

Determining the Electricity Energy Generation Potential From Animal Derived Biogas by Thematic/Digital Mapping Method: Example of Eastern Anatolia Region

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Abstract— Considering the reduction of fossil energy sources, which are described as non-renewable energy, their harmful effects on the environment and their negative effects on human health, studies on renewable energy sources have gained momentum in the global sense. The issue of electricity energy production from biogas, which is one of the renewable energy sources, has become increasingly popular in recent years. In this study, the animal numbers of the provinces in the Eastern Anatolia Region were evaluated using the 2021 data of the Turkish Statistical Institute and the manure, biogas and electricity energy production amounts of the provinces in the region were determined. Using these amounts, thematic/digital maps were prepared on the basis of provinces and evaluations were made in terms of quantity. When a comparison is made in terms of the amount of manure that can be produced in the provinces of the Eastern Anatolia region for 2021, Erzurum ranked in the first place with 3.732.151,72 ton/year and when a comparison is made in terms of the amount of biogas and electricity that can be produced, the province of Van is ranked in the first place with 157.888.540,72 m³/year and 742.076.141,38 kWh/year. The amounts of manure, biogas and electricity energy that can be produced from all 14 provinces in the region for 2021 have been determined as 22.613.873,02 ton/year, 1.003.183.755,12 m³/year and 4.714.963.649,12 kWh/year, respectively. According to the data obtained from the website of the Republic of Turkey Ministry of Energy and Natural Resources, the amount of electricity energy used by Turkey in 2021 is 329,6 billion kWh. Considering this rate, it has been determined that the electricity energy that can be obtained from animal-derived biogas in the Eastern Anatolia Region can met approximately 1.45% of our country's electricity energy needs for 2021.

Keywords: biogas, electricity, energy, manure, renewable, thematic maps, waste

1 INTRODUCTION

Rapid growth in the world population and technological developments have led to a significant increase in fossil fuel consumption with serious environmental effects [1, 2]. Such environmental impacts have also led to serious health problems and critical climate changes. Developing technology causes an increase in energy consumption need in direct proportion. As the welfare level of people increases, the amount of energy used also increases. The depletion of fossil fuels due to being non-renewable resources and their harmful effects on the environment lead people to renewable energy sources [4, 5]. Biogas, which is a renewable energy, is a gas that is formed during the decomposition of biomass as a result of the joint activities of various bacterial groups in an airless environment and contains predominantly methane (CH₄) and carbon dioxide (CO₂). In order to produce biogas; animal waste, vegetative waste, organic domestic solid waste, etc. can be used. Biogas can be used to produce electricity and heat energy [6]. There are many studies conducted abroad and in our country on biogas energy.

The importance of the subject has been tried to be conveyed by giving information about some recent studies. Arshada et al. [7] conducted studies to determine the amount of electricity energy that can be produced from

poultry waste in Pakistan. As a result of the calculations, they determined that 280 MWh/day electricity could be produced from biogas produced from poultry waste, and this would be a valuable renewable energy addition to the country's existing energy system. Ramos-Suárez et al. [8] carried out studies considering that biogas production from the manure of animals produced on farms in the Canary Islands could be an additional energy source for heat and/or electricity production. To assess the potential biogas production and contribution to renewable energy production in the Canary Islands, calculations were performed using data from different livestock farms scattered throughout the islands. The results showed that animal manure as a biogas source could be associated with a total biogas potential of 27.1 Mm³/year with an equivalent installed power capacity of 6.8 MWe. Mohammad and Ardebili [9] carried out studies to determine the energy production potential by determining the amount of animal and vegetative waste in Iran. It has been determined that the total amount of agricultural waste is 24.3 million ton and can be evaluated as a potential raw material for the production of 6.542 million m³ of biogas, 2.443 million liters of bio-butanol and 2.082 million m³ of biohydrogen. In addition, it has been determined that the biogas potential arising from livestock and slaughter wastes

