Turkish Journal of Agriculture - Food Science and Technology, 12(s4): 2913-2919, 2024
DOI: https://doi.org/10.24925/turjaf.v12is4.2913-2919.7325

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Efforts to Reduce Carbon Footprint of Dokuz Eylül University Tınaztepe Campus in İzmir, Türkiye

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ARTICLE INFO

Research Article

Received : 13.11.2024
Accepted : 06.12.2024

Keywords:
Carbon Foot Print
Energy Efficiency
Sustainability
University Campus
Method

ABSTRACT

Current study intends to find out the carbon footprint of Dokuz Eylül University's Tınaztepe Campus and comprehensively assess its environmental impact in the process. The study provides a detailed analysis of carbon emissions resulting from the campus's energy consumption, transportation, water usage, and other sources. Based on these analyses, the total CO_2 emmission of the campus has been determined, taking into account the carbon sequestration capacity of the university's forested area. Calculations performed using the IPCC Tier 1 Model estimate that Tınaztepe Campus's total annual carbon footprint is 2,458.44 tons of CO_2. Additionally, the annual carbon footprint per capita has been calculated as 0.059 tons of carbon footprint. According to the findings, the largest portion of carbon emissions is from natural gas consumption, while the smallest is from water consumption. In light of this data, various strategic recommendations have been developed to reduce the campus's carbon footprint. These recommendations include measures such as increasing energy efficiency, adopting more sustainable transportation methods, and reducing water consumption. The results of this study provide valuable insights for universities to consider when developing sustainability policies.

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Introduction

The increasing global production and consumption, along with the rising global temperatures, are among the most widely discussed environmental issues worldwide. These problems arise from the rapid increase in the greenhouse gases in the atmosphere. They create global environmental threats like resource depletion, desertification biodiversity losses. The main gas that creates the greenhouse effect is carbon dioxide (CO_2) gas emitted into the atmosphere as a result of human activities with the use of fossil fuels (oil, coal, natural gas) (Tuckett, 2019). Therefore, research on CO_2 gas analysis has grown in recent years, resulting in the development of the 'Carbon Footprint' concept (Gökçek et al., 2019). Carbon footprint refers to greenhouse gas emissions resulting from activities such as energy production, waste management, transportation and consumption, and it is usually calculated as carbon dioxide equivalent in tons. Therefore, carbon footprint is the carbon dioxide equivalent measure of greenhouse gas emissions caused directly or indirectly by a product or an action during its life cycle (Wiedmann and Minx, 2008). The term carbon footprint is synonymous with "greenhouse gas inventory" (Franchetti and Apul, 2013).

Greenhouse gases (GHG) are gases that absorb and re-radiate heat in the atmosphere, thus keeping the atmosphere warmer than it should be. The main greenhouse gases in the atmosphere are water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluoric carbon (HFCs), perfluoric carbon (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). While there were six greenhouse gases until 2013, NF_3 was included in the list of greenhouse gases after 2013 in accordance with the opinions of the Kyoto Protocol Committee. The duration of each greenhouse gas in the atmosphere and its effect on global warming are different from each other (Brander and Davis 2012). Among these gases, carbon dioxide (CO_2) is an end product released as a result of the metabolization of carbon-containing nutrients. The atmosphere is homeostatic and contains a small amount of CO_2, approximately 0.03% (Odum and Barrett, 2016). Based on recent measurements (December 2024) from the Mauna Loa Observatory, which reflect values close to the global atmospheric average, the concentration of CO_2 in the atmosphere has been determined to be 424.6 ppm (0.042%) (NOAA Global Monitoring Laboratory, 2024). Despite this, it is also a gas

that has a great effect on global warming. It is the most common greenhouse gas released by anthropogenic effects. The carbon footprint is divided into two categories: primary and secondary carbon footprints. The primary carbon footprint (direct carbon footprint) is the direct measure of CO_2 emissions resulting from the combustion of fossil fuels used due to consumption of energy and transportation (Pandey et al., 2011). The secondary carbon footprint (indirect carbon footprint) is defined as the measure of CO_2 emissions that occur during the entire life cycle of the products we use, from production to degradation (Aras and Kalaycıoglu, 2020).

