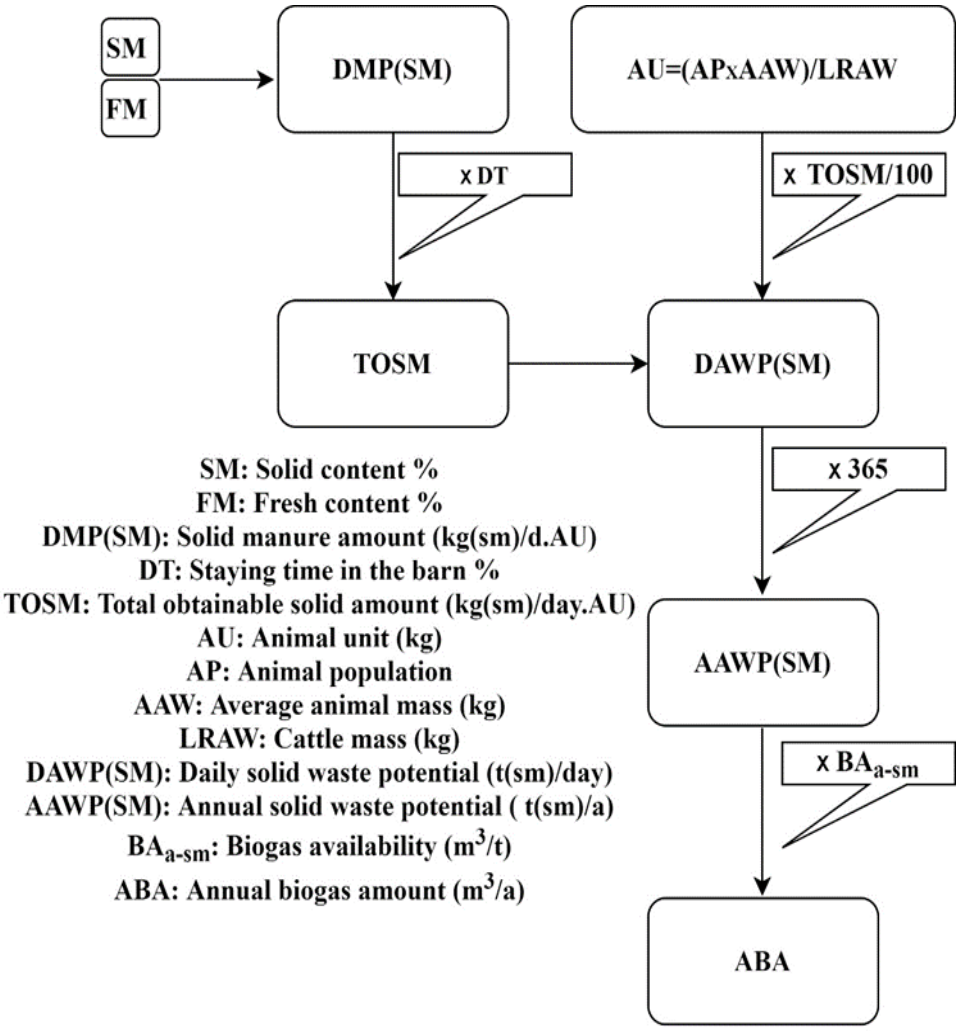

Figure 1. The theoretical calculation of the biogas potential [6, 12, 19]

Table 3 Parameters used in the calculation [6, 12, 19]

Animal	FM	SM	DMP	DT	TOSM	AAW	BAa-sm
Dairy cattle	33.33	12.7	4.233	65	2.7515	454	202
Meat cattle	34.68	11,6	4.023	25	1.0058	454	202
Horse-Donkey-Mule	37.71	21	7.9191	29	2.2965	250	300
Small ruminant	16.44	25	4.1100	13	0.5343	50	251
Turkey-Goose-Duck	26.61	25	6.654	68	4.5247	8	300
Chicken	25.29	25	6.323	99	6.2597	2	300

Data on the production areas of field crops were obtained using the statistics of plant production in the database of the Turkish Statistical Institute. Considering the distribution of agricultural areas by districts, Yalvaç has the highest area with approximately 25.34%. It is followed by Şarkikaraağaç (14.4%) and Gelendost (11.5%) districts, respectively. Approximately 60.81% of the cultivated areas in the province are composed of cereals and other herbal products, while 20.52% of them are fruits, beverages, and spice plants. Vegetables constitute 2.7% of the land and 0.03% of ornamental plants. Agricultural lands for Isparta are given in Table 4 [24, 25].