is 11,523.84 and 16,026 million m³/year, respectively. As a result of the analyzes made, it has been interpreted that Iran's total potential for bio-electricity production from these organic materials corresponds to around 62,808 106 kWh/year, which constitutes 27% of the total electricity consumption in the country. Caliskan and Ozdil [10] calculated the biogas potential produced from animal manure using data from various regions of Turkey between 2007 and 2019. In addition, the production of electricity potential that can be provided by using biogas obtained from animal manure sources has been examined. It has been determined that Eastern Anatolia and Central Anatolia Regions have the highest biogas potential with a rate of 19% compared to other regions due to the amount of manure obtained from animal wastes. It has been determined that 76.448×10^6 m³ potential methane content can be obtained from the biogas for the mentioned years and a heating value of $2.339.296 \times 10^6$ MJ can be obtained from this methane value. Aksay and Tabak [11] conducted a study to evaluate the biogas potential of animal manure and agricultural wastes in Turkey. In the study, results such as the amount of animal manure and agricultural waste, biogas potential, electricity production from biogas were mapped for 12 regions and 81 provinces. According to the results, it has been determined that Turkey's total collectable manure, agricultural waste and biogas potential was 176 million ton, 17 million ton and 17 billion m³ per year, respectively. Studies of many different researchers can be added to these summarized studies.

The energy issue, whose importance is increasing day by day, has become more important especially with the COVID-19 pandemic that emerged in 2019. Researchers are trying all kinds of ways to obtain energy. In this study, the biogas and electricity energy production amounts of the Eastern Anatolia Region for 2021 were evaluated using the data obtained from the Turkish Statistical Institute. The amount of electricity energy that can be produced and how much of our country's energy needs can be met were also discussed.

2 MATERIAL AND METHOD

The amount of animal waste (bovine, ovine and poultry) was determined by choosing the Eastern Anatolia Region, which is one of the 7 regions of Turkey, and the data obtained by switching to the amount of energy production (manure, biogas and electricity amount) were supported by thematic/digital maps. The study area consists of 14 provinces in total. The study area is shown on the thematic map with population data for 2021 [12] (Figure 1).

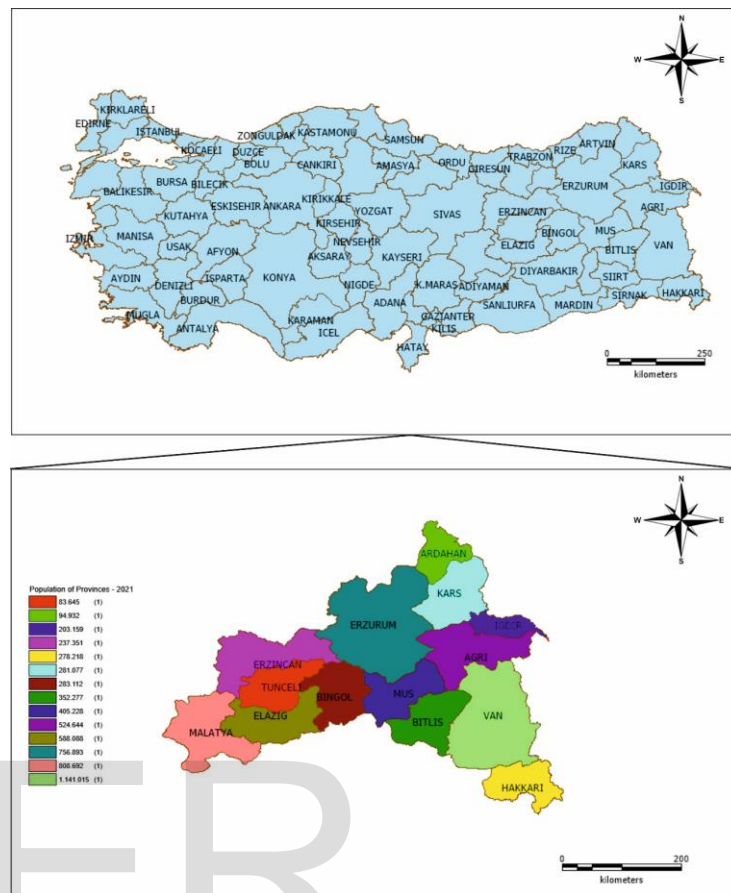


Fig. 1. Study area and population data of provinces (2021)

