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SUSTAINABLE DEVELOPMENT IN AGRICULTURE: ENVIRONMENTAL AND ECONOMIC PERSPECTIVES

TARIMDA SÜRDÜRÜLEBİLİR KALKINMA: ÇEVRESEL VE EKONOMİK PERSPEKTİFLER

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Assist. Prof. Dr. Ahmet KASAP

Tokat Gaziosmanpaşa University,
Turhal Faculty of Applied Sciences,
Electronic Commerce and Management
E-mail: ahmet.kasap@gop.edu.tr
Orcid Number: 0000-0001-7231-2693

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ABSTRACT

This study compares certain environmental and economic indicators at Turkey, European Union (EU), OECD countries and global level in the context of sustainable development. The study analyses sustainability differences between countries by examining indicators such as CO_2 emissions, renewable energy consumption, GDP growth rate, methane emissions from agriculture and freshwater withdrawal. The findings show that Turkey is at higher levels in terms of carbon emissions compared to OECD and EU countries, while it lags behind developed countries in renewable energy consumption. In order to eliminate these differences in Turkey's sustainable development performance, there is a need to increase the use of renewable energy resources and environmentally friendly policies to reduce carbon emissions. The study also suggests that Turkey should focus on environmental policies for sustainable management of water resources and reduction of methane emissions from agriculture.

Keywords: Sustainable Development, Carbon Emissions, Economic Sustainability, Environmental Sustainability

ÖZET

Bu çalışma, sürdürülebilir kalkınma bağlamında Türkiye, Avrupa Birliği (AB), OECD ülkeleri ve küresel düzeyde belirli çevresel ve ekonomik göstergelerin karşılaştırmasını yapmaktadır. Çalışmada CO_2 emisyonları, yenilenebilir enerji tüketimi, GSYH büyüme oranı, tarım kaynaklı metan emisyonları ve tatlı su çekimi gibi göstergeler incelenerek ülkeler arasındaki sürdürülebilirlik farklılıkları analiz edilmiştir. Elde edilen bulgular, Türkiye'nin karbon emisyonları açısından OECD ve AB ülkelerine kıyasla daha yüksek seviyelerde olduğunu, yenilenebilir enerji tüketiminde ise gelişmiş ülkelerin gerisinde kaldığını göstermektedir. Türkiye'nin sürdürülebilir kalkınma performansında bu farklılıkların giderilmesi için yenilenebilir enerji kaynaklarının kullanımının artırılması ve karbon emisyonlarını azaltmaya yönelik çevre dostu politikalara ihtiyaç duyulmaktadır. Çalışma, ayrıca Türkiye'nin su kaynaklarının sürdürülebilir yönetimi ve tarım kaynaklı metan emisyonlarının azaltılması için çevresel politikalara odaklanması gerektiğini önermektedir.

Anahtar Kelimeler: Sürdürülebilir Kalkınma, Karbon Emisyonları, Ekonomik Sürdürülebilirlik, Çevresel Sürdürülebilirlik

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1. INTRODUCTION

Sustainable development is defined as the use of resources in a way that meets the needs of the present generation while preserving the ability of future generations to meet their own needs. This concept is based on the goal of ensuring both economic growth and environmental protection simultaneously (Spash, 2002: 64). Gaining prominence with the Brundtland Report, sustainable development emphasizes the necessity of integrating environmental, economic, and social dimensions, highlighting the need for sustainable resource management (Turan, 2018: 206). This approach is essential for ensuring sustainability in a world facing the risk of resource depletion (Yağış, 2024: 345).

The agricultural sector holds a strategic position in achieving sustainable development goals. This sector contributes to society in various areas, from food production to rural development, necessitating the efficient and effective use of natural resources. However, considering the impacts of agricultural activities on natural resources such as water and soil, the need for widespread adoption of sustainable agricultural practices arises (Savci, 2012: 78). The agricultural sector has the potential to leave a positive environmental impact but also poses risks of exacerbating environmental issues if mismanaged (Çakmak and Acar, 2022: 6).

Particularly in combating climate change, the agricultural sector plays a crucial role. Agricultural activities are seen as one of the main contributors to greenhouse gas emissions, accelerating global warming (Alvarado et. al., 2021: 3). Activities such as fertilizer use and agricultural water consumption negatively affect ecosystem health, making it challenging to achieve sustainable development goals (Savci, 2012: 78). In this context, sustainable agricultural practices are vital for reducing environmental impacts, conserving natural resources, and contributing to the economy.

