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Biochar production potential analysis of Isparta, Turkey for 2019-2020

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ABSTRACT: Although biochar has been researched worldwide, it has not been adequately recognized in Turkey. Biohar has many advantages, such as carbon retention, reducing greenhouse gas emissions, improving soil and improving crop productivity. In this study, the potential of conversion of agricultural and animal wastes of Isparta, Turkey to biomass was theoretically calculated. Data from the Turkish Statistical Institute for 2019 and 2020 were used to determine the biochar transformation potential. Calculations were made separately for each year and the results were compared. In 2019, it was determined that the total biochar conversion potential value of agricultural and animal production wastes was 42383 tons and in 2020 it was determined that this value was 43592 tons. Approximately 42988 tons of biochar were obtained per year when the average of both years was taken. Given the proportional change in biochar production in 2020 compared to 2019, there is an increase of about 3%.

Keywords – *biochar, animal manure, agricultural waste, Isparta*

1. Introduction

In recent years, renewable energy sources have become the focus of attention due to their energy potential and non-environmental damage (Quan et al., 2016; El-Naggar et al.,2019). Biomass is a sustainable energy source that has a faster life cycle than fossil fuels. It is also abundant , CO_2-free, low sulfur content, easy to store and non-polluting renewable material that can be used in heat and fuel production. Biomass energy is one of the fourth largest potential energy sources in the world and is therefore considered the energy carrier of the future (Masnadi et al., 2014; Vu Ly et al., 2015). Agricultural, animal and industrial wastes are important biomass sources in Turkey and it is estimated that approximately 285 million tons of waste are produced annually.

A large part of agricultural production waste is directly burned and evaluated or left on the site. By using animal and farm waste in agricultural lands, harmful substances contained in waste reduce soil yield and cause environmental pollution (Tanczuk et al., 2019). Recycling, processing system and waste reduction targets have been determined for how sustainability can be addressed in the use of waste in many countries around the world. Biomass sources are evaluated by applying various conversion processes and obtaining alternative biofuels with properties equivalent to existing fuels. One of the conversion processes for biomass is pyrolysis, and this method is the process of thermal degradation or decomposition of substances in an oxygen-free environment. By pyrolysis technology, biofuel, carbon-rich material and hydrocarbon-rich biogas products can be obtained (Tripathi et al., 2016; Dursun, 2020). Organic waste, the main component of solid biomass, has a high potential to produce biochar.

Biochar is a carbon-rich organic material that serves the purpose of soil fertility, removal of heavy metals from water and soil, as well as its use for energy purposes. It has recently become widespread in production and use around the world and has become the focus of researchers with its features of reducing greenhouse gas emissions and improving soil fertility (Huang et al., 2019; Manolikaki and Diamadopoulos, 2019).

Uzoma et al. (2011) conducted a research to determine the physicochemical properties of biochar produced from cow manure and its effect on corn yield. Biochar was derived from dry cow dung pyrolized at 500 °C (Uzoma,et al.,2011). Lee et al. (2013a) compared the properties of biochars produced by sugarcane pulp, paddy straw, palm kernel bark, and umbrella tree with slow pyrolysis and examined their effects on soil fertility (Lee et al ., 2013a). Kantarli et al., (2016) compared the fuel properties of biochar obtained by pyrolysis of chicken farm waste at 250-500°C. (Kantarli et al.,2016). Sümer et al. (2016), theoretically determined the potential of agricultural and animal wastes to be converted to biochar in Turkey and determined the potential of biochar production. In the study, it was determined that the biological conversion potential of agricultural and animal production wastes was 3942654 tons (Sumer et al., 2016). Zornoza et al. (2016) examined the stability, nutrient content and waterproof properties of raw materials, pyrolysis temperature and waiting time of biochar produced using fertilizers, crop wastes and urban solid wastes (Zornoza et al., 2016). Manya et al. (2018), measured and compared CO_2 retention capacities after the activation of biomass products obtained using different types of biomass such as rice husks, vine leaves, and coconuts (Manya et al., 2018). Akdeniz (2019) has critically analyzed the role of biochar in livestock and poultry waste composting, identifying gaps in our current knowledge and suggesting future research directions. (Akdeniz,2019). Rehman et al. (2020) determined the effect of different soil species on water retention capacity and corn growth by producing biochar from animal manure by pyrolysis process at different temperatures (Rehman et al., 2020). Dursun (2020) stated that the total biochar conversion potential of Malatya's animal and plant wastes was 132319 tons. It was stated that 72.4% of the total biochar potential was made up of animal and 27.6% of plant waste (Dursun, 2020). Akça et al. (2020) examined some physicochemical properties of biochar obtained from paddy stalks by slow pyrolysis at 400°C with advanced analytical techniques (Akça et al., 2020). Rodriguez et all. (2021) investigated the change in mineral composition and functional groups of biochar products obtained at combined different pyrolysis temperatures of agricultural and industrial wastes. (Rodriguez et al., 2021).