Table 4 Isparta agricultural areas (decares) [24, 25]

District	Fruits, beverages, spice herbs	Vegetables	Ornamental Plants	Cereals and other herbal products	Fallow field	Uncultivated area
City center	27170	7110	646	71328	43112	24870
Aksu	5811	3083	-	19882	14512	64120
Atabey	10441	3142	-	40343	16000	14730
Eğirdir	64627	1989	-	28352	40162	79770
Gelendost	60019	919	-	157655	14500	18090
Gönen	14445	1774	-	71708	48000	39810
Keçiborlu	12496	5080	-	123835	17767	26640
Senirkent	88563	12118	-	37328	7090	10890
Sütçüler	2466	2385	-	20835	60600	83980
Uluborlu	29512	44	-	5605	1475	22110
Yalvaç	77485	8706	-	385143	42000	66790
Yenişarbademli	5884	604	-	7385	11000	15660
Şarkikaraağaç	16822	9049	-	262339	5400	15090
Total	415.741	56.003	646	1.231.738	321.618	482.550

In Isparta, 440996 tons of field products were produced according to 2018 TUIK data. While sugar beet has the largest share in this production with 117986 tons, peanuts have the lowest share with 42 tons. Corn, barley, and wheat products follow sugar beet, respectively. The production amount of field products belonging to the Isparta center and districts are given in Table 5 [24, 25]. In 2018, 872452 tons of fruit, beverage, and garden plants were produced in Isparta center and its districts. Production amounts of grape, apple, cherry, peach, apricot, pear, almond, and hazelnut are given in Table 6 [24, 25]. While the most produced product was the apple, the least was hazelnuts. Table 7 is used for the theoretical biomass potential from agricultural product wastes. The formulas for the calculation are given at the bottom of the table [15, 16].

Table 5. Field crops production (tons) [24, 25]

District	Wheat	Barley	Corn	Rye	Oat	Bean	Sugar beet	Chickpea	Potato
City center	3088	8159	4451	100	119	454	2156	10	1130
Aksu	771	888	2117	-	-	2228	-	2	44
Atabey	108	6897	6958	-	538	221	29844	6	121
Eğirdir	3941	393	515	-	-	151	-	35	395
Gelendost	11634	11850	172	-	-	207	-	6542	-
Gönen	2194	9104	2669	-	53	42	4903	26	582
Keçiborlu	6119	11809	3444	-	-	226	110	45	-
Senirkent	1257	5781	3880	-	1625	1124	22056	5	76
Sütçüler	1437	533	59	-	13	271	-	18	57
Uluborlu	152	355	150	-	13	13	-	34	-
Yalvaç	32867	22222	16119	237	2100	1870	-	4971	5156
Yenişarbademli	255	97	2746	-	-	442	-	-	-
Şarkikaraağaç	26326	13698	63113	336	290	1825	58917	873	14
Total	90149	91786	106393	673	4751	9074	117986	12567	7575

Table 6. Horticultural crops production (tons) [24, 25]

District	Grape	Apple	Cherry	Peach	Apricot	Pear	Almond	Hazelnut
City center	10759	7246	3739	3438	132	183	131	2
Aksu	-	15532	65	96	-	4	-	-
Atabey	538	10793	1942	949	152	211	65	-
Eğirdir	266	364703	920	1282	74	733	120	-
Gelendost	529	182736	1536	819	732	71	78	-
Gönen	1957	4508	2580	96	80	135	49	17
Keçiborlu	6240	3225	878	140	190	207	787	-
Senirkent	26888	75001	15850	1062	2584	197	1051	-
Sütçüler	70	1501	292	259	-	171	22	-
Uluborlu	275	10381	5215	14	13	178	57	19
Yalvaç	35036	19648	1083	317	5018	1460	165	-
Yenişarbademli	323	2527	808	61	-	8	9	6
Şarkikaraağaç	6339	19600	1367	265	5018	463	166	-
Total	89220	717401	36275	8798	13993	4021	2700	44