2. SUSTAINABLE DEVELOPMENT AND THE AGRICULTURAL SECTOR

Sustainable development emphasizes the need for harmony between economic growth and environmental protection, making it especially relevant for resource-intensive sectors like agriculture. The agricultural sector plays a crucial role in addressing the population's nutritional and economic needs. However, due to its significant environmental impacts, such as greenhouse gas emissions, water resource depletion, and soil degradation, it requires restructuring aligned with sustainability principles. Achieving a balance between environmental sustainability and economic growth in agriculture is a fundamental goal of sustainable development.

From an environmental perspective, agricultural activities present numerous challenges. Giannakis et. al. (2019) highlight that agricultural growth in the EU, especially in Southeastern Europe, increases air pollution and mortality rates, underscoring the need for eco-friendly policies. Similarly, Karaer and Gürlük (2003) note that environmental issues in developing countries lead to larger productivity losses compared to developed nations, obstructing progress toward sustainability. Excessive fertilizer use exacerbates these issues by polluting soil and water, as Savci (2012) points out, necessitating stricter regulations.

Economically, the agricultural sector is vital for development, particularly in rural areas. In Turkey, Turan (2018) emphasizes the sector's contributions to long-term economic growth and rural employment. However, he also advocates for measures to mitigate its environmental effects. Agriculture's economic significance, while vital, must be balanced with sustainable practices to ensure its longevity and alignment with broader development goals.

Promoting renewable energy in agriculture is a key strategy for sustainability. Khan et. al. (2020) demonstrate that renewable energy use in Scandinavian agriculture reduces environmental degradation and supports sustainable growth. Similar strategies in Turkey, such as encouraging renewable energy and reducing reliance on fossil fuels, could yield economic and environmental benefits.

Water resource management is another critical issue in agricultural sustainability. Giannakis et. al. (2019) stress the need for efficient water use to mitigate environmental impacts, particularly in water-scarce regions. Advanced irrigation systems and water-saving technologies are essential for Turkey to achieve sustainable agricultural practices and address its high agricultural water consumption.

Overall, balancing the environmental and economic impacts of agriculture is essential for sustainable development. While agriculture supports economic growth and employment in countries like Turkey, it also poses environmental challenges. Policies promoting renewable energy, efficient resource use, and eco-friendly practices are crucial for achieving sustainability goals. These efforts not only enhance environmental protection but also ensure the agricultural sector's long-term viability.

3. LITERATURE REVIEW

The dimensions of sustainable development—environmental, economic, and social—have been extensively examined in recent research on agriculture, energy, and economic growth. These studies highlight the environmental impacts of agricultural activities, the relationship between ecological footprints and sustainable development, and the role of renewable energy in improving environmental quality.

Studies reveal that agricultural activities pose significant threats to environmental sustainability. Nagendran (2011) identifies fertilizers, pesticides, and waste as key contributors to pollution, emphasizing the complexity of waste management. Brunekreef et. al. (2015) highlight the health risks of particulate matter emissions from agriculture, stressing the need for stricter controls. Giannadaki et. al. (2018) show that a 50% reduction in ammonia emissions could prevent over 200,000 deaths annually, while Giannakis et. al. (2019) link agricultural growth in the EU to increased particulate emissions and adverse health outcomes.

Ecological footprint studies explore the link between economic growth and environmental degradation. Kızılgöl and Öndes (2022) confirm that GDP and urbanization increase ecological footprints in OECD countries. Charfeddine (2017) and Zhou et. al. (2022) similarly find that energy consumption and urbanization exacerbate environmental issues. Espoir et. al. (2024) use machine learning to show the impact of economic growth and poverty on Africa's sustainability.

Renewable energy and economic growth significantly affect environmental quality. He et. al. (2024) find that resource depletion worsens ecological footprints but mineral rents can support sustainability if used wisely. Khan et al. (2020) highlight renewable energy's role in improving environmental quality, a finding echoed by Baz et. al. (2019) in Pakistan. Alvarado et. al. (2021) emphasize the potential of R&D investments to reduce environmental degradation.

Air pollution, climate change, and agriculture interact to affect food security and public health. Singh et. al. (2023) find that agricultural ammonia emissions threaten crop yields and food security in India. Aneja et al. (2009) link ammonia emissions to PM2.5 pollution, while Bauer et. al. (2016) highlight the global threat posed by ammonia emissions in densely populated areas.

Economic and social factors also influence environmental sustainability. Okumuş (2020) confirms the Environmental Kuznets Curve in Turkey, noting urbanization's role in environmental degradation. Kara et. al. (2024) advocate for high-value industrial exports, while Yağış (2024) and Turan (2018) underline agriculture's contributions to Turkey's economic growth.