Higher education institutions serve as role models in reducing greenhouse gas emissions by implementing initiatives like carbon-neutral and green campuses and by educating communities through academic efforts. Dokuz Eylül University operates in 20 different locations across the province of İzmir, consisting of 18 faculties, 10 institutes, 1 conservatory, 8 vocational schools, a Research Hospital, and 1 Oral and Dental Health Application and Research Center, totaling 49 application and research centers. Tınaztepe Campus is the university's main campus, located in the Buca district of İzmir, and is the largest campus with an area of 4.5 million m². Many significant academic units are located on Tınaztepe Campus. Various faculties such as the Faculty of Science, Faculty of Law, Faculty of Fine Arts, Faculty of Literature, Faculty of Maritime, Faculty of Business, Faculty of Engineering, Faculty of Architecture, Faculty of Tourism, and the State Conservatory offer a wide range of educational opportunities. The School of Applied Sciences and the School of Foreign Languages are also located on this campus. Additionally, research-oriented units such as the Institute of Fine Arts, Institute of Social Sciences, Atatürk Principles and History of Reforms Institute, and Institute of Natural Sciences are present on the campus (DEU Strategy Development Department, 2023). The population of Tınaztepe Campus is 41,836, including 1,463 personnel and 40,373 students, for the educational academic year 2022-2023.

Dokuz Eylül University Tınaztepe Campus stands out with its vast green areas and forested regions, providing a peaceful environment for students and academics. The campus is distinguished by its landscape enriched with various vegetation and trees, offering green spaces where individuals can rest and walk between classes. The approximately 3.5 million m² of forested areas on the campus host a rich biodiversity, with various flora and fauna species (Figure 1). (DEU Sustainability Office[1], 2024).

In Tınaztepe Campus, as in all other campuses, there are buildings designed with extensive glass facades to maximize the use of daylight. Additionally, the widespread use of LED lighting, motion-sensor lighting products that detect movement in large common areas, central heating systems in the campuses, central cooling systems in new buildings, A+ rated electrical appliances, and the fact that all 11,400 computers in the University's IT Department inventory have Energy-Plus certification, are indicators of energy efficiency. Dokuz Eylül University launched its Solar Energy Project in 2021. By 2024, the installation of panels has been completed, and the electricity generated from the solar energy system is designed to meet 83% of the annual energy consumption across all university units. The Tınaztepe phase of the panels, installed across seven campuses, has a total capacity of 4840 kWe and includes installations on rooftops and land. The project was accepted on May 3, 2023, and energy production has begun (Figure 2). (DEU Sustainability Office[2], 2024). In Türkiye, by the end of 2022, energy-related emissions accounted for the largest share of total greenhouse gas emissions at 71.8% in CO_2 equivalent, followed by agriculture with 12.8%, industrial processes and product use with 12.5%, and the waste sector with 2.9% (TUIK, 2024).

Figure 1. Views of open areas from Tınaztepe Campus

Figure 2. Views from solar energy panels in Tınaztepe Campus

This highlights the significance of electricity, a secondary energy source, in contributing to the carbon footprint. IPCC, GHG Protocol, UNFCCC, ISO 14064 Standard are the guides in determining carbon emission (Gao et al., 2014). Among them, IPCC (Intergovernmental Panel on Climate Change) is the United Nations body responsible for making scientific assessments on climate change. IPCC examines climate change science and prepares reports to guide governments and decision makers.

The current study will, for the first time, calculate and evaluate the carbon footprint of Tınaztepe Campus, the largest and central campus of Dokuz Eylül University, using the IPCC Tier 1 Methodology based on real and up-to-date data. This study brings to light a significant environmental metric for one of İzmir's most prominent campuses, utilizing the Tier 1 approach to deliver an insightful and methodical analysis of its carbon footprint.

Materials and Methods

This study is confined to the 2023 data collected from all units within Tınaztepe Campus. The primary carbon footprint in this study has been calculated using the IPCC calculation methodology. The IPCC guidelines outline the process for collecting, calculating, assessing, and reporting greenhouse gas inventory data, covering areas such as energy, industrial processes, solvent and product use, agriculture, land use, forestry, and waste management. The IPCC methodology categorizes emission calculation methods into three different levels, referred to as Tiers (IPCC, 2006). In this study, the IPCC Tier 1 approach has been used according to the data of the university campus.