The numbers of bovine, ovine and poultry in the provinces of the Eastern Anatolia Region obtained from the Turkish Statistical Institute (TSI) 2021 data are given in Table 1.

Table 1. Animal numbers of the provinces in the Eastern Anatolia Region [13]

Province	Number of Bovine	Number of Ovine	Number of Poultry
Agri	413.012	1.427.144	236.455
Ardahan	331.468	118.527	295.053
Bingöl	132.307	696.131	808.614
Bitlis	88.991	795.230	95.534
Elazığ	187.326	1.089.120	6.844.851
Erzincan	128.289	550.077	1.354.928
Erzurum	860.404	900.623	213.061
Hakkari	37.923	676.719	59.673
Iğdır	100.400	1.402.380	132.059
Kars	620.723	604.755	893.192
Malatya	174.986	367.606	6.085.786
Muş	335.798	1.250.000	467.007
Tunceli	29.314	491.571	84.150
Van	166.401	3.384.220	462.032

In the calculations, the annual average amount of manure, the amount of biogas produced from 1 ton of animal manure and the amount of electricity produced from 1 m³ of biogas are given in Table 2.

Table 2. Amount of manure, biogas and energy by animal breed [14]

Animal Breed	Annual Average Manure Amount (ton/year)	Biogas (m ³) produced from 1 ton of animal manure	Electricity produced from 1 m ³ biogas (kWh)
Bovine	3.6	33	4.7
Ovine	0.7	58	4.7
Poultry	0.02	78	4.7

The following equations were used to calculate the amount of manure, biogas production and electricity production [15].

$$\text{AWA: Annual Waste Amount (ton/year)} \quad \text{AWA} = \text{NA} \times \text{APAPA} \quad (1)$$

$$\text{ABA: Annual Biogas Amount (m}^3\text{/year)} \quad \text{ABA} = \text{AWA} \times \text{BCR} \quad (2)$$

$$\text{AEA: Annual Electricity Amount (kWh/year)} \quad \text{AEA} = \text{ABA} \times \text{EER} \quad (3)$$

NA: Number of Animals, APAPA: Annual Production Amount Per Animal, AWA: Annual Waste Amount, BCR: Biogas Conversion Rate, EER: Energy Exchange Rate.

Calculations made are shown with tables and thematic/digital maps. Excel 10 program was used to make the calculations, and the Mapinfo Pro program was used to create the thematic/digital maps.

3 RESULTS AND DISCUSSION

3.1 Obtainable Manure Amounts and Thematic / Digital Maps

In this study conducted to determine the biogas and electricity energy potential of the Eastern Anatolia Region, for 2021; it has been determined that a total of 12.986.431,20 ton/year manure can be obtained from bovine animals, 9.627.872,10 ton/year from ovine animals and 360.647,90 ton/year from poultry. It has been determined that a total of 22.613.873,02 ton/year of manure can be obtained from all the numbers of bovine, ovine and poultry in the Eastern Anatolia Region (Table 3).