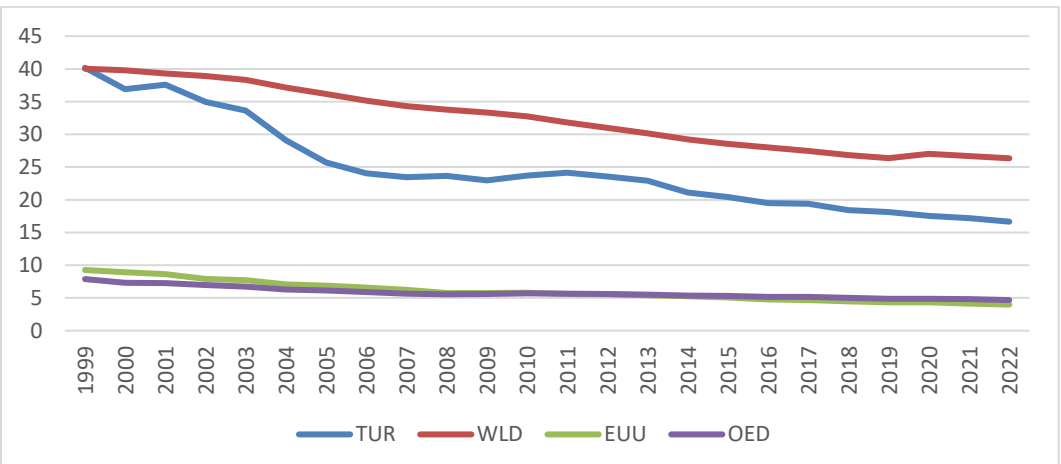
Lastly, sustainability policies are key to mitigating environmental impacts. Harizanova and Stoyanova (2018) and Aneja et. al. (2009) stress the need for environmentally friendly agricultural policies. Qureshi et al. (2016) emphasize reducing emissions in Pakistan, while Aziz et. al. (2023) highlight renewable energy's role in Gulf Arab States' sustainability efforts.

4. SUSTAINABLE DEVELOPMENT AND THE AGRICULTURAL SECTOR

4.1. Economic Contributions of the Agricultural Sector

The agricultural sector plays a significant role as one of the primary drivers of economic growth in developing countries. Agriculture contributes to the economy not only through food production but also by creating employment and supporting regional development (Giannakis et. al., 2019: 894). For communities living in rural areas, agriculture serves as a fundamental livelihood source and supports the diversification of economic activities (Alvarado et. al., 2021: 2). In developed countries, although agriculture accounts for a smaller share of the overall economy, it is considered a critical component of sustainable development (Çakmak and Acar, 2022: 6).

The employment rate in the agricultural sector is a key indicator highlighting the importance of agriculture in terms of rural development, economic transformation, and labor force dynamics. In developing countries, the agricultural sector typically accounts for a larger share of total employment, whereas this share is lower in industrialized countries. For all subsequent graphs in this section, data are presented for Turkey (TUR), the world average (WLD), European Union countries (EUU), and OECD countries (OED). Graph 1 shows the changes in the share of agricultural employment as a percentage of total employment for Turkey (TUR), the world average (WLD), European Union countries (EUU), and OECD countries (OED) between 1999 and 2022.



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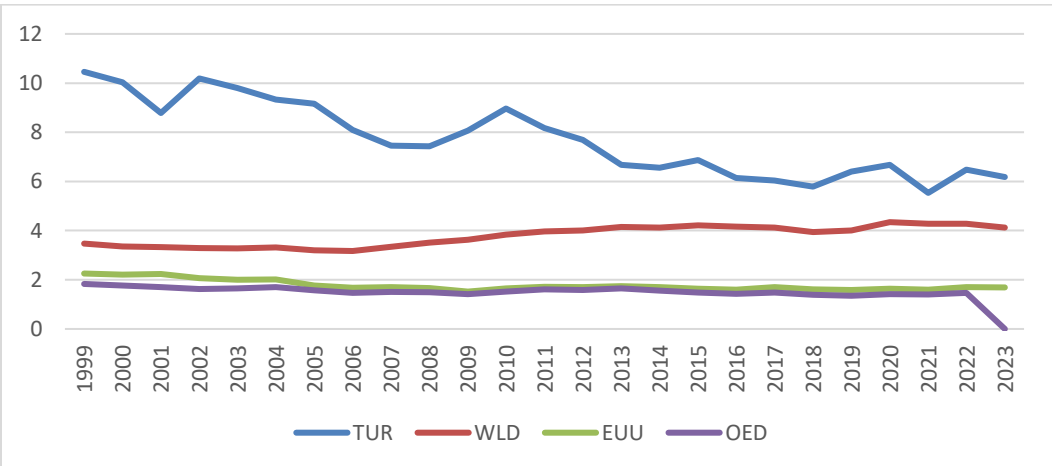
Graph 1: Agricultural Employment (% of Total Employment)

