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Determination of the Energy Potential of Hazelnut Residues in Ordu, Türkiye

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Abstract

Ordu province is the leader in hazelnut production in Türkiye and therefore has an important potential in terms of hazelnut shells and husks. The aim of this study is to determine the biomass potential of the province of Ordu, to investigate the energy potential of hazelnut waste and to provide querryable database using geographic information systems. By collecting data on the geographical distribution of hazelnut production areas and their calculated potential for biomass and energy production in the province of Ordu, a database has been created that allows spatial queries. This database was visualized and analyzed through GeoMedia Professional 6.1. It was determined that the districts with the highest biomass production potential are the central province, Ünye and Fatsa, respectively. In addition, the energy potential was calculated at 2,321 GWh, which is significantly higher than the electricity consumption of the province of Ordu, which is 1,375 GWh. The results showed that hazelnut waste, which has low economic value, has a high potential for biomass and energy production. Using hazelnut waste as biomass in the region both promotes sustainable energy production and prevents dependence on fossil fuels by enabling the city to use clean energy sources.

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1. INTRODUCTION

Renewable energy sources are becoming increasingly important around the world. Renewable energy sources are preferred instead of fossil fuels to meet energy needs in a sustainable and environmentally friendly way (Degirmencioglu et. al., 2019). One of the most important reasons for this is the depletion of fossil fuels, another reason is that they play an important role in reducing the environmental impact of fossil fuels and combating global problems such as climate change (Olabi & Abdelkareem, 2022; Ertuğrul, 2023). Organic materials such as plant and animal waste and wood are known as biomass. In this context, biomass is a source of considerable interest among renewable energy sources due to its potential to reduce dependence on fossil fuels and facilitate an environmentally friendly approach to energy production (Olabi & Abdelkareem, 2022).

While hazelnuts are cultivated in numerous countries worldwide, Türkiye stands as a dominant player in global hazelnut production, accounting for approximately 64% of global output (FAO, 2022). As reported by the Turkish Statistical Institute (2017), 16 provinces in Türkiye are engaged in the production of hazelnuts. The Black Sea region is the primary contributor to hazelnut production, which plays an economic and social role for the region. In Türkiye, Ordu province, which is one of the most significant hazelnut production centres of the Black Sea region, leads in hazelnut production, accounting for the largest portion. (Table 1).

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Table 1. *Distribution of hazelnut production in Türkiye*

Provinces	Area (ha)	Production (tons)	%
Artvin	8.665	6.314	1.0
Bartın	6	6.765	1.1
Bolu	1.089	366	0.05
Düzce	62.685	69.344	10.7
Giresun	117.111	105.023	16.25
Gümüşhane	802	723	0.1
Kastamonu	7.471	5.213	0.9
Kocaeli	8.062	7.53	1.2
Ordu	**227.183**	**200.938**	**31.10**
Rize	3.607	1.303	0.2
Sakarya	72.598	82.708	12.8
Samsun	90.623	90.857	14.0
Sinop	1.701	1.175	0.2
Tokat	2.802	3.511	0.5
Trabzon	65.35	39.126	6
Zonguldak	23.593	22.572	3.5
Sum of 16 Provinces	699.341	643.468	99.6
Sum of other Provinces	3.287	2.532	0.4
Total Türkiye	702.628	646.000	100

Moreover, the geographical location and climatic characteristics of the region make Ordu province extremely important for hazelnut production. The hazelnut orchards and production capacity in the region are known to meet a significant portion of the global and local hazelnut demand. The observation that hazelnut is not only used commercially but also has industrial uses makes it a versatile product. Waste from the pruning of hazelnut groves is an important source of biomass production (Monarca et al., 2013). A significant body of research has been conducted recently on the potential contribution of biomass to energy production, with a particular focus on the advantages it offers. These include the reduction in reliance on fossil fuels, the enhancement of rural economies through the utilisation of previously under-utilised waste, and the Carbon-neutral life cycle of biomass sources. Tun and Juchelková (2019) undertook a study to determine the bioenergy potential of Myanmar. Residues provided from agriculture, wood and animal production are taken into account in the study. The residue-to-product ratios (RPR) have been used with production data to determine the waste amounts of plant production. The energy potentials were determined by multiplying the residue amount values with the lower heating values (LHV). It was stated that bioenergy has a significant role to play in the sustainable development of Myanmar by improving self-sufficiency in energy production. Studies on assessing potential of biomass energy revealing utilization possibilities have been published in prestigious journals. In this context, the potential for biomass energy to mitigate climate change and ensure energy sustainability has been determined (Ben-Iwo et al., 2016; Toklu, 2017).

