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Assessment of Biogas Production Potential of Livestock Wastes In Tokat Province by Geographic Information Systems (GIS) Technologies

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Abstract: The present study was conducted to determine the biogas production potential of livestock wastes of Tokat Province with intensive livestock facilities by the aid of GIS technologies, to identify possible use of these wastes in energy production and to determine the contributions provided to economy. Biogas production potential of Tokat Province was calculated as 301 434 m^3/day with an energy equivalent of 502 390 kWh/day. Since livestock facilities are common in the region and it is easy to collect livestock waste, livestock wastes among the animal wastes were taken into consideration and pilot central biogas facilities were designed for 250, 500 and 1 000 animal capacities. Floor plans, cross-sections and side wives were all drawn in AutoCAD and dimensioning, energy analyses and costing were performed for those facilities. ArcMAP software was used in analyses to determine the locations, numbers and capacities of biogas facilities based on animal intensities and distances between rural settlements. Analyses revealed that 228 biogas facilities could be constructed for 250 animal, 171 facilities for 500 animal and 131 facilities for 1 000 animal.

Keywords: Biogas, Animal waste, Geographic information systems, Tokat

1. Introduction

Energy is an indispensable part of human life and is a significant indicator of economic and social development. It is highly effective in improvement of life standards and plays a vital role in technological production and development. Fossil fuels have commonly been used to meet world energy demands for ages. But is evident that such resources will not be able to meet the demands of mankind in near future and consequently an energy bottleneck is envisaged for the upcoming years. So, renewable energy sources should be investigated and put into practice to overcome this prospective bottleneck in energy supply.

Rapid increase in world population, industrialization, urbanization, technological developments and improved life standards all are depleting limited sources and ultimate increases in energy consumptions come to forefront as a significant problem. Despite the limited sources of fossil fuels, there is ever-increasing demand for energy. Excessive fossil fuel consumptions increase the atmospheric carbon dioxide levels and such a increase will eventually reach to threatening levels in near future. Thus, mankind is always searching for alternative energy sources because of depleting fossil fuel sources and possible environmental impacts of fossil fuel consumptions. Therefore, there is an urgent need for proper and reuse use of currently available resources and for putting new resources into service. Right at this point, new and renewable energy resources come into mind since fossil fuels have been depleted rapidly, have irrecoverable damages on natural life and environment, threaten the future generations and limited sources are distributed unevenly throughout the world. There are several studies carried out to benefit from alternative renewable energy sources instead of

* *This study presents partial results of a Graduate Thesis.*

fossil fuels. Agricultural, livestock and domestic wastes are considered as an alternative source of energy in Turkey as it was in various other parts of the world to meet a portion of energy demand and to overcome the problems related to energy resources. Therefore, there is a need for research to assess the energy production potential of such wastes, about the anaerobic digestion conditions and proper digesters. The studies on biogas production technologies should be supported and anaerobic treatment technologies should be developed.

For proper implementation of biogas technologies in Turkey, regional or local potentials should initially be determined. Tokat Province of Turkey has significant potential with regard to agricultural and livestock activities. Total livestock inventory of the province is 384 795 bovines, 258 944 ovine (sheep and goats) and 248 156 poultry (Anonymous, 2014). The province has also significant infrastructure and land resources for energy forestry and biofuels. However, biomass energy production from plant materials, livestock and forest wastes, grass lands, domestic and industrial wastes is not still at desired levels (Karaman and Ozguven, 2012). Livestock wastes are piled up over the fields and burnt as cowpat and such uses result in various environmental problems (Karaman, 2015). Despite the rapid growth of livestock industry of the province, possible use of livestock wastes and their conversion into energy sources are not assessed sufficiently. Thus, researches are needed to assess biogas production potential of these livestock wastes of the province.

The present study was conducted to determine province-wide distribution of livestock and biogas production potential of livestock wastes of Tokat Province, to determine the locations and capacities of potential biogas facilities by using Geographical Information Systems (GIS) technologies.