Table 7. Waste type, moisture information, product waste rate, lower calorific value, and availability of selected field crops and horticultural crops [15, 18, 21]

Products	Waste type	Average Humidity (H) (%)	Product waste ratio (PWR)	Lower heating value (LHV) (MJ/kg)	Average availability (%) (AP)
Wheat	Straw	13	1.13	16.7	15
Barley	Straw	13	1.22	18.5	15
Corn	Handle	16	1.88	17	60
Rye	Stub	8	0.57	15.5	60
Bean	Straw	12	0.37	18.5	15
Sugar beet	Stem and leaf	5	1.45	14.7	15
Peanut	Stem and leaf	60	0.45	13.6	95
Grape	Pruning	45	0.42	18	80
Apple	Pruning	40	0.19	17.8	80
Cherry	Pruning	40	0.19	21.7	80
Peach	Pruning	40	0.40	18.2	80
Apricot	Pruning	40	0.19	20	80
Pear	Pruning	38	0.22	18.2	80

$$TBP = AA\ x\ PWR\ x\ [1 - 0.01xH]$$

$$AEP = TBP\ x\ LHV\ x\ AP$$

TBP: Theoretical biomass potential

AEP: Available energy potential

AA: Annual amount of products in tons

Geographical Information Systems provide the opportunity to geographically coordinate and store data, query, and analyze data. In this study, the Kriging interpolation method in the Spatial Analysis module of the ArcGIS 10 program was used. The purpose of using this method is that data collection for every point in the study area is very costly and laborious. This method enables the determination of the predictive values of the data obtained from the sampling points in the study area regarding the remaining areas in the field. Thus, it creates a continuous surface from sample points within the boundaries [27].

3. Results and Discussion

Isparta's 2018 animal numbers with the basis of its districts and the usable waste potential of animal origin are given in Table 8. The biogas energy values obtained from the waste potential by animal type are given in Table 9. According to Table 8, a total of 122392.81 tons of usable animal waste were obtained annually. The vast majority of usable waste is dairy cattle with 68.31% and meat cattle with 18.14%. The last usable waste was obtained from turkey-goose-duck-chicken with 0.4%.

Table 8. Animal Waste Potential (ton/year)

District	Dairy Cattle	Meat Cattle	Horse-Donkey-Mule	Small ruminant	Turkey-Goose-Duck	Chicken
Aksu	3572.6	921.3	126.0	146.7	8.8	19.6
Atabey	3446.2	1086.1	10.2	394.9	5.8	39.3
Eğirdir	8739.9	1717.4	83.1	1283.6	7.7	271.8
Gelendost	3847.4	1027.6	34.6	602.2	13.8	166.1
Gönen	3287.9	812.9	8.8	429.2	22.9	73.5
Keçiborlu	5177.3	1770.2	32.3	449.9	2.7	93.6
City center	11521.2	2775.6	103.4	1816.3	292.2	2962.8
Senirkent	2554.3	498.9	16.6	687.6	2.4	7.8
Sütçüler	6224.5	1523.1	89.5	854.2	7.7	104.7
Uluborlu	597.3	446.5	23.1	322.5	2.4	11.1
Yalvaç	17778.6	4794.6	412.2	2112.3	49.5	452.9
Yenişarbademli	860.1	152.8	12.9	57.0	3.9	17.6
Şarkikaraağaç	15996.7	4677.8	194.3	1401.2	183.6	55.4
Total	83604.0	22204.8	1147.1	10557.5	603.4	4276.1

According to Table 9, cattle account for 82.7% of the achievable biogas potential. Small ruminants compose 10.25% of the potential, chickens compose 4.9% and other species make up the rest. Dairy cattle make the greatest contribution to the biogas potential with 16888006.39 m^3/year, while the Central District plays the greatest role in the formation of this value. The district where biogas potential is highest is Şarkikaraağac with 4657960.83 m^3/year, and the district where it is least is Yenişarbademli with 229227.26 m^3/year (Table 9).