The current study will thoroughly examine the carbon footprint of energy consumption, transportation, and other consumption activities at Dokuz Eylül University's Tınaztepe Campus, starting from the fuel consumption amounts. The amounts of gasoline and diesel are consumed by the University vehicles which are 81 in number. In addition, natural gas, water consumption, and electricity consumption for 2023 have been obtained from the university's official records.

According to the IPCC Tier 1 Method, CO_2 emissions are calculated incrementally. CO_2 emissions for each type of fuel used across the campus are determined separately. The first step in the calculation starts with the energy consumption derived from the fuel consumption and net calorific value (Equation 1). Then, the carbon emission factors for each fuel type, as outlined in the IPCC guidelines, are applied to determine the carbon amount of the fuel. The overall carbon amount is calculated by applying the carbon emission factor to the energy content of the fuel consumption identified in the previous step (Equation 2). In the third stage, the total combustion carbon emission is calculated by considering the amounts of carbon that do not oxidize during combustion. The oxidation percentages (combustion efficiency) of fuels determined by the IPCC are set at 0.99 for petroleum products and 0.995 for gaseous fuels. These values are multiplied by the carbon content identified in the previous step to calculate how much carbon has been oxidized (Equation 3). Finally, the net carbon value is converted into CO_2 form. The proportion of the molecular weight of CO_2 to that of carbon. Here, the CO_2 emission value resulting from the combustion of fuel is determined by multiplying the value found in the previous step by the ratio of the molecular weight of CO_2 to the molecular weight of carbon, which is 44/12 (Equation 4) (IPCC, 2006).

$$EI = FC \times FCC \times (1\ Gg / 10^3\ ton) \quad (1)$$

$$CA = CEF \times EI \quad (2)$$

$$CE = CA \times CCR \quad (3)$$

$$CO_2\ Emission\ (Gg\ CO_2) = CE \times (44/12) \quad (4)$$

EI : Energy Intake (TJ)
FC : Fuel Consumption(ton)
FCC : Effective Calorific Content (TJ/Gg)
CA : Carbon Amount (ton C)
CEF : Carbon Emission Factor (ton C/TJ)
CE : Carbon Emission (Gg C)
CCR: Carbon Combustion Rate

Table 1 summarizes the net calorific values, emission factors, and combustion rates of fuels according to the IPCC.

According to the latest data from the Ministry of Energy and Natural Resources of the Republic of Türkiye, 0.479 tons of CO_2-equivalent greenhouse gas emissions are emitted per unit of electricity consumption (Ministry of Energy and Natural Resources, 2024). This value reflects the carbon intensity of electricity generation in Türkiye, primarily influenced by the energy mix, including fossil fuels and renewable energy sources. For emissions calculations related to water consumption, the emission factor of 0.177 kg/m³, as indicated in the DEFFRA guidelines (DEFFRA, 2023), was applied.

Table 1. IPCC values for carbon footprint calculations (IPCC, 2006)

Fuel type	Calorific content (Tj/Gg)	Emmission factor (tC /Tj)	Carbon oxidation rate
Gasoline	44.3	18.9	0.99
Diesel	43.0	20.2	0.99
Natural gas	48.0	15.3	0.995

Table 2. 2023- Monthly use of electricity, natural gas and water in Tınaztepe Campus

Months	Natural gas consumption (m^3)	Electricity consumption (kWh)	Water consumption (m^3)
January	177,620	437,791.02	13,970
February	176,355	364,001	8,270
March	133,572	267,111	10,780
April	65,974	153,598	10,660
May	16,145	126,961.28	10,870
June	5,534	94,906.86	13,760
July	4,555	0.11	12,930
August	3,349	391,47.91	14,490
September	5,609	0.32	13,410
October	6,509	31,395.48	11,700
November	63,043	198,294.21	12,700
December	143,097	299,946.47	12,000
Total	801,362	2,013,154	145,540