2. Material and Methods

2.1. Material

The present study was conducted to determine livestock inventory of Tokat Province and to assess biogas production potential from livestock wastes by using GIS technologies. Therefore, initially, characteristics of current livestock facilities, their livestock inventories, distribution throughout the province, land resources and distribution, population distribution and geographical characteristics were investigated. Relevant data was gathered from Tokat Provincial Directorate of Food Agriculture and Livestock, TUIK (Turkish Institute of Statistics), DMI (State Meteorological Works). These data and supplementary satellite images, ArcGIS software and modules constituted the basic material of the study.

2.2. Method

The equations provided in Ergunes and Tarhan (2009) were used to calculate daily manure production, daily slurry amount, amount of water to be added to manure, daily total slurry volume, reactor (digester) volume (RH), total specific gas production, daily gas production, volume of gas tank.

In calculation made to determine biogas potential, optimum biogas conditions were assumed and the recommendations provided in Ergunes and Tarhan (2009) were considered to calculate daily manure production of an animal, biogas reactor volumes for different size facilities and hydraulic retention times.

Since livestock facilities are common in the region and it is easy to collect livestock waste, livestock wastes among the animal wastes were taken into consideration and pilot central biogas facilities were designed for 250, 500 and 1 000 animal capacities. Floor plans, cross-sections and side wives were all drawn in AutoCAD and dimensioning, energy analyses and costing were performed for those facilities.

The principles provided in Kaya and Ozturk (2012) were taken into consideration while calculating daily organic matter to be fermented or loaded into reactor (reactor loading) and reactor height. Reactor loading was taken as 5 kg/m^3/day as recommended and 33 m^3/day gas production was assumed per ton of manure Kaya and Ozturk (2012).

Reactor sizing was performed by considering the recommendation provided in Kaya and Ozturk (2012) for vertical cylindrical floating balloon type biogas facilities. Reactor diameters were taken as equal to reactor heights and the ratio of RH/GD=3/1was taken while calculating gas tank volumes (Kaya and Ozturk, 2012). While calculating livestock waste-based biogas production potential of the province, 30% of gas was assumed to be electricity, 60% heat and 10% loss through cogeneration method of the gas and thermic equivalent of biogas was taken as 20 MJ/m^3 (Kaya and Ozturk, 2012; Gulen and Arslan, 2005).

2.1.1 Site selection for biogas facilities

Geographical information systems (GIS) and Ordinary Kriging interpolation method were used to assess the biogas production potential of livestock waste in Tokat Province and to determine the proper sites for construction of pilot biogas facilities with different capacities based on number of animals in surrounding villages (Yaprak and Arslan, 2008).

ArcGIS (Version 9.3.1) software of Surveying Engineering of Gaziosmanpaşa University Engineering Faculty was used for data processing and analyses (ESRI, 2005). To prepare data base for rural settlements, composite satellite images (1997-98 dated IRS-1C black and white satellite images (053/041) with 6m resolution and 1997-1998 dated LANDSAT-TM color satellite images (174/32; 175/32) with 30 m resolution) taken in spring and summer seasons (Figure 1) and digital elevation data base with 20 m intervals obtained from 1/50000 scaled maps were used (Susam, 2000). Number of livestock obtained from Tokat Provincial Directorate of Food Agriculture and Livestock were incorporated into this data base. Proper sites, numbers and capacities of pilot biogas facilities were then selected by taking ArcGIS analyses results, number of animals in surrounding villages and distances between rural settlements.