According to TUIK 2018 data, 331662.45 tons of products (Table 10) have been obtained from field products used in the study in Isparta and its districts [23]. The biomass potentials of selected field crops are given in Table 11. The highest biomass potential available from field crops is obtained from barley production with 97421.66 tons, and the lowest biomass potential is obtained from peanut production with 13.91 tons. About 72% of the total biomass potential in the province consists of barley, wheat, corn beans, and chickpeas, while 28% consists of the remaining agricultural products.

Table 9. Biogas potential from animal waste (m^3/year)

District	Dairy Cattle	Meat Cattle	Horse-Donkey-Mule	Small ruminant	Turkey-Goose-Duck	Chicken
Aksu	721671.9	186103.4	37803.7	36814.9	2636.6	5888.2
Atabey	696134.9	219399.1	3046.5	99134.3	1746.1	11797.5
Eğirdir	1765472.0	346922.5	24925.5	322190.6	2304.9	81528.7
Gelendost	777169.6	207565.5	10385.7	151140.9	4147.0	49823.1
Gönen	664163.3	164200.2	2631.0	107722.1	6853.5	22042.9
Keçiborlu	1045810.9	357580.1	9693.3	112924.4	803.2	28082.1
City center	2327286.2	560662.1	31018.5	455880.9	87671.9	888840.8
Senirkent	515968.2	100769.2	4985.1	172580.7	724.6	2340.2
Sütçüler	1257345.8	307673.2	26864.2	214398.4	2313.6	31403.6
Uluborlu	120647.3	90185.2	6923.8	80934.4	715.9	3321.5
Yalvaç	3591267.6	968516.6	123658.4	530195.3	14841.9	135881.1

Yenişarbademli	173732.1	30870.2	3877.3	14302.2	1161.2	5284.3
Şarkikaraağaç	3231336.5	944922.9	58298.1	351706.1	55089.6	16607.7
Total	16888006.4	4485370.2	344111.0	2649925.2	181009.8	1282841.7

Table 10. Field crops biomass potential (tons)

District	Wheat	Barley	Stalk	Corncob	Rye	Oat	Bean	Sugar beet	Chickpea	Potato
City center	3035.8	8659,9	3514.5	1167.0	84.2	38.7	625.4	70.0	11.1	203.4
Aksu	757.9	842.5	1671.6	555.0	-	-	3069.1	-	2.2	7.9
Atabey	106.2	7320.5	5494.0	1824.4	-	175.2	304.4	969.9	6.6	21.8
Eğirdir	3874.4	417.1	406.6	135.0	-	-	208.0	-	38.7	71.1
Gelendost	11437.4	12577.6	135.8	45.1	-	-	285.1	-	7228.9	-
Gönen	2156.9	9662.9	2107.4	699.8	-	17.3	57.9	159.3	28.7	104.8
Keçiborlu	6015.6	12534.1	2719.4	903.0	-	-	311.3	3.6	49.7	-
Senirkent	1235.8	6135.9	3063.6	1017.3	-	529.1	1548.3	716.8	5.5	13.7
Sütçüler	1412.7	565.7	46.6	15.5	-	4.2	373.3	-	19.9	10.3
Uluborlu	149.4	376.8	11844	39.3	-	4.2	17.9	-	37.6	-
Yalvaç	32311.6	23586.4	12727.5	4226.4	199.4	683.8	2575.9	-	5492.9	928.1
Yenişarbademli	250.7	102.9	2168.2	720.0	-	-	608.9	-	-	-
Şarkikaraağaç	25881.1	14539.1	49834.0	16548.2	282.7	94.4	2513.9	1914.8	904.7	2.5
Total	88625.5	97421.6	84007.9	27896.2	566.3	1546.9	12499.4	3834.5	13886.5	1363.5

Table 11 shows the biomass potential that can be obtained from garden products. The highest biomass potential originating from garden products is obtained from apples with 81783.71 tons and hazelnuts with at least 88.17 tons. When the total biomass potential of horticultural products is examined, the highest biomass potential was obtained from apples with 81783.71 tons and hazelnuts with at least 88.17 tons. Apple constitutes 70% of the total biomass potential and grapes 17%. When the biomass potential of apples is evaluated, Eğirdir is in the first place with 41576.14 tons, while Sütçüler is in the last place with 171.11 tons. When the total biomass potential of the grape is evaluated, Yalvaç was the district that made the most contribution and Aksu was the least.