In this study, the conversion potential of biochar, which can be obtained from agricultural and animal production wastes of Isparta, was investigated. Agricultural and animal production data obtained from the Turkish Statistical Institute (TUIK) for the years 2019 and 2020 were used as waste potential. The possibilities of converting the identified waste potential into biochar have been discussed.

2. Material and Methods

In this study, Isparta's plant and animal production data were examined first. Products with waste potential that can be used in biochar production have been identified. Biochar production is determined for 2019 and 2020. In determining the waste potential of the selected products, annual production statistics were obtained from the Turkish Statistical Institute.

In order to determine the biochar production potential, the size of the harvested land, the number of trees and the number of animals are needed. Dairy cattle, egg chickens, turkey, geese, ducks, sheep and goats were used as animal species. Plant data consists of waste of field products (sunflower, corn, sugar beet, potato, tomato) and garden products(apple, pear, cherry, almond, walnut, plum, cherry, fig, peach, nectarine, olive pruning) (TUİK, 2020). In the determination of animal production wastes (manure), the coefficients specified in Table 1 were used.

Daily wet manure quantities per determined animal were accepted (in brackets) for dairy cattle (27.2 kg), goat - sheep (2.2 kg) and egg chicken, turkey, goose, duck (0.08 kg) (Dursun,2020; LIFE 03 TCY).

According to Table 1, the total number of animals used in the study was 1836450. The amount of dry manure depending on the total number of animals was 337290 tons per year.

It has been calculated that the total amount of available dry manure obtained as a result of animal production was 79287 tons/year for 2019 and 80549 tons/year for 2020.

Table 1. Parameters and potentials of biochar conversion from animal waste

Animal Type with Biochar conversion ratio (BA) 35 %	Year	Number of Animals (NA)	Wet Manure (WM) ton/year	Dry Manure Ratio (DWM) %	Dry Manure (DM) ton/year	Availability Ratio (RA) %	Available Dry Manure (ADM) ton/year
Dairy Cattle	2020	87576	869455	12,7	110421	65	71773
	2019	87139	865116		109870		71415
Water Buffalo	2020	224	2224		282		184
	2019	173	1718		218		142
Sheep	2020	341591	274298	25	34838	13	4529
	2019	310025	248950		31617		4110
Goat	2020	243668	195665		24850		3230
	2019	227468	182657		23197		3016
Chicken	2020	223645	6531		829	99	822
	2019	289362	8449		1073		1062
Turkey	2020	1205	36		4		4
	2019	17157	501		64		63
Goose	2020	1054	31		4		4
	2019	1972	58		7		7
Duck	2020	798	23		3		3
	2019	3393	99		13		12
Total		**1836450**	**2655811**		**337290**		**160376**

With the intention of determining the amount of waste in field crops, the size of the harvested land were used.The coefficients and availability parameters hold by the California Energy Commission were used to account for annual amounts of waste and usable waste.Waste coefficients and parameters are given in Table 2 (Sümer et al., 2016; TUIK,2020; LIFE 03 TCY). The total amount of waste is 81917 tons per year. According to field product data, available waste in 2020 is 19947 tons/year and in 2019 is 21013 tons/year.

Table 2. Field product residues and biochar conversion potential

Product with Biochar Conversion Ratio (BF) 35%	Year	Harvested area (HA) da	Residue Coefficient (RC) ton da^{-1} year	Amount of Residue (AFR) ton year^{-1}	Availability Ratio (RF) %	Available Residue (AR) ton year^{-1}
Sunflower	2020	374	0.180	67	0.5	34
	2019	386	0.180	70		35
Corn	2020	26085	0.998	26033		13016
	2019	25497	0.998	25446		12723
Sugar Beet	2020	20913	0.510	10666		5333
	2019	17733	0.510	9044		4522
Potato	2020	3072	0.296	909		455
	2019	3254	0.296	963		482
Tomato	2020	13548	0.321	4349		2175
	2019	13612	0.321	4370		2185
Total		**124474**		**81917**		**40960**

Tree pruning activities in Vineyard and garden work also create wastes related to biochar production. Fruit tree numbers were taken into account for these wastes. The values in Table 3 were used as the pruning waste coefficient of fruit trees (Sümer et al., 2016; Dursun, 2020). The availability ratio was accepted as 70%, and the annual pruning waste and available waste amounts of fruit trees were calculated. The total pruning waste is 63277 tons per year. Total garden pruning waste availability for 2019 was found to be 21307 tons/year and 22987 tons/year for 2020. For conversion to biochar, 35% conversion rate was used for all wastes, taking into account the slow pyrolysis method with the highest efficiency given in Table 4 (Lehmann and Joseph,2009; Dursun,2020). The formulas given in Table 5 were used for theoretical biohar conversions.