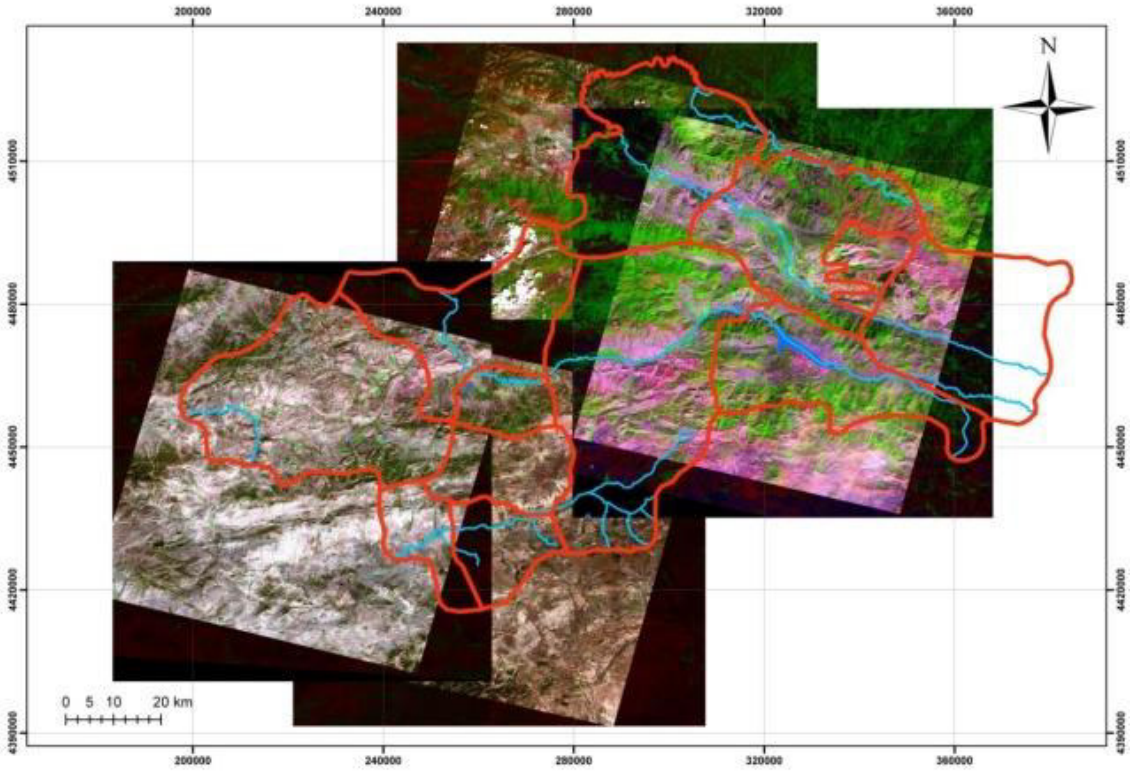

Figure 1. Composite satellite image frames used in this study

The present study was composed of the following stages: Selection of criterion and study area, data base and process design, data gathering, arrangement of overlay site selection data and site selection. The flow chart for site selection is presented in Figure 2.