Table 3. The amount of manure that can be obtained from the provinces in the Eastern Anatolia Region (ton/year) (2021)

Province	Bovine Animal	Ovine Animal	Poultry Animal	Total
Ağrı	1.486.843,2	999.000,8	4.729,1	2.490.573,10
Ardahan	1.193.284,8	82.968,9	5.901,06	1.282.154,76
Bingöl	476.305,2	487.291,7	16.172,28	979.769,18
Bitlis	320.367,6	556.661	1.910,68	878.939,28
Elazığ	674.373,6	762.384	136.897,02	1.573.654,62
Erzincan	461.840,4	385.053,9	27.098,56	873.992,86
Erzurum	3.097.454,4	630.436,1	4.261,22	3.732.151,72
Hakkari	136.522,8	473.703,3	1.193,46	611.419,56
Iğdır	361.440	981.666	2.641,18	984.669
Kars	2.234.802,8	423.328,5	17.863,84	2.675.795,14
Malatya	629.949,6	257.324,2	121.715,72	1.008.989,52
Muş	1.208.872,8	875.000	9.340,14	2.093.212,94
Tunceli	105.530,4	344.099,7	1.683	451.313,10
Van	599.043,6	2.368.954	9.240,64	2.977.238,24
Total	12.986.431,20	9.627.872,10	360.647,90	22.613.873,02

3.2 Obtainable Biogas Amounts and Thematic/Digital Maps

For 2021, it has been determined that a total of 416.636.637,12 m³/year biogas can be obtained from bovine animals, 558.416.581,80 m³/year from ovine animals and 28.130.536,20 m³/year from poultry animals. It has been determined that a total of 1.003.183.755,12 m³/year biogas can be obtained from all the numbers of bovine, ovine and poultry animals in the Eastern Anatolia Region. In addition, the percentages of biogas amounts that can be produced on the basis of provinces are also calculated and shown (Table 4).

Table 4. Biogas amounts that can be obtained from the provinces in the Eastern Anatolia Region (m³/year) (2021)

Province	Bovine Animal	Ovine Animal	Poultry Animal	Total	%
Ağrı	49.065.825,6	57.942.046,4	368.869,8	107.376.741,80	10,7
Ardahan	39.378.398,4	4.812.196,2	460.282,68	44.650.877,28	4,45
Bingöl	15.718.071,6	28.262.918,6	1.261.437,84	45.242.428,04	4,50
Bitlis	10.572.130,8	32.286.338	149.033,04	43.007.501,84	4,28
Elazığ	22.254.328,8	44.218.272	10.677.967,56	77.150.568,36	7,69
Erzincan	15.240.733,2	22.333.126,2	2.113.687,68	39.687.547,08	3,95
Erzurum	102.215.995,2	36.565.293,8	332.375,16	139.113.664,16	13,86
Hakkari	4.505.252,4	27.474.791,4	93.089,88	32.073.133,68	3,19
Iğdır	11.927,52	56.936.628	206.012,04	57.154.567,56	5,69
Kars	73.741.892,4	24.553.053	1.393.379,52	99.688.324,92	9,93
Malatya	20.788.336,8	14.924.803,6	9.493.826,16	45.206.966,56	4,50
Muş	39.892.802,4	50.750.000	728.530,92	91.371.333,32	9,10
Tunceli	3.482.503,2	19.957.782,6	131.274	23.571.559,80	2,34
Van	19.768.438,8	137.399.332	720.769,92	157.888.540,72	15,73
Total	416.636.637,12	558.416.581,80	28.130.536,20	1.003.183.755,12	100,00

The numerical ranges of biogas amounts that can be obtained from bovine animals are shown on the thematic/digital map as in Figure 2.

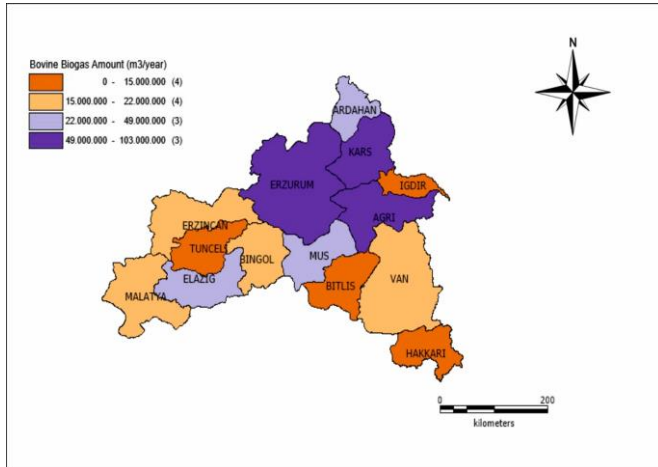


Fig. 2. Amount of biogas that can be obtained from bovine animals (m³/year)