Table 11. Horticultural biomass potential (tons)

District	Grape	Apple	Cherry	Peach	Apricot	Pear	Almond	Hazelnut
City center	2485.3	826.0	426.2	825.1	15.0	25.0	49.5	4.0
Aksu	-	1770.6	7.4	23.0	-	0.5	-	-
Atabey	124.3	1230.4	221.4	227.8	17.3	28.8	24.6	-
Eğirdir	61.4	41576.1	104.9	307.7	8.4	99.9	45.4	-
Gelendost	122.2	20831.9	175.1	196.6	83.4	9.7	29.5	-
Gönen	452.1	513.9	294.1	23.0	9.1	18.4	18.5	34.1
Keçiborlu	1441.4	367.6	100.1	33.6	21.7	28.2	297.6	-
Senirkent	6211.1	8550.1	1806.9	254.9	294.6	26.9	397.5	-
Sütçüler	16.2	171.1	33.3	62.2	-	23.3	8.3	-
Uluborlu	63.5	1183.4	594.5	3.4	1.5	24.3	21.6	38.1
Yalvaç	8093.3	2239.9	123.5	76.1	572.0	199.1	62.4	-
Yenişarbademli	74.6	288.1	92.1	14.6	-	1.1	3.4	12.0
Şarkikaraağaç	1464.3	2234.4	155.8	63.6	572.0	63.2	62.8	-
Total	20609.8	81783.7	4135.4	2111.5	1595.2	548.5	1021.1	88.2

The Kriging method, a geostationary method, is widely used to predict properties in non-measuring points or areas. In this method, weights are based not only on the distance between the measured points and the prediction location but also on the overall spatial arrangement of the measured points [27, 28]. In this study, Isparta provincial border was geographically coordinated and digitized using ArcGIS 10 program. 13 district boundaries were created within the provincial borders, and the values of animals and agricultural products for each district (energy potentials calculated using Figure 1 and Table 7) were recorded in the attribute table created in the program. Using the Kriging interpolation method in the ArcGIS spatial analysis module, spatial distribution maps of the values entered in the province were created. In Figure 2, the maps of the energy potentials that can be obtained from dairy cattle, horse-donkey-mule, sheep-goat, and chicken are given according to the amount of biogas potential obtained in Table 9. According to Figure 2, while the highest energy potential was obtained from dairy cattle, the least energy was obtained from horse-donkey-mule animal species. High values are shown on the map in colors close to red, while low values are shown in colors close to blue.