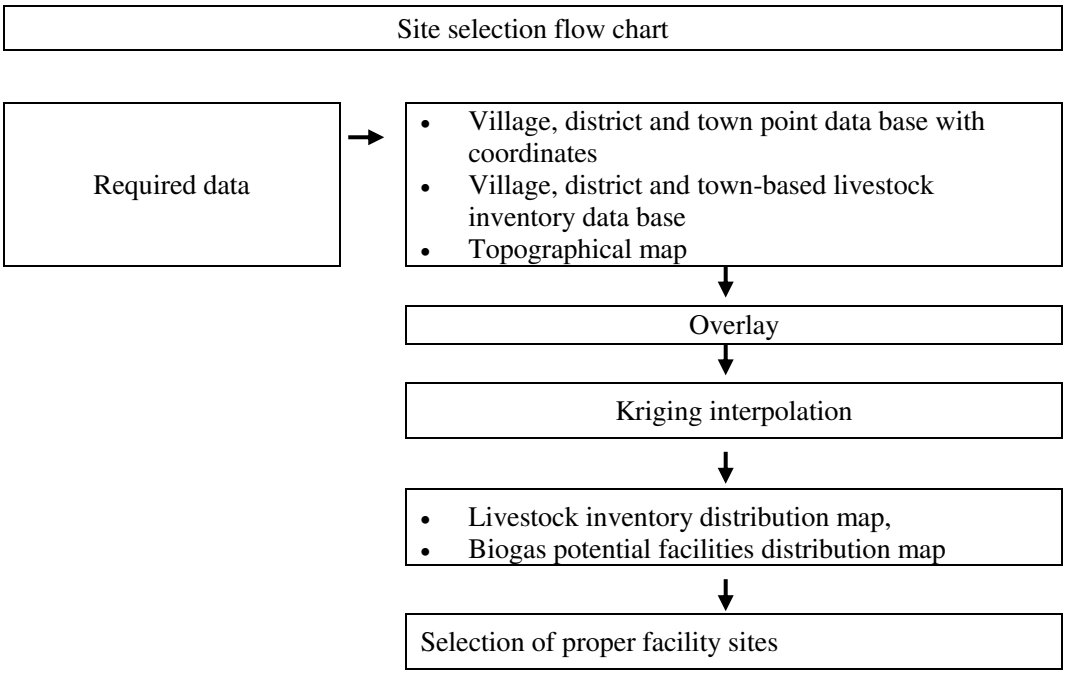

Figure 2. Site selection flow chart

3. Results and Discussion

3.1.Biogas Potential and Energy Production of Tokat Province

There are 384 795 bovines, 258 944 ovine and 248 156 poultry of which 239 805 are hens and 8 351 are the other poultry. Of this livestock inventory, 55% are local races, 35% are hybrid and 10% are culture races. The ratio of culture races was significantly at low levels. Of total ovine inventory, 84% are sheep and 16% are goats. Of total poultry inventory, 91% are hens, 3% are goose, 2% are turkey and 2% are duck. Of livestock facilities, 63% have an animal inventory of 1-10, 2% have 11-20, % have 21-30, 3% have 31-40, 1.5% have 41-50, 1.4% have 51-100 and only 0.2% have an animal inventory of over 101. Of this bovine inventory, 70.5% are dairy cows and 29.5% are beef cattle (Anonymous, 2014). Livestock-based biogas potential of Tokat Province and energy equivalents are provided in Table 1.

3.2. Design of pilot biogas facilities for Tokat Province

Since livestock facilities are common in the region and it is easy to collect livestock waste, livestock manure among the animal wastes were taken into consideration for biogas production. Since biogas facilities have high initial investment costs and return on investment takes longer, livestock manure is not well utilized in the region and excessive manure haphazardly piled up over the fields and result in various environmental problems, pilot biogas facilities were designed for 250, 500 and 1 000 bovine manure capacities. Collection and storage of manures of rural settlements at a certain place will reduce the facility cost, time and labor losses. Environmental problems will also be eliminated through the use of such wastes in biogas production.

Livestock inventories of villages obtained from Tokat Provincial Directorate of Food Agriculture and Livestock were incorporated into rural settlement map obtained from Surveying

Engineering Department of Gaziosmanpaşa University Agricultural Faculty through "Arc Editor Tools" menu of ArcGIS software. Incorporated inventories were converted into spatial distribution map by using Kriging interpolation technique and ultimately distribution maps of livestock inventories and potential biogas facilities were obtained. The inventory distribution map was separated into four sections indicating 1-250, 250-500, 500-750, 750-1 000 cattle with different colors (Figure 3).

Table 1. Total biogas potential of Tokat Province and energy equivalents

TOWNS	DMP (ton/day)	Reactor volume (m^3)	DGP (m^3/day)	Total energy equivalent (kWh/day)	Cogenerated energy equivalents (kWh/day)		
					Electricity	Heat	Loss
ALMUS	453	29 452	16 895	93 861	28 158	56 317	9 386
ARTOVA	364	22 673	12 942	71 900	21 570	43 140	7 190
BAŞÇİFTLİK	117	7 401	4 244	23 578	7 073	14 147	2 358
ERBAA	755	51 964	30 227	167 928	50 378	100 757	16 793
MERKEZ	1 629	104 000	59 660	331 444	99 433	198 867	33 144
NİKSAR	1 113	70 545	40 392	224 400	67 320	134 640	22 440
PAZAR	264	16 538	9 451	52 506	15 752	31 503	5 251
REŞADİYE	514	33 665	19 399	107 772	32 332	64 663	10 777
SULUSARAY	292	18 030	10 267	57 039	17 112	34 223	5 704
TURHAL	1 241	78 609	45 009	250 050	75 015	150 030	25 005
YEŞİLYURT	311	19 411	11 075	61 528	18 458	36 917	6 153
ZİLE	1 180	73 275	41 873	232 628	69 788	139 577	23 263
TOTAL	8 234	525 563	301 434	1 674 633	502 390	1 004 780	167 463