In the graph, it can be observed that agricultural employment in Turkey was above 35% in 1999. However, in the following years, this rate consistently declined, falling below 15% by 2022. This decrease can be explained by the economic

transformation process in Turkey, particularly the shift towards the industrial and service sectors. The decline in the share of agriculture in employment is also associated with rural-to-urban migration and the growth of non-agricultural sectors. A similar downward trend is observed in the global average, although this decline is slower compared to Turkey. In European Union and OECD countries, agricultural employment rates have remained at significantly low levels. This indicates that these countries have adopted a structure focused on high technology and productivity in agriculture, enabling production with less labor.

The contribution of the agricultural sector to GDP is also considered an important economic indicator. The share of agricultural activities in GDP reflects the growth rate of the sector and the overall economic structure of the country (Okumuş, 2020: 31). In countries where agriculture holds a significant weight in the economy, developments in the sector directly contribute to economic performance, thus creating a positive impact on achieving sustainable development goals (Baz et. al., 2019: 7). In this context, comparing the value-added ratios of the agricultural sector allows for an analysis of the economic structure and its contribution to sustainable development.

Graph 2 illustrates the percentages of agriculture, forestry, and fishing value-added in GDP for Turkey, the world average, European Union, and OECD countries between 1999 and 2023. Among these regions, Turkey stands out as the country allocating the highest share of GDP to the agricultural sector. Particularly in 1999, this share exceeded 10%, though it showed a declining trend over the years. After the 2008 global financial crisis, some fluctuations were observed in the contribution of the agricultural sector, yet the overall trend remained downward. This decline aligns with the increasing share of the industrial and service sectors in Turkey's economy.



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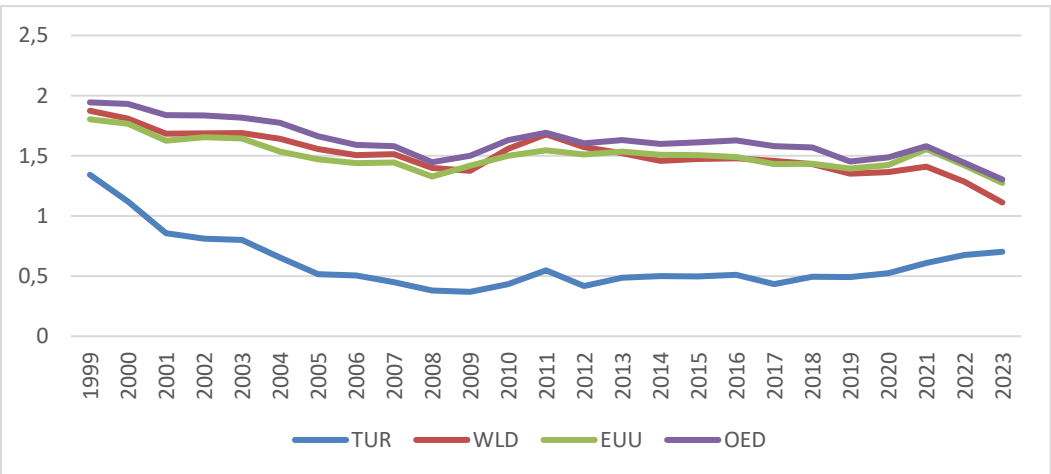
Graph 2: Agriculture, Forestry, and Fishing, Value Added (% of GDP)

Looking at the global average, the contribution of agriculture to GDP has remained relatively stable. While the global contribution of the agricultural sector to GDP is low, this rate is approximately half of Turkey's level. This can be attributed to the

sectoral distribution differences between developed and developing countries. European Union and OECD countries have the lowest contributions of agriculture to GDP. In OECD countries, the value added from agriculture has decreased to nearly zero levels. This indicates that in industrialized economies, the contribution of agriculture to the economy is relatively minimal, and these countries rely more on an economic structure based on sectors like technology, industry, and services.

Graph 2 demonstrates that in developing countries like Turkey, agriculture remains an important component of the economy. However, with the economic transformation process, the share of agriculture has gradually decreased. On the other hand, the low share of the agricultural sector in developed countries and regions like the OECD highlights the reduced role of agriculture in economic development and the dominance of other sectors. These differences underline the necessity for each country to develop strategies tailored to its economic structure within the framework of sustainable development policies.