Table 3. Pruning residues and biochar conversion potential of garden products

Garden Product with Biochar Conversion Ratio (BG) 35 %	Year	Number of trees (NG)	Pruning Coefficient (PC) kg/tree.year	Pruning Residue (APR) ton/year	Availability Ratio (RG) %	Available Pruning Residue (PR)ton/year
Apricot	2020	379573	5.79	2198	70	1539
	2019	363190		2103		1472
Apple	2020	6976491	2.34	16325		11428
	2019	6069368		14202		9942
Pear	2020	126792	2.45	311		217
	2019	124364		305		213
Cherry	2020	1172062	5.90	6915		4841
	2019	1196278		7058		4941
Almond	2020	294595	5.81	1712		1198
	2019	282838		1643		1150
Walnut	2020	159204	3.43	546		382
	2019	140106		481		336
Plum	2020	182430	7.34	1339		937

	2019	175555		1289		902
Morello	2020	264466	5.37	1420		994
	2019	255324		1372		960
Fig	2020	3545	4.58	16		11
	2019	3358		15		11
Peach	2020	236176	7.23	1708		1195
	2019	229495		1659		1162
Nectarine	2020	27585	7.23	199		140
	2019	26340		190		133
Olive	2020	16550	9.08	150		105
	2019	13420		122		85
Total		**1335382**		**63277**		**44294**

Table 4. Biochar conversion ratios of different pyrolysis methods

Pyrolysis	Conditions	Liquid (%)	Biochar (%)	Gas (%)
Fast process	Medium temperature for 1 second (500^{0}C)	75	12	13
Medium speed	Medium temperature for 10-20 seconds (500^{0}C)	50	20	30
Slow process	Long time low temperature (400^{0}C)	30	35	35
Gasification	Long time in steam high temperature (800 ^{0}C)	5	10	85

Table 5. Biochar conversion formulas

For Animals	For Field Products	For Garden Products
WM= N_A x DWM x 0.365	AFR = HA x RC	APR = N_G x PC
DM = WM x DMR (%)	AR = AFR x R_F (%)	PR = APR x R_G
ADM = DM x R_A(%) BP_A = ADM x B_A(%)	BP_F = AR x B_F (%)	BP_G = PR x B_G

3. Results and Discussion

Isparta has an important place in Turkey's livestock and agricultural economy. It is among the special agricultural regions of Turkey due to its climate characteristics, fertile soil structure, location and transition zone between Mediterranean and continental climate. Total agricultural land is 251282 ha. In the last two decades, the total presence of cattle in the province has changed by 142% and in small ruminant by 72%. Accordingly, the number of cattle and small ruminant managements in the province also increased. The number of cattle enterprises was 13575 and the number of small enterprises was 4972 (Anonim, 2021). The biochar-related results obtained for animal and plant species using the data and formulas given in Table 1-5 are given in Table 6.The biochar conversion potentials by using slow pyrolysis depending on the number of cattle, small ruminant and poultry in 2019 and 2020 are given in Figure 1. The biochar conversion potential was calculated separately for each animal species. The total biochar potential for all animal species in 2019 was 27940 tons, while it is 28192 tons in 2020. It was found that the percentage change in biochar potential by year is of the same value (50%), since there are no very significant differences in the number of animals for cattle. When the percentage biochar potential is evaluated according to the years for the small ruminant and poultry, there is a 4% increase in small ruminant and a 16% decrease in poultry. The reason for the decline in the poultry group is that the number of turkey has decreased by about 93%. In 2019 and 2020, it was observed that 90% of the total distribution of animal manure potential for the conversion of biomass is cattle, 9% is small ruminant and 1% is poultry manure.