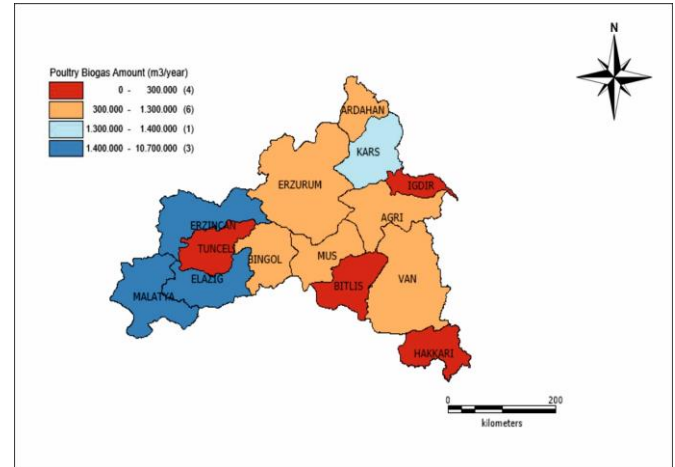


Fig. 4. Amount of biogas that can be obtained from poultry animals (m³/year)

The numerical ranges of biogas amounts that can be obtained from ovine animals are shown on the thematic/digital map as in Figure 3.

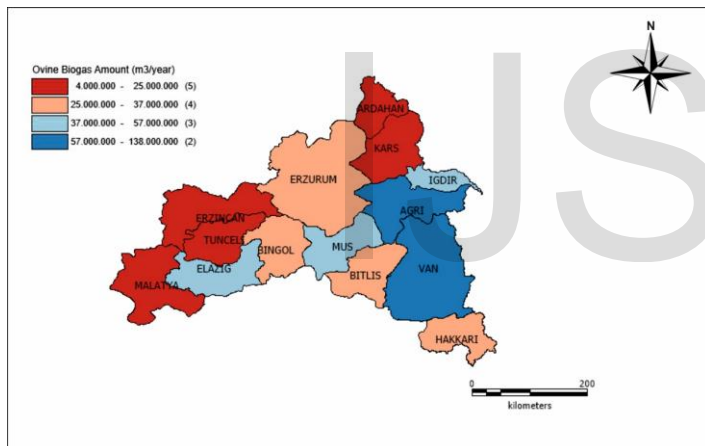


Fig. 3. Amount of biogas that can be obtained from ovine animals (m³/year)

The numerical ranges of biogas amounts that can be obtained from poultry animals are shown on the thematic/digital map as in Figure 4.

3.3 Obtainable Electricity Energy Amounts and Thematic/Digital Maps

For 2021, it has been determined that a total of 1.958.192.194,50 kWh/year electricity energy can be obtained from bovine animals, 2.624.557.934,48 kWh/year from ovine animals and 132.213.520,14 kWh/year from poultry animals. It has been determined that a total of 4.714.963.649,12 kWh/year electricity energy can be obtained from all the numbers of bovine, ovine and poultry animals in the Eastern Anatolia Region. In addition, the percentages of electricity energy that can be produced on the basis of provinces are also calculated and shown (Table 5).