The economic contributions of agriculture are further strengthened by agricultural export activities that increase a country's foreign exchange earnings. Agricultural product exports create a positive impact on a country's trade balance and serve as a source of income for economic growth (Turan, 2018: 204). Countries, particularly by utilizing foreign exchange earnings from agricultural exports to invest in industrial and service sectors, support their economic development (He et. al., 2024: 3). In this regard, the agricultural sector stands out not only as a driver of domestic economic development but also as a sector that positively affects international trade balance.



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Graph 3: Agricultural Raw Material Exports (% of Merchandise Exports)

Graph 3 compares the agricultural raw material export ratios of Turkey, the world average, European Union countries, and OECD countries between 1999 and 2023. According to the data in Graph 3, Turkey's share of agricultural raw material exports in total merchandise exports is among the lowest compared to other regions. While this ratio was above 1% in 1999, it showed a downward trend over the years, stabilizing at

approximately 0.5% after 2010. This indicates that industrial products have become increasingly dominant in Turkey's foreign trade structure, and the share of agricultural products in total exports has declined

The decline in Turkey's agricultural raw material exports reflects an economic transformation consistent with its industrialization process. Unlike Turkey, the global average, European Union, and OECD countries maintain a share of approximately 1.5% in agricultural raw material exports, showing a more stable trend. The lack of significant fluctuations in these regions between 1999 and 2023 suggests that the share of agricultural products in foreign trade remains relatively steady. Although the importance of agriculture in the economy is relatively low in the European Union and OECD countries, the preservation of a certain share in agricultural product exports is noteworthy.

4.2. Environmental Impacts of the Agricultural Sector

The agricultural sector, by its very nature, is heavily dependent on environmental resources, making the management of its environmental impacts crucial for sustainable development. Agricultural activities exert pressure on natural resources by causing environmental issues such as soil degradation, depletion of water resources, and greenhouse gas emissions (Aneja et. al., 2009: 4236). Evaluating the environmental impacts of agriculture within the framework of sustainability is essential for protecting future food security and managing natural resources effectively (Harizanova and Stoyanova, 2018: 1073).

One of the most significant environmental impacts of agricultural production is its contribution to the increase in greenhouse gas emissions. Livestock activities, in particular, result in the release of potent greenhouse gases such as methane (CH4) and nitrous oxide (N2O) into the atmosphere, thereby contributing to climate change (Almaraz et. al., 2018: 5). Practices like intensive fertilizer use and soil cultivation lead to chemical pollution in soil and water ecosystems, threatening the balance of these ecosystems (Savci, 2012: 78). This highlights the necessity of adopting sustainable practices in agriculture.

Another critical environmental impact of agriculture is the overuse of water resources. Irrigation activities, especially in regions at risk of water scarcity, result in declining groundwater levels and harm biodiversity (Singh et. al., 2023: 3). The increasing population and rising water demand further underscore the need for water-efficient technologies in agriculture (Karaer and Gürlük, 2003: 199). In this context, the sustainable management of water resources is essential for the continuity of agricultural production activities.

4.2.1. Agricultural Carbon Dioxide (CO2) Emissions

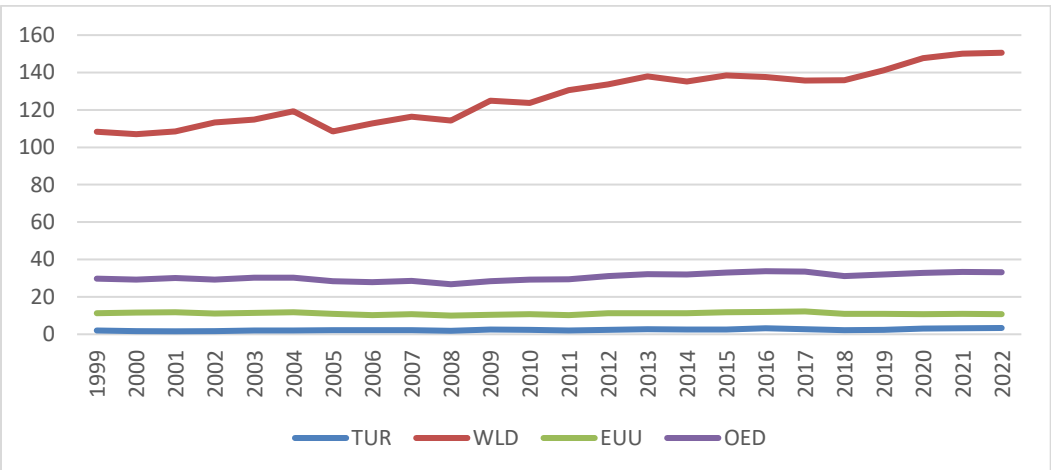
The agricultural sector significantly impacts climate change by contributing to various greenhouse gas emissions. Carbon dioxide (CO2) emissions originate from activities such as fossil fuel use, soil tillage, and fertilization within the agricultural sector, posing a threat to environmental sustainability (Aneja et. al., 2008: 4236). In particular, the intensive use of fossil fuel-powered agricultural machinery and high

fertilizer application rates increase CO2 emissions into the atmosphere, contributing to global warming (Bauer et. al., 2016: 5396).