Table 6. Biohar potentials

Animal Type	**BPA (ton/year) - Year**	**Field Product**	**BPF (ton/year) - Year**	**Garden Product**	**BPG (ton/year) Year**
Dairy Cattle	25121 -2020 24995 -2019	Sunflower	12-2020 12-2019	Apricot	538-2020 515-2019
Water buffalo	64-2020 50-2019	Corn	4556-2020 4453-2019	Apple	4000-2020 3480-2019
Sheep	1585-2020 1439-2019	Sugarbeet	1867-2020 1583-2019	Pear	76-2020 75-2019
Goat	1131-2020 1056-2019	Potato	159-2020 169-2019	Cherry	1698-2020 1729-2019
Chicken	287-2020 372-2019	Tomato	761-2020 765-2019	Almond	419-2020 403-2019
Turkey	2-2020 22-2019			Walnut	134-2020 118-2019
Goose	1-2020 3-2019			Plum	328-2020 316-2019
Duck	1-2020 4-2019			Morello	348-2020 336-2019
				Fig	4-2020 4-2019
				Peach	418-2020 407-2019
				Nectarine	49-2020 47-2019
				Olive	37-2020 30-2019

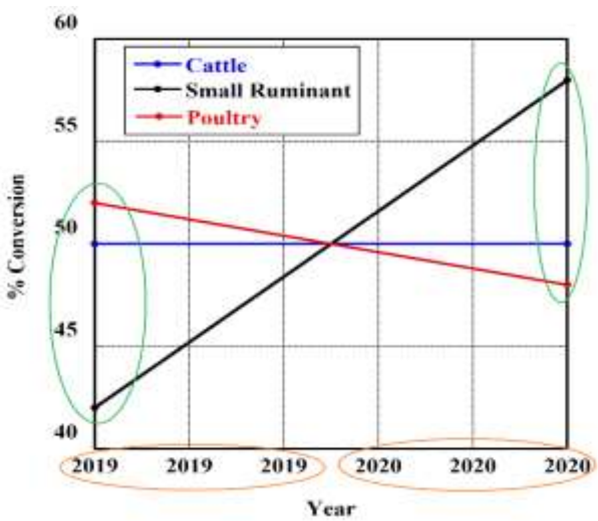

Figure 1. Animal-derived biochar conversion % potentials.

The biochar production potentials of field products calculated for 2019 and 2020 are given in Figure 2 as a percentage. Wheat, barley, oats, grain group wastes are important and widely used feed sources for livestock sector. The biochar conversion potential determined by taking into account the products left in the field after harvest, was determined as 14335 tons per year. The biochar conversion potentials of tomatoes and sunflowers are examined, it is seen that there is no percentage change. There is not much change in both crops in the area harvested according to the years. When the biochar conversion potential of sugar beet, potato and corn are examined by year, the largest proportional change was observed in sugar beet with 8%. The least proportional change has been in corn.