Table 5. The amount of electricity that can be obtained from the provinces in the Eastern Anatolia Region (kWh/year) (2021)

Province	Bovine Animal	Ovine Animal	Poultry Animal	Total	%
Agri	230.609.380,3	272.327.618,1	1.733.688.06	504.670.686,46	10,70
Ardahan	185.078.472,5	22.617.322,14	2.163.328.596	209.859.123,24	4,45
Bingöl	73.874.936,52	132.835.717,4	5.928.757,848	212.639.411,77	4,50
Bitlis	49.689.014,76	151.745.788,6	700.455,288	202.135.258,65	4,28
Elazığ	104.595.345,4	207.825.878,4	50.186.447,53	362.607.671,33	7,69
Erzincan	71.631.446,04	104.965.693,1	9.934.332,096	186.531.471,24	3,95
Erzurum	480.415.177,4	171.856.880,9	1.562.163,252	653.834.221,55	13,86
Hakkari	21.174.686,28	129.131.519,6	437.522,436	150.743.728,32	3,19
Iğdır	56.059,344	267.602.151,6	968.256,588	268.626.467,53	5,69
Kars	346.586.894,3	115.399.349,1	6.548.883,744	468.535.127,14	9,93
Malatya	97.705.182,96	70.146.576,92	44.620.982,95	212.472.742,83	4,50
Mus	187.496.171,3	238.525.000	3.424.095,324	429.445.266,62	9,10
Tunceli	16.367.765,04	93.801.578,22	616.987,8	110.786.331,06	2,34
Van	92.911.662,36	645.776.860,4	3.387.618,624	742.076.141,38	15,73
Total	1.958.192.194,50	2.624.557.934,48	132.213.520,14	4.714.963.649,12	100,00

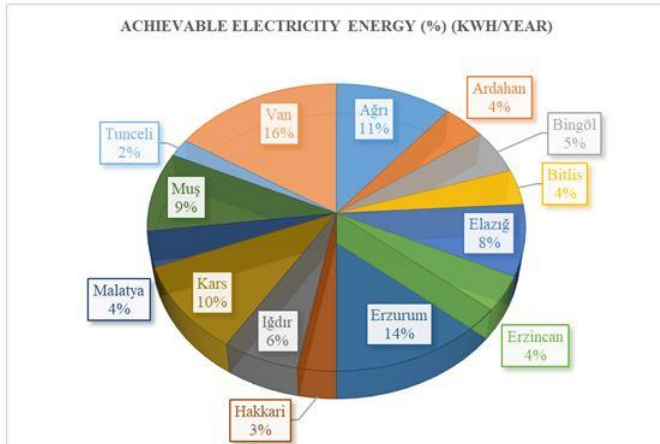


Fig. 5. Percentages of electricity energy amounts that can be produced

The numerical ranges of electricity energy amounts that can be obtained from bovine animals are shown on the thematic/digital map as in Figure 6.

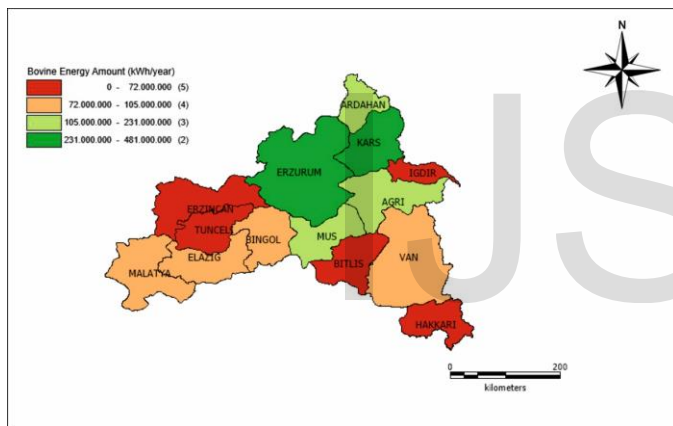


Fig. 6. Amount of electricity energy that can be obtained from bovine animals (kWh/year)

The numerical ranges of electricity energy amounts that can be obtained from ovine animals are shown on the thematic/digital map as in Figure 7.