CO2 emissions tend to rise with changes in agricultural production processes and the increasing prevalence of industrialized farming practices. The industrialization of agriculture has intensified processes such as mechanized farming, pesticide use, and fertilization, further elevating emissions (He et. al., 2024: 7). This increase accelerates climate change, complicating the agricultural sector's capacity to achieve sustainability goals. Reducing CO2 emissions is possible through the adoption of sustainable agricultural practices.

Sustainable agricultural practices include innovative technologies aimed at reducing carbon emissions and the widespread adoption of organic farming techniques. Encouraging the use of renewable energy sources in agricultural activities and transitioning to low-carbon farming methods are among the measures that can be taken in this context (Çakmak and Acar, 2022: 5). Such sustainable practices are seen as a critical step toward developing environmentally friendly agricultural strategies (Alvarado et. al., 2021: 10). Reducing agricultural CO2 emissions is vital not only for environmental sustainability but also for securing future agricultural production. Controlling greenhouse gas emissions in the agricultural sector emerges as an effective long-term strategy for combating climate change.

Graph 4 shows the yearly changes in agricultural CO2 emissions for Turkey, the global average, European Union countries, and OECD countries. The graph reveals a consistent upward trend in global agricultural CO2 emissions. This trend highlights that the expansion and intensification of agricultural production, driven by the growing global population, exacerbate environmental impacts. Between 1999 and 2022, global agricultural CO2 emissions increased from approximately 100 Mt CO2e to 140 Mt CO2e. This rise underscores the need for a transition to more sustainable practices in the agricultural sector to combat climate change.



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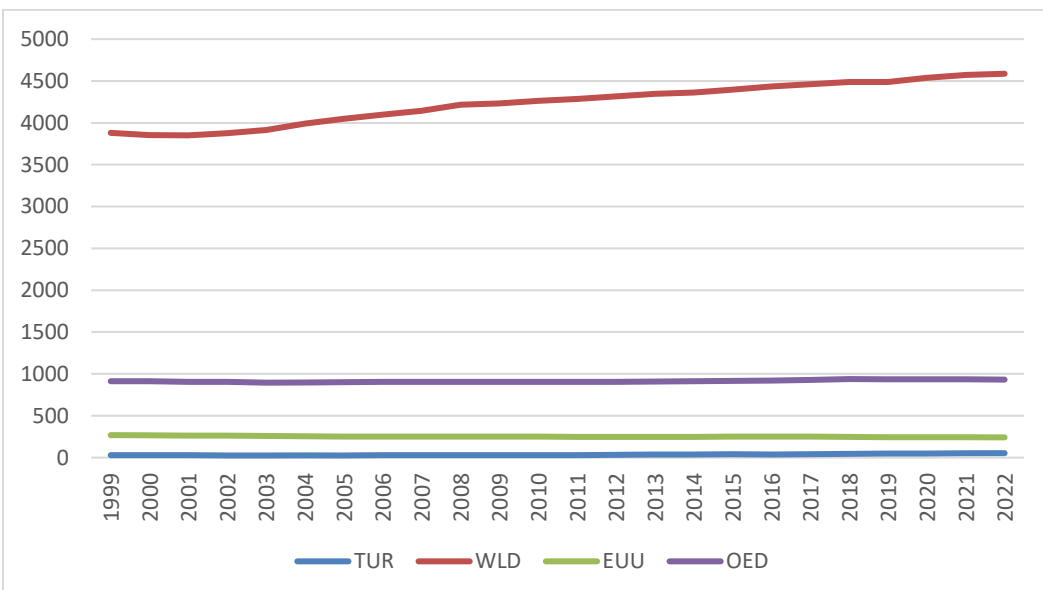
Graph 4: Agricultural Carbon Dioxide (CO2) Emissions (Mt CO2e)

Turkey's agricultural CO2 emissions, on the other hand, have remained relatively low and did not show significant increases between 1999 and 2022. This suggests that Turkey's agricultural activities have had comparatively limited environmental impacts or that agricultural technologies in Turkey have not employed emission-intensive processes to the same extent as in more industrialized countries.