DMP: Daily Manure Production, DGP: Daily Gas Production

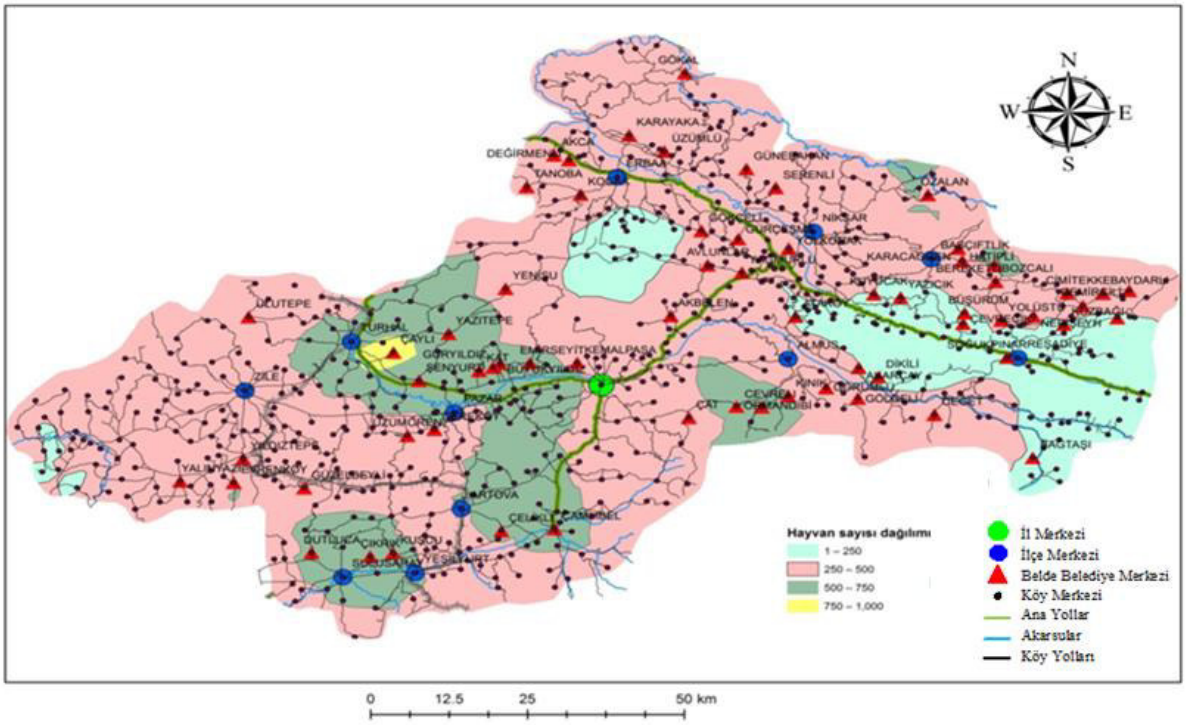

Figure 3. Livestock inventory distribution map of Tokat Province

Livestock inventory distribution map created was overlain on rural settlement vector map (Yaprak and Arslan, 2008) and the resultant map was sectioned based on inventory distribution and the distances between rural through Kriging interpolation technique settlements. Over this map, locations of 250, 500 and 1 000 animal waste capacity biogas facilities were marked and presented in Figure 4.