In 2015, Karaca (2015) conducted research to map the potential of biomass energy from field crops and horticultural products by determining the residue amounts by using the residue-to-product ratios (RPR), availability (A) and lower heat values (LHV). Karaca (2015) produced a quarriable database by using ArcGIS

software to map the findings. Ertuğrul et al. (2024) determined the bioenergy potential of South-Central Texas by analysing the outputs of field and horticultural crops including walnut and peach wastes. The research team investigated the potential of pruning and fruit waste for walnuts, which, as a shelled fruit, produces waste that is comparable to that of hazelnuts. In the research, the energy potential of walnut shells and tree pruning waste was calculated and included in the results. Utilizing the wastes as energy sources not only contributes to sustainable energy production but can also be considered as a solution to environmental problems such as waste management. This situation allows the utilization of hazelnut shells in economic, environmental, and social terms. For this purpose, determining the potential of biomass production from hazelnut wastes in Ordu province is of great importance for the development of energy strategies in the region. The objective of this study is to determine the bioenergy potential of hazelnut wastes in Ordu. To achieve this goal, the spatial distribution of hazelnut production, possible utilizable waste amounts and the energy potentials were investigated and mapped in Ordu province.

2. MATERIAL AND METHOD

Material

Hazelnut production, hazelnut varieties and distribution data of the Ordu province (Table 2) were collected from Turkish Statistical Institute (TSI, 2017). GeoMedia Professional 6.1, the geographical information systems (GIS) software was used as a tool for processing data and producing maps. This software has been used reliably in previous studies to create a database where interactions can be queried (Özgünaltay Ertuğrul et al., 2019; Özgünaltay Ertuğrul & Değirmencioğlu, 2021).

Table 2. *Distribution of hazelnut production in Ordu (TSI, 2017)*

District	**Production Quantity (tons)**
Akkuş	3596
Altınordu	30055
Aybastı	7463
Fatsa	32031
Gölköy	9266
Gülyalı	3906
Gürgentepe	4971
Kabadüz	7404
Kabataş	4456
Korgan	6103
Kumru	7792
Mesudiye	2375
Perşembe	18431
Ulubey	18957
Çamaş	6867
Çatalpınar	4449
Çaybaşı	5292
Ünye	32558
İkizce	7600

Method

This study was carried out within the scope of the master's thesis written by Balci Kuru (2017). In order to determine the biomass potential of hazelnut wastes in Ordu province, areas with hazelnut production and production amounts were organized by Excel. Yield values were calculated together with the potential biomass production amount and the energy yield obtained from this production.

In addition, a literature review was conducted to determine the biomass and energy potential and formulas were examined as a result of this literature review. According to Bilanzdija et al. (2012), the number of fruit-bearing trees (T_f) was taken into account, and it was assumed that there is an available biomass potential of 3.05 kg per tree after pruning. It was also assumed that there is an energy potential (EP_T) of 53.28 MJ per tree (Bilanzdija et al., 2012). Energy potential of hazelnut pruning wastes (EP_P) depending on the number of fruiting trees (Tf) was calculated according to Eq. 1.

$$EP_P\ (MJ) = EP_T \times T_f \quad (1)$$

The ratio of shell/product (RPR) that can be obtained from hazelnut fruit is 1.07 (Mardikis et al., 2004) and the energy potential of hazelnut biomass is 17.47 MJ kg^{-1} according to Bilanzdija et al. (2012). Accordingly, considering the production amount (P) potential shell-based waste amount is calculated by Eq. 2 and the energy potential of shells (EP_S) is calculated by Eq. 3. Total energy potential is determined by summation of the EP_P and the EP_S (Eq. 4).

$$AB_S = P \times RPR \quad (2)$$

$$EP_S\ (MJ) = EP_T \times T_f \quad (3)$$

$$EP\ (MJ) = EP_P + EP_S \quad (4)$$

In order to provide better understanding of the contribution of the thermal potential to the province of Ordu, assuming that electricity can be produced from all available waste, the potential electricity production can be calculated using Eq.5.

$$EP_E\ (kWh) = EP \times 0.277778 \quad (5)$$

3. RESULTS AND DISCUSSION

As a result of both the literature review and the analyses conducted in this study, it has provided important contributions regarding the biomass potential in the province of Ordu. Bilanzdija et al. (2012) underlined that there is a significant amount of pruning waste in fruit production in apple, pear, apricot, peach, nectarine, cherry, sour cherry, walnut, almond, fig, grape and olive. Similarly, when the geographical distribution of hazelnut fruit in Ordu province was examined, it was determined that Ünye, Merkez and Fatsa districts had the highest hazelnut production and yield values among 19 provinces, respectively. Hazelnut trees were found to contribute significantly to the biomass potential in Ordu province, which is in line with the study by Bilanzdija et al. (2012).