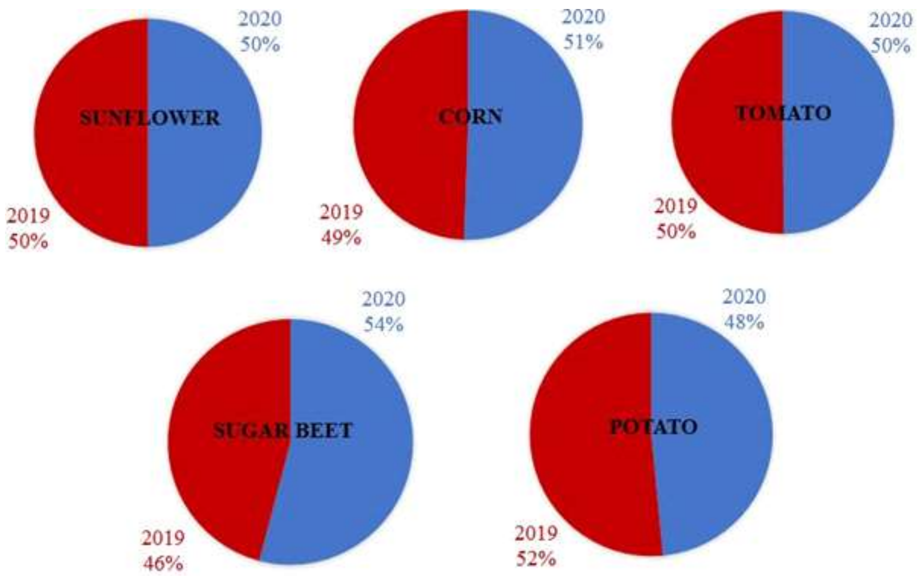

Figure 2. Biochar conversion % potential from field products

For the years 2019 and 2020 of garden products, the percentage changes in the biochar conversion potentials obtained according to the relevant parameters that vary by product and the slow pyrolysis method are given in Figure 3. Since there are no significant differences in the number of trees when evaluating the biochar potential, it seems that the potential amount of products was at values close to each other. It was determined that the total biochar conversion potential of the garden product of both years is 15505 tons/year and the average annual is 7753 tons/year. When the percentage distribution of the total biochar conversion potential was examined, it was determined that the apple tree with 48.2% and the cherry tree pruning waste with 22% were followed in the first place. The least is the pruning waste of fig trees with 0.05%. When biochar conversion potential change was evaluated according to years, it was found that olive (10%), walnut (6%), apple (4%), apricot, cherry, almond, plum, peach, nectarine (2%) rates increased, and pear and figs did not change

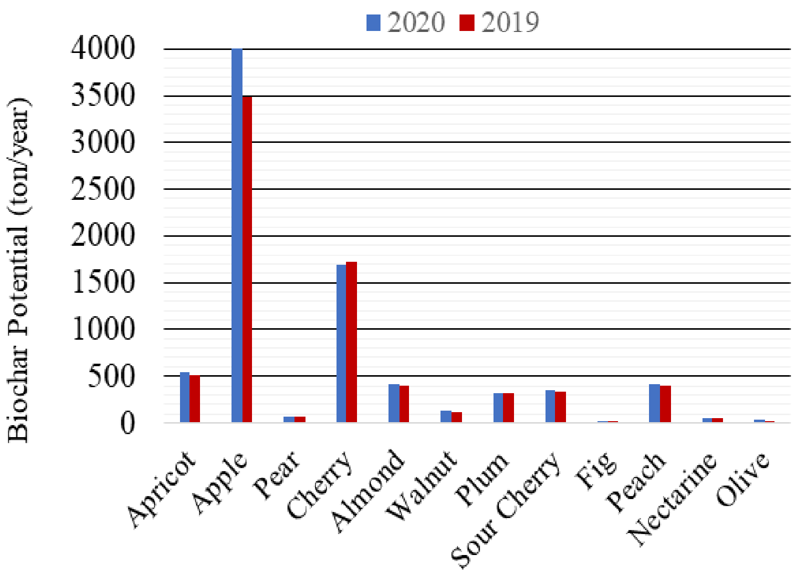

Figure 3. Biochar conversion potential from garden products

4. Conclusion

It is of great importance to be able to use economically environmentally and socially sensitive methods, including combating greenhouse gas emissions, while meeting the demand for energy needs. Plant and animal wastes are among the important biomass sources that contribute to renewable energy production. Waste from crop production activities is mostly burned. Toxic gases formed as a result of the burning process cause air pollution. Biogas production is the first that comes to mind when evaluating animal waste. The wastes can be used not only to produce biogas, but also to produce biochar as an alternative. With slow pyrolysis, wastes can be converted to biochar, taking into account its advantages such as reducing greenhouse gas emissions and increasing soil fertility. It is believed that biochar will be an alternative to obtaining energy from organic waste, and when evaluated economically, its production will be given importance in the coming years. In this study, biochar conversion potential for Isparta, Turkey related to field, garden products and animal data for 2019-2020 was calculated. In addition, the relevant years were compared in three categories.

For 2019;

- It was determined that the total amount of available dry manure obtained as a result of animal production was 79287 tons/year and the potential for biochar conversion is 27941ton/year.
- According to field product data, the available waste was found to be 19947 tons/year and the biochar conversion potential is 6982 tons/year.
- The total available garden pruning waste was found to be 21307 tons/year, and the biochar conversion potential was found to be 7460 tons/year.

For 2020;

- It was determined that the total amount of available dry manure obtained as a result of animal production was 80549 tons/year and the potential for biochar conversion is 28192 tons/year.
- According to field product data, it was determined that the available waste was 21013 tons/year and the biochar conversion potential is 7355 tons/year.

• It was found that the total available garden pruning waste was 22987 tons/year, and the biochar conversion potential is 8045 tons/year.

In 2019 and 2020, it was observed that 90% of the total distribution of animal manure potential for the conversion of biochar is cattle, 9% is small ruminant and 1% is poultry manure. According to the relevant years, there was no proportional change in the biochar conversion potential of tomato and sunflower products, while an 8% increase in sugar beet was observed. When evaluating the biochar conversion potential change in 2020 compared to 2019, it was determined that olive (10%), walnut (6%), apple (4%), apricot, cherry, almond, plum, cherry, peach, nectarine (2%) rates increased, while pear and figs did not change.

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