Table 3. Annual CO_2 emissions due to the sources

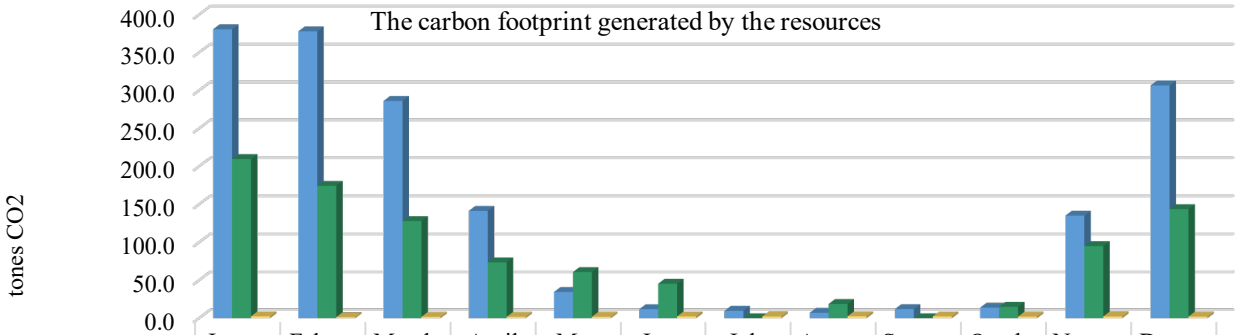
Energy type	Consumption	CO_2 emmissions (tones CO_2)	Ratio (%)
Gasoline	141,89 liter	31.91	0.99
Diesel fuel	179,261 liter	474.78	14.77
Natural gas	801,362 m^3	1,717.69	53.44
Electricity	201,315,6 kWh	964.30	30.00
Water	145,540 m^3	25.76	0.80
Total		3,214.44	100.00

Results and Discussion

To calculate the university's primary carbon footprint for the year 2023, data on electricity use, gasoline and diesel consuption, natural gas utilization, and water consumption were obtained from the university are presented in Table 2. The primary sources of greenhouse gas effects—natural gas, electricity, and water consumption—have been specified on a monthly basis, and the contributions of these factors to the carbon footprint have been evaluated monthly.

According to the official data obtained from the university, the natural gas consumption for 2023 is 801,362 m^3. The density of natural gas was assumed to be 0,8 kg/m^3. Additionally, the electricity consumption for the university in 2023 is reported to be 7,480,322 kWh. Due to the implementation of the Solar Energy Project, 5,467,165.36 kWh electricity was generated from solar energy. Therefore, the electricity purchased from external sources, contributing to the carbon footprint, is 2,013,154 kWh, and calculations were performed based on this value. Natural gas, electricity, and water consumption across the university were recorded monthly, while data on motor vehicle fuel consumptions could be found on an annual basis. The annual carbon footprint calculated based on these factors, using the IPCC Tier 1 method, is presented in Table 3. According to this calculation, the total annual CO_2 emissions for DEU's Tınaztepe campus amount to 3,214.44 tons. When examining the sources of this emission, natural gas emerges as the largest contributor at 53.44%, followed by electricity at 30.00%. The reason for natural gas emissions surpassing those from electricity can be attributed to the solar energy system, which became operational in May 2023. When examining the campus's electricity consumption data, 73% of the total electricity consumption was provided from renewable energy, and this reduced the carbon footprint by the same proportion. The third-largest contributor to CO_2 emissions on campus is the diesel fuel used in university vehicles, accounting for 14.77 % of the carbon footprint.

The monthly distribution of CO_2 emissions generated by natural gas, electricity, and water consumption data, which we obtained from the university administration, is shown in Figure 3. Accordingly, the highest CO_2 emissions were observed in January, February, and December, which are the coldest months in İzmir. Looking at the average temperature data for İzmir, the coldest months are identified as January, February, and December, respectively (Figure 4) (Weatherspark, 2023). Heating at DEU Tınaztepe campuses is provided by central natural gas radiator systems, explaining the high natural gas usage during these months. With the arrival of spring, fuel consumption decreases. Starting from June, İzmir experiences the hot days typical of the Mediterranean climate, and central or individual air conditioning units are used within the campus for cooling purposes. Although this increases electricity consumption, the activation of solar energy systems during the same period has significantly reduced CO_2 emissions (Figure 3).Irregularities in electricity transmissions that occurred until the system began operating consistently after its commissioning in May impacted the data for July and September. These irregularities were regulated after October (Table 3).