Furthermore, it has been found that the amount of biomass did not vary with tree age but was directly proportional to the number of trees, which is consistent with our results (Monarca et al., 2013). Depending on the number of fruits bearing trees, the total biomass potential of Ordu province was determined as 471,465 t. When analysed based on districts, it is observed that the Central district (62,660 t), Ünye (60,587 t) and Fatsa (56,066 t) have the highest biomass potential (Figure 1).

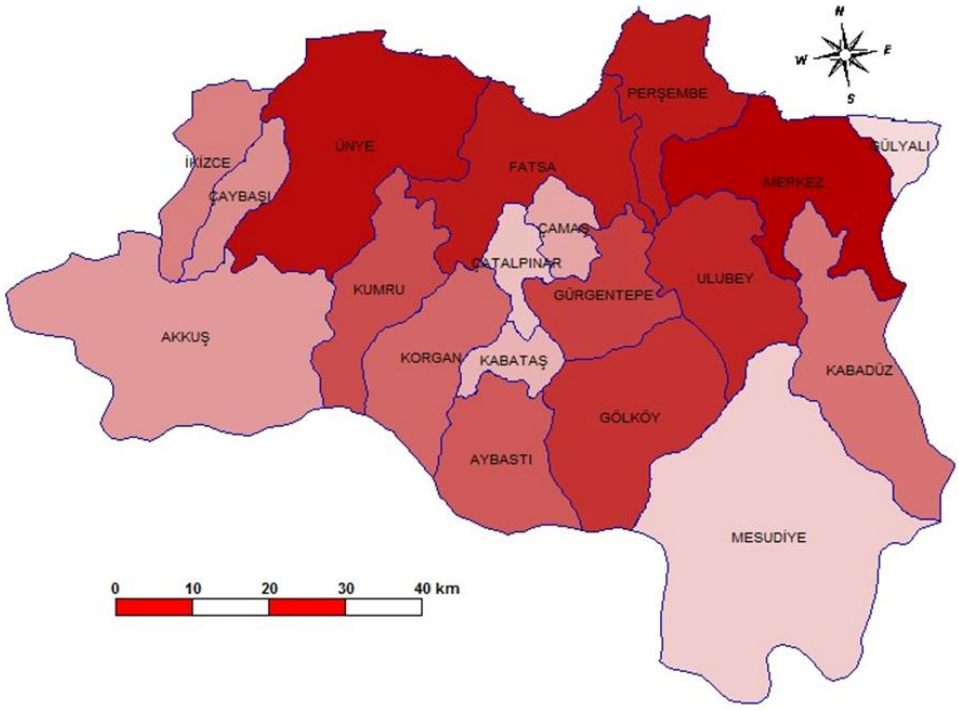

Figure 1. *Thematic map of waste potential in Ordu districts*

The total energy potential of hazelnut wastes that can be obtained from Ordu is 8,289,371 GJ and much higher than the greenhouse tomato waste in Kırşehir, 4,046 GJ (Boyacı et al., 2021). Based on districts, the energy potential is 1.095GJ for Central District, 1,058 GJ for Ünye and 1.032 GJ for Fatsa (Table 3 and Figure 2). The electricity equivalent of the total energy potential is 2,321 GWh that is much higher than the electricity consumption of the Ordu province which is 1,375 GWh for 2021 (TSI, 2021). This shows that hazelnut residues have a significant potential for energy production.