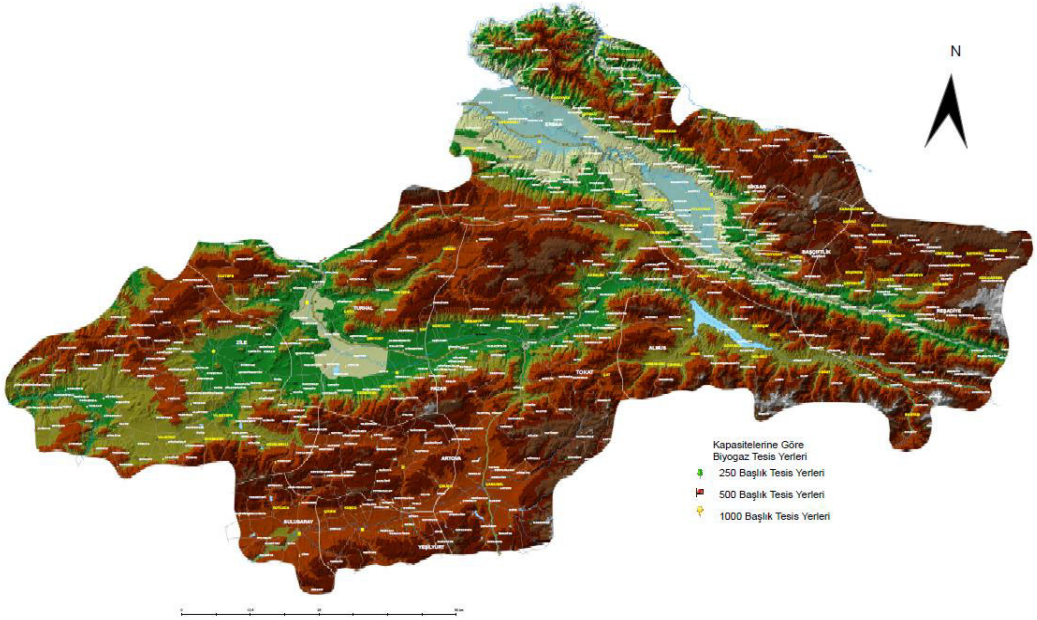

Figure 4. Capacity-based locations of biogas facilities

Table 2. Number of facilities, biogas potentials and energy equivalents

TOWNS	Number of biogas facilities (number of livestock)			DGP (m^3/day)	Total energy equivalent (kWh/day)	Cogenerated energy equivalents (kWh/day)		
	250	500	1 000			Electricity	Heat	Loss
ALMUS	16	13	7	11 893	66 072	19 822	39 643	6 607
ARTOVA	6	9	8	9 512	52 844	15 853	31 707	5 284
BAŞÇİFTLİK	5	1	1	1 869	10 383	3 115	6 230	1 038
ERBAA	32	25	10	20 730	115 167	34 550	69 100	11 517
MERKEZ	28	31	25	32 275	179 306	53 792	107 583	17 931
NİKSAR	35	21	21	27 349	151 939	45 582	91 163	15 194
PAZAR	8	2	4	4 756	26 422	7 927	15 853	2 642
REŞADİYE	41	14	2	13 088	72 711	21 813	43 627	7 271
SULUSARAY	5	5	4	5 266	29 256	8 777	17 553	2 926
TURHAL	10	9	19	17 661	98 117	29 435	58 870	9 812
YEŞİLYURT	3	3	6	5 604	31 133	9 340	18 680	3 113
ZİLE	39	38	24	35 846	199 144	59 743	119 487	19 914
TOTAL	228	171	131	185 849	1 032 494	309 748	619 497	103 249

DGP: Daily Gas Production

The present results revealed that in Tokat Province, 228 facilities with 250 livestock waste capacity, 171 facilities with 500 livestock waste capacity and 131 facilities with 1000 livestock waste capacity could be constructed to convert livestock waste into biogas. The province has then a capacity for 530 pilot biogas facilities. Number of biogas facilities is provided in Table 2 based on livestock intensity, distances between the villages,

number of villages in towns and number of livestock in facilities.