	January	February	March	April	May	June	July	August	September	October	November	December
Natural Gas	380.7	378.0	286.3	141.4	34.6	11.9	9.8	7.2	12.0	14.0	135.1	306.7
Electricity	209.7	174.4	127.9	73.6	60.8	45.5	0.0	18.8	0.0	15.0	95.0	143.7
Water	2.5	1.5	1.9	1.9	1.9	2.4	2.3	2.6	2.4	2.1	2.2	2.1

Figure 3. Monthly CO_2 emissions due to the resources

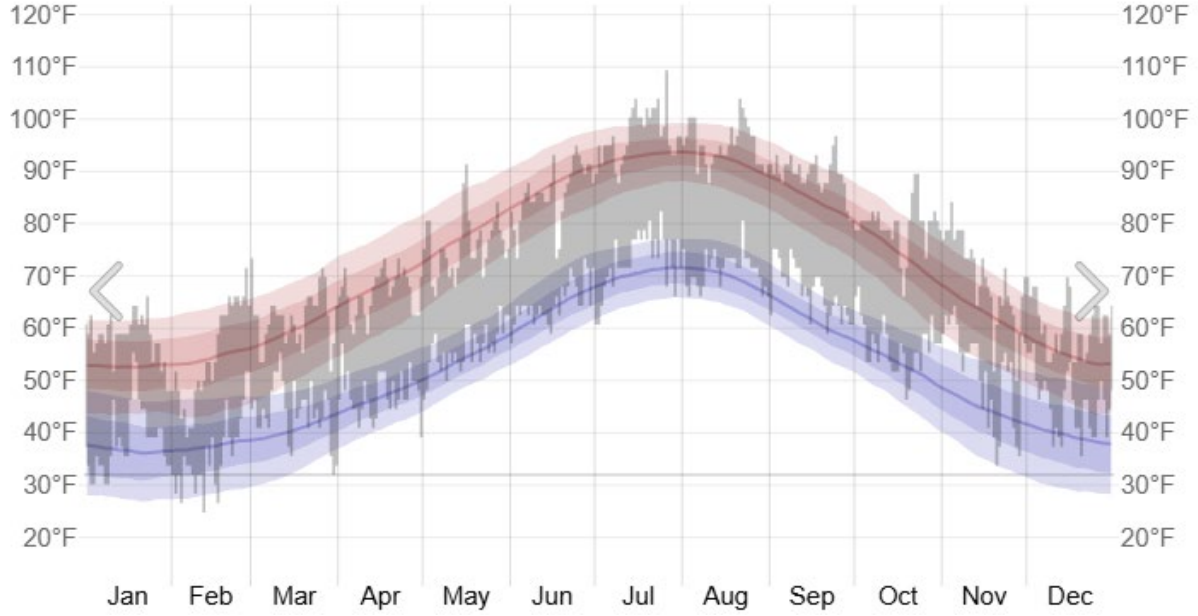


Figure 4. Average temperatures of Izmir (WeatherSpark, 2023)

The Tınaztepe Campus of Dokuz Eylül University is located on a total area of 450 hectares, of which 350 hectares are classified as forest land. The carbon absorption capacity of this forest land, acting as carbon sinks, is assumed to be 2.16 tons of CO_2 per hectare (Luyssaert et al., 2008). This indicates that 756 tons of CO_2 emissions are absorbed by the forests on the Tınaztepe campus. In this case, the total CO_2 emissions generated in 2023 were calculated to be 2,458.44 tons.

When evaluating carbon dioxide emissions calculated by universities using different methodologies; in 2019, Erciyes University, with a population of 56,623, reported 25,747 tons of carbon dioxide emissions, equating to 0.45 tons per capita (Erciyes University, 2019). In 2021, Ondokuz Mayıs University, with an 8800-decare campus, recorded a per capita carbon footprint of 1.4 tons annually (Ondokuz Mayız University, 2021). In 2023, Özyeğin University reported a per capita carbon footprint of 0.848 tons (Özyeğin University, 2024)

In 2019, Abdullah Gül University calculated its carbon footprint intensity at 0.86 tons per capita, while Ege University, another major university in İzmir, reported per capita CO_2 emissions of 0.201 tons annually (Abdullah Gül University, 2024; Ege University 2024)