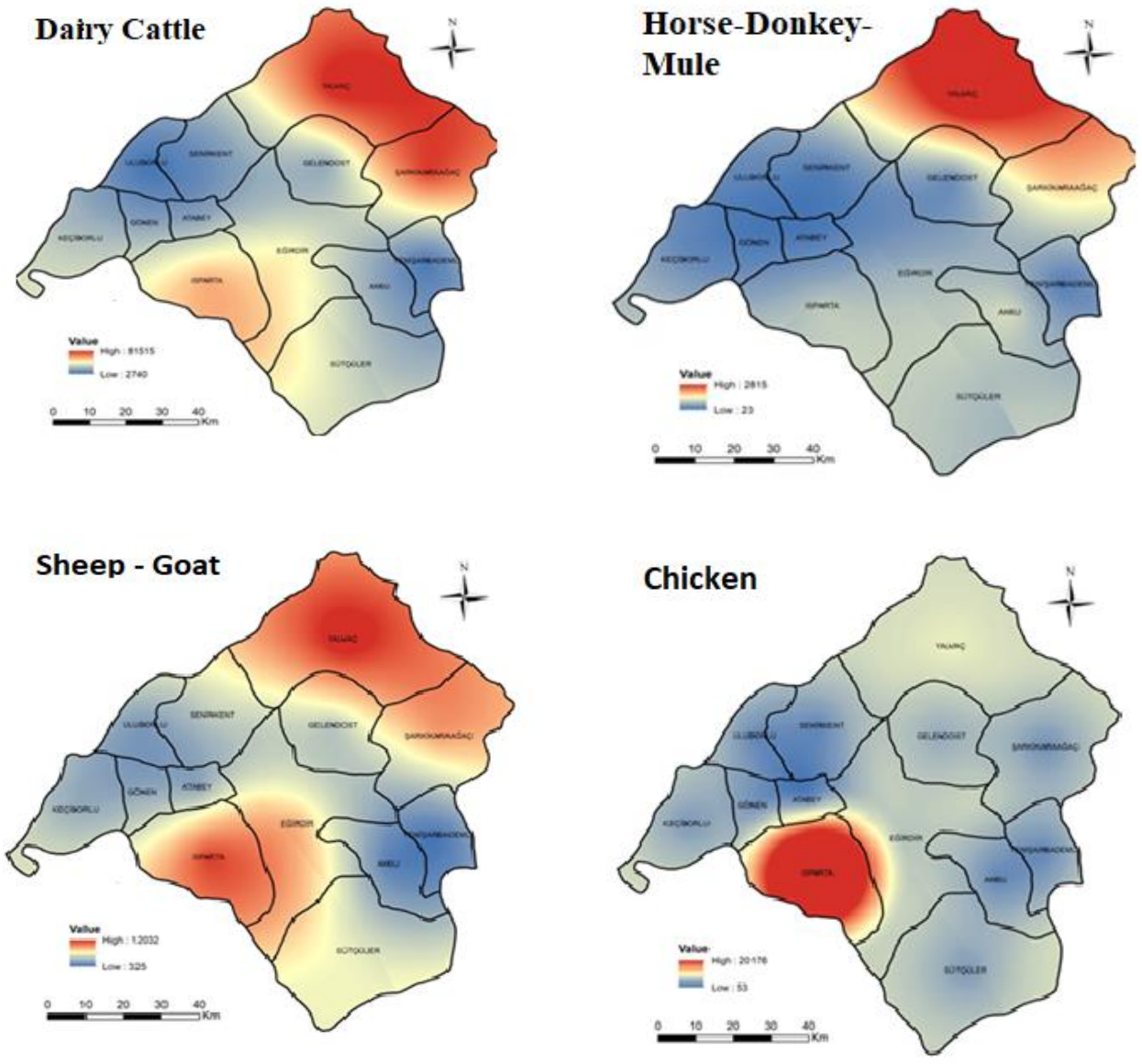

Figure 2. Energy potential according to animal species in Isparta

In Figure 3, the map of the energy potentials that can be obtained for wheat, barley, corn, and beans is given on a district basis. High values are shown on the map in colors close to red, while low values are shown in colors close to blue. When the energy potential of horticultural products is examined, it is seen that the highest energy potential is obtained from apples. The energy potential that can be obtained from all horticultural crops comes from apples the most and hazelnut the least. Rye and peanut from field crops could not be mapped due to the lack of biomass potential in each district. The energy potential of rye and peanuts has been calculated as 1478.12 GJ/year. A total of 71789.68 GJ/year, which can be obtained from the garden products cherry throughout the province, has been calculated (Figure 4). In figure 4, high values are shown on the map in colors close to red, while low values are shown in colors close to blue.