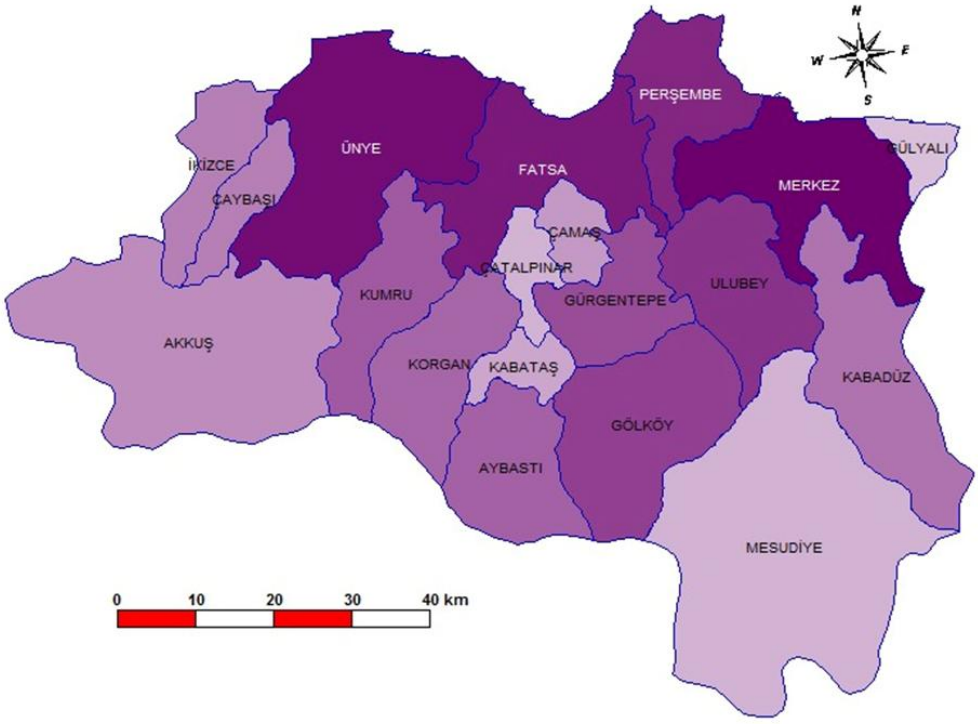

Figure 2. *Thematic map of total energy potential of hazelnut wastes*

This high energy potential observed in Ordu province can encourage the use of sustainable energy sources while reducing dependence on traditional energy sources. Furthermore, this is likely to support both socio-economic growth at the local level and environmental sustainability by utilization of agricultural wastes.

Table 3. *Energy Potential of Hazelnut Wastes by Districts in Ordu in 2015*

District Name	Total Production Area (ha)	Production (t)	Number of Bearing Trees	Energy Potential of Pruning Wastes (GJ)	Energy Potential of Shells Pruning Wastes (GJ)	Total Amount of Biomass (t)*	Total Energy Potential (GJ)
Center	27.08	26,961	15,975,000	851,148	243,468	62,660	1,094,616
Ünye	29.67	29,674	14,835,600	790,441	267,968	60,587	1,058,408
Fatsa	26.97	26,747	14,832,950	790,299	241,536	56,066	1,031,835
Perşembe	19.33	17,981	9,664,000	514,898	162,375	38,770	677,273
Ulubey	17.67	15,930	8,837,250	470,849	143,854	35,188	614,703
Gölköy	14.07	9,346	7,520,000	400,666	84,398	27,767	485,064
Gürgentepe	10.13	7,353	6,076,800	323,772	66,400	22,335	390,172
Kumru	11.77	9,051	5,887,000	313,659	81,734	22,634	395,393
Aybastı	9.01	6,318	4,917,000	261,978	57,054	18,263	319,032
Korgan	8.75	7,132	4,822,115	256,922	64,405	18,394	321,327
Kabadüz	8.64	7,702	4,754,365	253,313	69,552	18,482	322,865
İkizce	9.43	8,162	4,718,000	251,375	73,706	18,609	325,081
Çaybaşı	6.33	6,016	3,795,480	202,223	54,327	14,686	256,550
Akkuş	5.50	3,901	3,300,000	175,824	35,228	12,081	211,052
Çamaş	7.01	6,114	3,056,950	162,874	55,212	12,433	218,086
Kabataş	4.67	3,459	2,801,200	149,248	31,236	10,332	180,484
Çatalpınar	4.87	4,014	2,432,500	129,604	36,248	9,494	165,852
Mesudiye	3.04	2,284	1,674,145	89,198	20,625	6,287	109,824
Gülyalı	3.25	2,793	1,624,100	86,532	25,222	6,397	111,754
TOTAL	227.19	200,938	121,524,455	6,474,823	1,814,548	471,465	8,289,371

* This value indicates both potential biomass after pruning and hazelnut shell biomass potential

4. CONCLUSION

As one of the Carbon-neutral and renewable energy sources, biomass not only protects the environment but also reduces the use of fossil fuels and dependence on import of energy. In addition, the utilization of hazelnut shells and pruning wastes in energy production offers an important resource for increasing the renewable energy potential of Ordu province, which is important for both environmental sustainability and economic development of the city. As a result, strategies should be developed to increase the contribution of hazelnuts, one of Türkiye's most important export products, to energy, which is one of our main import expenditures, and to ensure that hazelnut waste is used more effectively in energy production. While research data show that Ordu province has an annual electricity consumption of 1,375 GWh/year, the energy production potential of the province from hazelnut wastes is nearly twice the annual energy consumption. It is estimated that the energy production facilities to be established, particularly in the Central District, Ünye and Fatsa, represent an important opportunity for both Ordu Province and Türkiye.

AUTHOR CONTRIBUTIONS

Conceptualization, E.B. and Ö.E.; methodology, E.B. and Ö.E.; fieldwork, E.B.; software, E.B. and Ö.E.; title, E.B. and Ö.E.; validation, E.B.; formal analysis, E.B.; research, E.B.; sources, E.B.; data curation, E.B.; manuscript-original draft, E.B.; manuscript-review and editing, E.B. and Ö.E.; visualization, E.B.; supervision, Ö.E. All authors have read and legally accepted the final version of the article published in the journal.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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