Pilot biogas facility potential of Tokat Province is presented in Figure 5. The resultant map revealed that Zile, Turhal, Pazar, Merkez and Artova towns were more suitable for 1 000 livestock capacity facilities, Başçiftlik, Almus, Sulusaray and Yeşilyurt towns were more suitable for 500 livestock waste capacity facilities and Reşadiye and Erbaa towns were more suitable for 250 livestock manure capacity facilities. The places with up to 250 livestock were indicated in purple color, places with 250-500 livestock were indicated in green and the places with above 500 livestock were indicated in red.

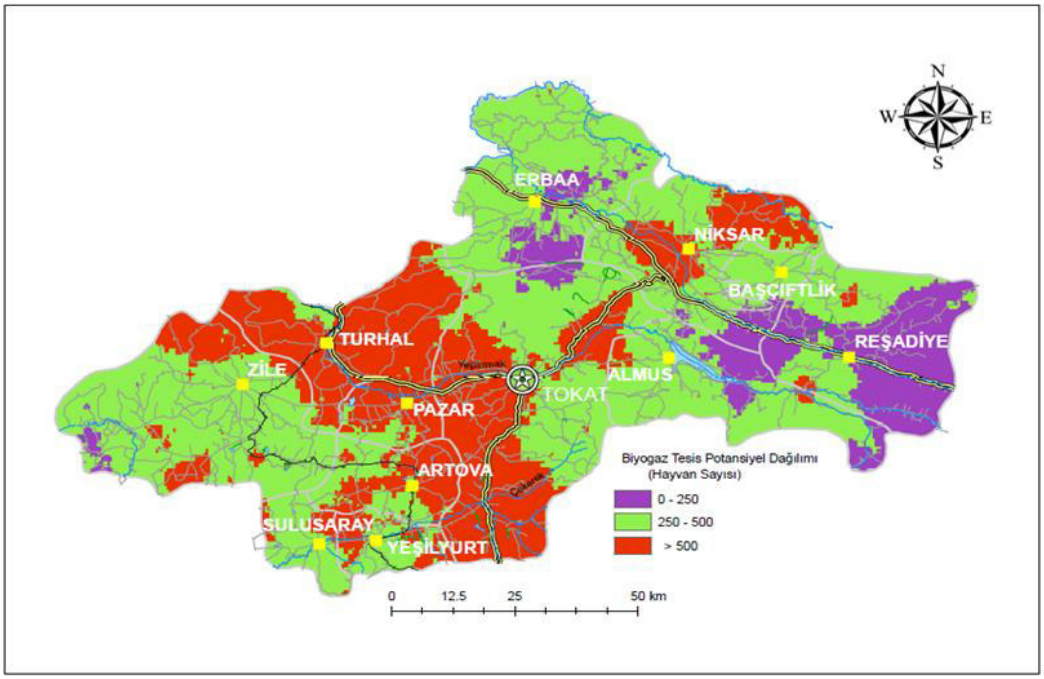

Figure 5. Potential distribution of biogas facilities designed for Tokat Province

4. Conclusions

Livestock manure is stored open fields and creates various problems on environment in Tokat Province. Besides being used over the agricultural lands as fertilizer, manure is also used for heating and cooking in rural parts of the province. When the manure is used for heating purposes, sufficient heat is not produced and post-burning residues are not able to be used as fertilizer. Energy obtained from direct burning is relatively lower than the energy obtained through conversion of manure into biogas. Using manure over agricultural fields is also more economical than converting it to energy through direct burning. On the other hand, fermented fertilizer from the biogas facilities to be designed is more beneficial for soil and has a potential to reduce chemical fertilizer use over agricultural lands.

GIS technologies were used to determine the possible locations and capacities of the biogas facilities to be used in the province. Such technologies allowed the user to organize the relevant information in shorter time and with less cost, to take rapid and consistent decisions and to reach the optimum solutions for problems. The user with GIS technologies was able to visualize the prospective locations for the facilities and also able to integrate and questions possible solutions. GIS technologies can also be used for the best implementation of manure collection, storage and processing phases. Such systems with complex data processing in short times, current data use and wholesome planning capabilities are now constituted the heart and therefore an integral part of planning sector.

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