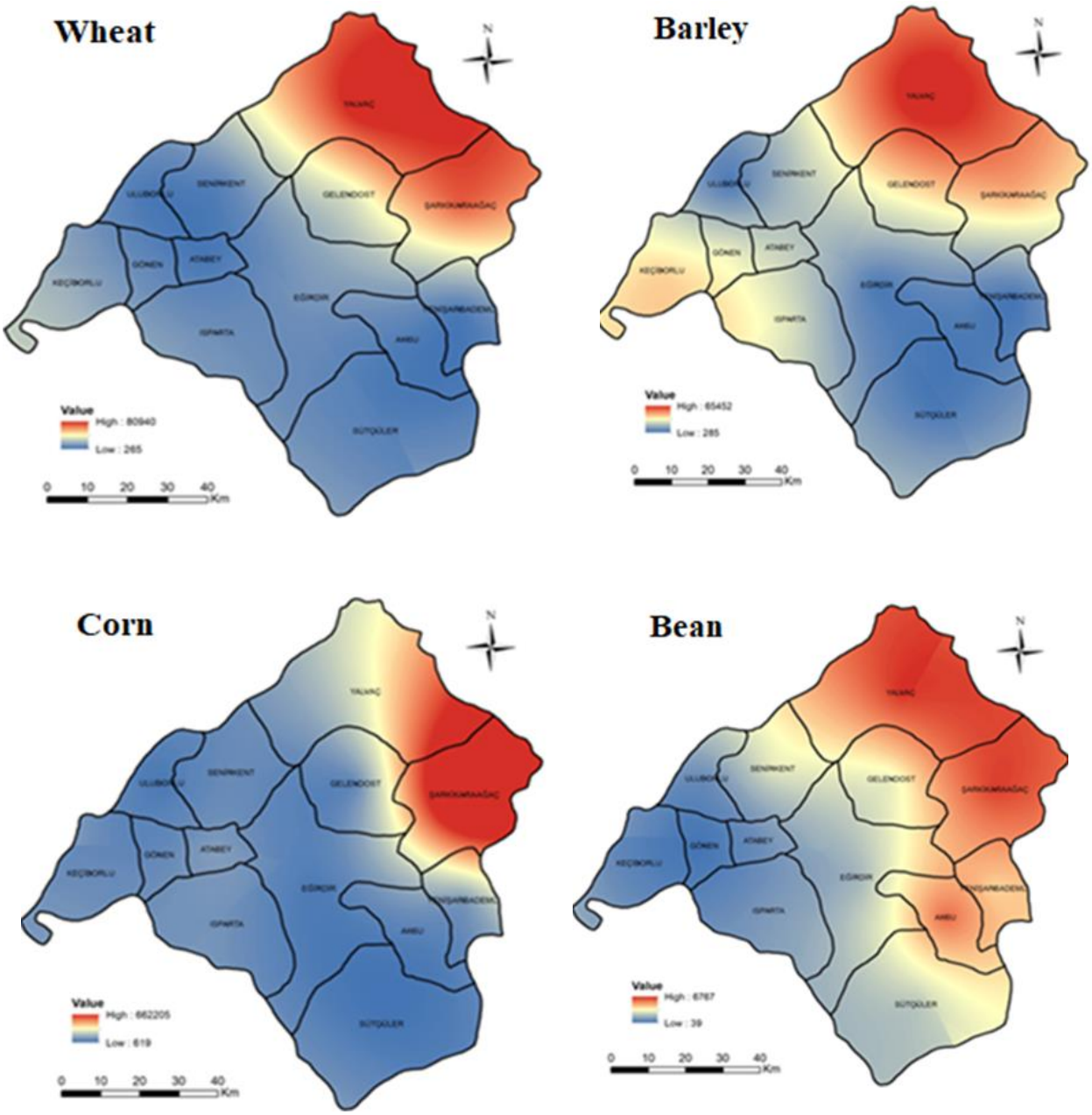

Figure 3. Energy potential that can be obtained from field products in Isparta

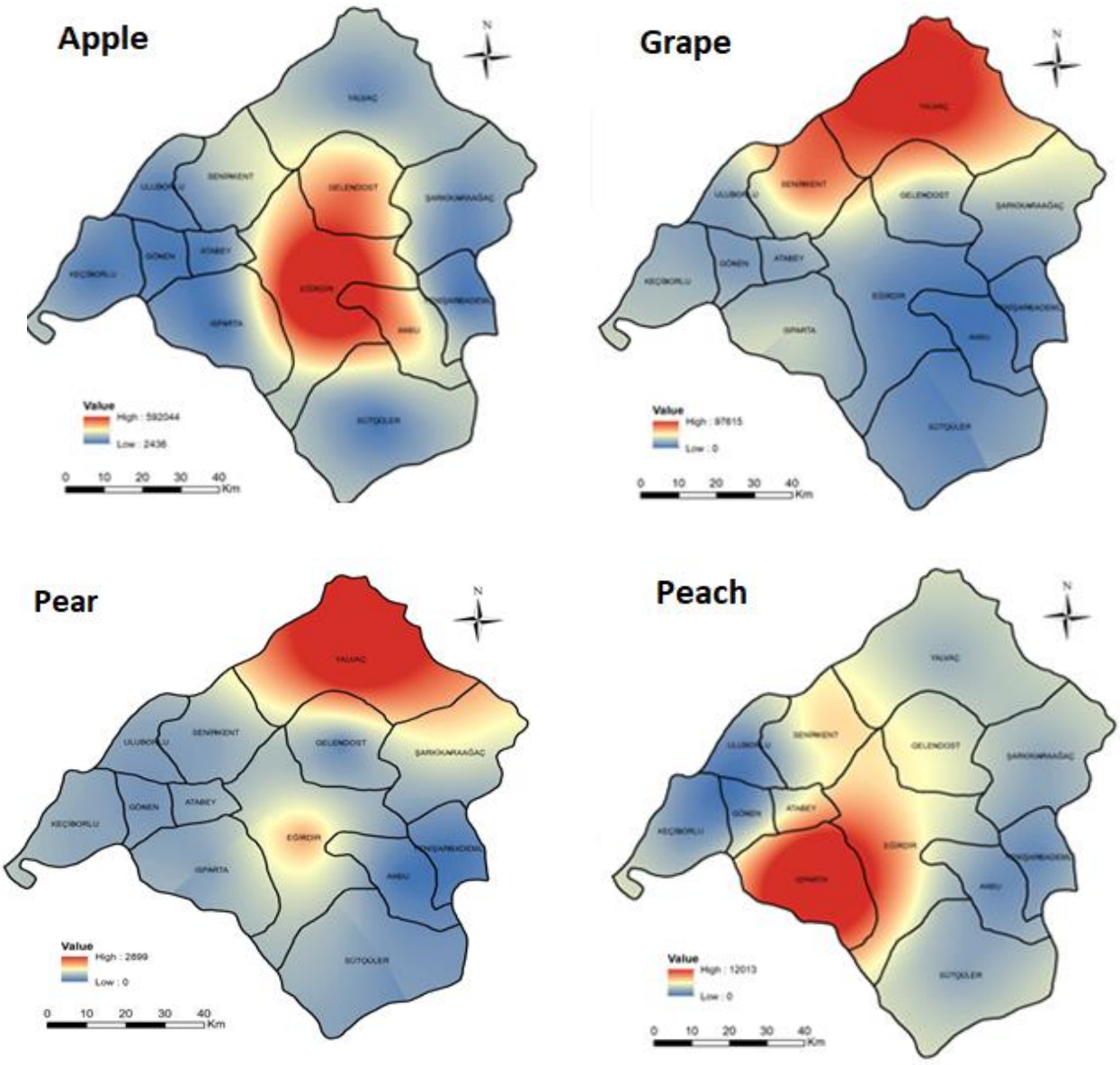

Figure 4.. Energy potential that can be obtained from horticultural products in Isparta

4. Conclusion and Suggestions

The energy competition between the countries has caused rapid oil consumption, global warming, and the deterioration of the ecosystem. It is necessary to turn to renewable energy sources to reduce oil over time, warming the world and not destroying ecosystems. To meet the general energy demand in Türkiye, it is tried to switch to renewable energy sources that can be used in the long term as much as possible. In this study, according to TUIK 2018 data, the biogas and energy potential of animal manure and agricultural wastes in Isparta were determined all the data and the results obtained were and digital maps were created. According to 2018 data in the center and
districts of Isparta, 443555.82 tons of biomass potential was determined from some agricultural (field and garden) products. The total thermal capacity of these wastes was determined to be 3549790.42 GJ/year. It has been calculated that a total of 25831264.2 m^3/year of biogas can be obtained from animal waste and the heating value of this value is 586369.70 GJ/year. Studies on biomass energy potential, energy use rate, and environmental effects in Türkiye will enable the creation of databases related to the field. With this study,

mapped thematically in GIS. Thus, the data differences between the districts and the visual observation of the obtained results were provided. The database obtained by the study will create a healthy resource for future studies on different subjects to be made throughout the province.

Contributions of the Authors

Kazım KUMAŞ: Conceptualization, methodology
Kerem KEPDENİZ: Conceptualization, methodology, investigation, visualization
Ali AKYÜZ: Conceptualization, writing - review & editing

Conflict of Interest Statement

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

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