4.2.2. Agricultural Methane (CH4) Emissions

The agricultural sector is a significant source of CH4 emissions, primarily due to livestock activities. Methane is a more potent greenhouse gas compared to carbon dioxide, having a substantial impact on global warming (Kara et. al., 2024: 624). The majority of agricultural methane emissions originate from animal digestion and manure management processes, with cattle farming being a primary contributor to increased methane emissions (Almaraz et. al., 2018: 4). Methane emissions from livestock activities are higher in intensive farming systems, increasing the amount of methane released into the atmosphere. The rising number of livestock and the intensification of these activities have led to an increase in methane emissions from the agricultural sector over the years (Aneja et. al., 2009: 4235). Transitioning to more sustainable livestock systems is essential to achieving methane reduction targets in the fight against climate change (Giannadaki et. al., 2018: 1311).

Strategies to reduce methane emissions include the use of feed additives, changes in animal feeding practices, and improvements in manure management techniques. These measures are considered effective methods for reducing methane production and aim to minimize the environmental impacts of livestock activities (Charfeddine, 2017: 364). Additionally, transitioning to lower-intensity livestock systems has the potential to enhance environmental sustainability (Aziz et. al., 2023: 770). Graph 5 illustrates the trends in agricultural methane emissions in Turkey, the global average, European Union, and OECD countries from 1999 to 2022.



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Graph 5: Agricultural Methane (CH4) Emissions (Mt CO2e)

Globally, agricultural methane emissions show a consistent upward trend throughout the graph. In 1999, these emissions were approximately 4000 Mt CO2e, gradually increasing by 2022. This trend indicates that expanding livestock activities continue to drive methane emissions, posing a significant risk in terms of climate change. Since livestock farming is a growing sector, especially in developing countries, reducing methane emissions should be a priority in global environmental policies.

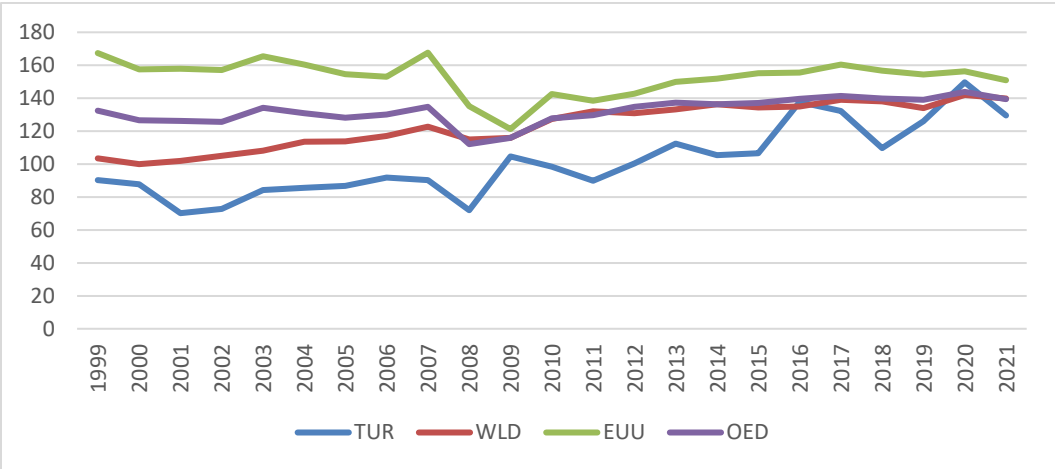
In Turkey, methane emissions have remained at relatively low levels. The stable and low levels of agricultural methane emissions in Turkey suggest that the livestock sector makes a comparatively limited contribution to emissions on a global scale. While this provides an advantage for Turkey in terms of emission reduction targets, it should be balanced with policies aimed at enhancing the economic potential of the livestock sector. Similarly, agricultural methane emissions in the European Union and OECD countries have also remained at low levels. This reflects the effectiveness of modern and efficient livestock practices in limiting methane emissions in developed countries. It also suggests that agricultural policies in these countries are shaped with a focus on environmental protection.

4.2.3. Environmental Consequences of Fertilizer Use

Fertilizer use in agriculture is a widely preferred method to enhance crop productivity; however, excessive fertilizer application can have adverse environmental effects. Chemicals such as nitrogen and phosphorus in fertilizers infiltrate soil and water ecosystems, causing pollution and disrupting natural balances (Savci, 2012: 78). This situation particularly leads to pollution of groundwater and surface water bodies, a decline in biodiversity, and the intensification of environmental problems such as eutrophication in aquatic ecosystems (Baz et. al., 2019: 7).