In 2019, the carbon emission calculation at the University of Oulu in Finland, with a campus population of 16,900 students, identified 19,072 tons of carbon dioxide emissions, corresponding to a per capita carbon footprint of 1.29 tons. This relatively high value is attributed to the inclusion of Scope 1, 2, and 3 emissions in the calculation framework (Kiehle et al., 2022). In 2020, the University of Bologna reported 16,467 tCO_2e in emissions, which was reduced to 15,753 tCO_2e after accounting for offsets and emissions avoided through the internal generation of renewable energy. This corresponds to a per capita CO_2 emission of 0.173 tons, yearly (Battistini et al., 2020). In 2022, the per capita carbon footprint at Iğdır University was calculated as 0.28 tons, including 4 categories (Tırınk et al., 2023). Besides, n 2020, carbon dioxide emissions at Binali Yıldırım University in Erzincan, calculated using the IPCC Tier 1 method for comparison. This study amounted to 1,826.54 tons of CO_2 for a campus population of 25,281. This translates to an annual per capita carbon footprint of 0.072 tons (Kurnuç Seyhan and Çerçi, 2022).

Conclusion

In this study, the carbon footprint of Dokuz Eylül University's Tınaztepe Campus for the year 2023 was calculated. Using the IPCC Model Tier 1 approach, the primary carbon footprint of the university, including carbon sinks, was determined to be 2,458.44 tons of CO_2. Considering the population of 41,836 people on the Tınaztepe Campus, the per capita carbon footprint is calculated to be 0.058 tons of C annually. This result highlights a significant carbon footprint advantage for DEU Tınaztepe Campus when compared to the intensity values reported by other universities. The significant differences can be attributed to the use of the more limited Tier 1 methodology in the current study. This approach relies on general emission factors and broader assumptions rather than detailed, site-specific data, which can lead to variations when compared to more comprehensive methodologies such as Tier 2 or Tier 3. Analyzing the sources of carbon emissions, it was found that the largest share, 53.44 %, comes from natural gas consumption, while the smallest share, 0.80%, results from water consumption.

The current study calculates CO_2 emissions at the Tınaztepe Campus of Dokuz Eylül University using the Tier 1 methodology. This method, as outlined by the IPCC, employs generalized emission factors and readily available data, offering a foundational approach to estimating emissions. This situation explains the differences in per capita CO_2 emission values when compared with other universities. Comprehensive and reliable data on biodegradable waste generated by the campus was unavailable due to limited resources, making it challenging to accurately calculate emissions from this source. Detailed studies on waste management have already commenced on the university campus and will be fully integrated into emission calculations in future assessments. This inclusion will ensure a more comprehensive evaluation of the university's carbon footprint, encompassing emissions from biodegradable and other waste sources.

Regarding the university's efforts to reduce its carbon footprint, the initiation of the Solar Energy Plant project, a renewable energy source, and the greening efforts aimed at protecting and expanding forest areas are positive indicators. Since the system was not fully operational for the entire year in 2023, only the impact of renewable energy for 6 months was reflected in this value. It is expected that this value will decrease further in the coming years.

Dokuz Eylül University also uses natural daylight-optimizing glass facades, LED lighting, and Energy Star certified devices to promote energy efficiency. These measures result in energy savings of more than 75% of total energy consumption. The university's firm policies in this regard continue.

The university's senior management demonstrates commitment and support by encouraging the reduction of its carbon footprint and promoting sustainable resource use. Educational activities and projects are organized to raise awareness of environmental issues and climate change, and the university competes annually in international rankings to prove its status as a green and sustainable university, showing increasing success.

Declarations

This study was presented at the 7th International Anatolian Agriculture, Food, Environment and Biology Congress, (Kastamonu, TARGID 2024).

Ethical Approval Certificate

The data used in the study was provided to us by the Directorate of Strategy Development at Dokuz Eylül University. (May 2024).

Author Contribution Statement

Elif Duyuşen Kokulu: Data collection, writing the original and final draft, discussion and assessment

Eylül Ceren Özyürek: Investigation, formal analysis

Fund Statement

This work was not funded by any institution.

Conflict of Interest

There is no conflict of interest for this paper.

Acknowledgments

We extend our appreciation to Mr. Azmi Topal, Branch Manager at the Directorate of Strategy Development at Dokuz Eylül University, for supplying us with consistent and accurate data throughout this study.

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