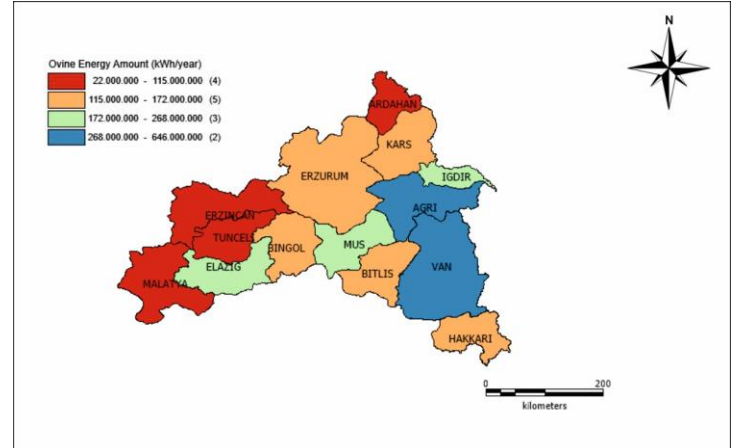


Fig. 7. Amount of electricity energy that can be obtained from ovine animals (kWh/year)

The numerical ranges of electricity energy amounts that can be obtained from poultry animals are shown on the thematic/digital map as in Figure 8.

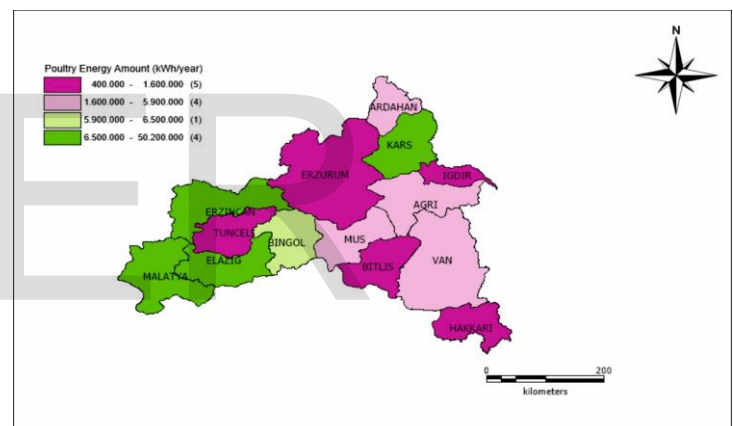


Fig. 8. Amount of electricity energy that can be obtained from poultry animals (kWh/year)

4 CONCLUSIONS

Population growth, globalization and developments in technology have led to an increase in energy needs and the search for renewable energy sources has accelerated on a global scale. The issue of electricity energy production from biogas, which is one of these sources, has recently come to an important point. Considering this situation, various studies are carried out and efforts are made to contribute to energy production. In this study, calculations of the amount of manure, biogas and electricity energy that can be produced based on the animal numbers of the Eastern Anatolia Region were made and numerical/thematic maps were prepared in line with the results obtained. The main purpose of the study was to determine the amount of electricity energy that can be produced from the biogas potential, which is considered as a renewable energy

source. In this direction, calculations were made using the animal numbers data of the provinces of the Eastern Anatolia Region obtained from the Turkish Statistical Institute.

As a result of all the calculations, it has been determined that 4.714.963.649,12 kWh of electricity energy can be produced from animal manures in the Eastern Anatolia Region for 2021. According to the data of the Republic of Turkey Ministry of Energy and Natural Resources [16], the total electricity energy consumed by our country in 2021 is 329.6 billion kWh. In this case, it can be said that the electricity energy that can be obtained from biogas of animal derived in the Eastern Anatolia Region can meet 1.45% of the electricity energy need of our country. In addition, it is possible to obtain plant-based bioenergy in the Eastern Anatolia Region. This factor should be taken into account in future studies. In this way, the amount of energy that can be produced will also increase.

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