Nitrates resulting from fertilizer use reach water resources, causing negative impacts on both human health and the environment. Nitrates accumulating in groundwater can contaminate drinking water, leading to health issues, especially in rural areas (Harizanova and Stoyanova, 2018: 1072). Additionally, the degradation of soil structure by chemical fertilizers and the reduction in long-term productivity underscore the importance of sustainable agricultural practices once again (Alvarado et al., 2021: 10).

To mitigate the environmental impacts of fertilizer use, it is essential to adopt sustainable agricultural practices. The use of organic fertilizers offers an effective solution to reduce the negative effects of chemical fertilizers. Organic farming methods not only minimize the environmental damage caused by fertilizers but also preserve soil structure, supporting long-term agricultural productivity (Qureshi et al., 2016: 373). Furthermore, precision fertilization techniques, ensuring the timely and accurate application of fertilizers, are considered a critical step toward achieving environmental sustainability (Çakmak and Acar, 2022: 6). Graph 6 illustrates the changes in fertilizer consumption per hectare in Turkey, the global average, European Union, and OECD countries from 1999 to 2021.



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Graph 6: Fertilizer Consumption (Kilograms Per Hectare)

In European Union countries, fertilizer consumption per hectare is notably high and has shown some fluctuations over the years. Fertilizer use peaked in the early 2000s, decreased slightly following the 2008 crisis, but began to rise again after 2015. This suggests that EU countries employ a fertilizer-intensive approach in agricultural production, focusing on enhancing productivity. However, high fertilizer consumption may pose risks to sustainable agriculture, making it crucial to implement balancing policies in this area.

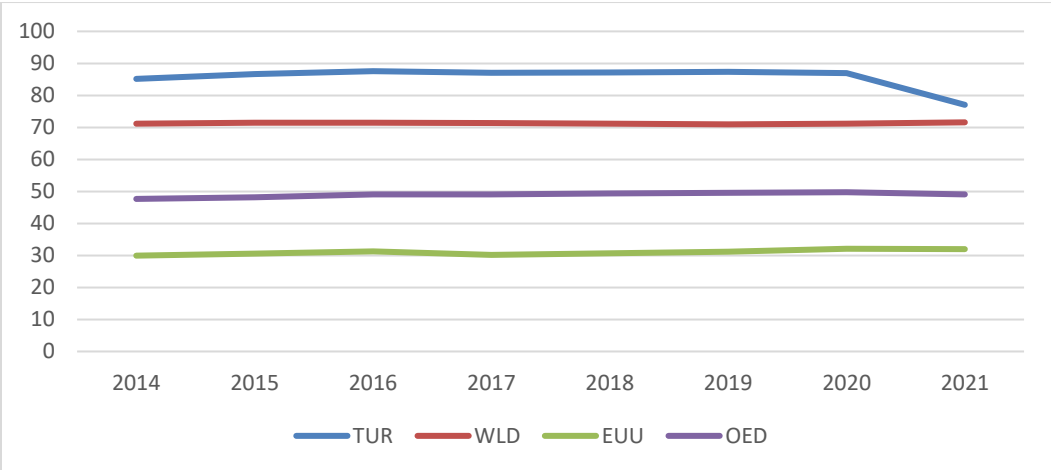
In Turkey, fertilizer consumption has remained below the global average but has shown a slight upward trend since 1999. Starting from 2010, there has been a noticeable increase in fertilizer use per hectare in Turkey, though it still lags behind the levels of the EU and OECD. This indicates that Turkey has not yet adopted intensive fertilizer use in agricultural production and may still rely on more natural methods. Fertilizer consumption in OECD countries and the global average has remained relatively stable. The steady usage rates in these regions suggest that environmentally friendly practices in agricultural production processes may have been established to some extent.

4.2.4. Water Consumption and Water Management Issues

The agricultural sector is one of the most intensive users of resources in terms of water consumption. Irrigated crop production consumes a significant portion of freshwater resources globally, threatening ecological balance in regions at risk of water scarcity (Karaer and Gürlük, 2003: 199). The pressure on water resources has been increasing due to the impacts of climate change, making water management and efficient water use essential in agriculture (Turan, 2018: 204). The increase in water consumption leads to the depletion of groundwater levels and a decline in biodiversity, causing irreversible damage to aquatic ecosystems (Espoir et al., 2024: 7). To mitigate the environmental impacts of agricultural water consumption, implementing modern irrigation techniques such as drip irrigation is crucial. These techniques optimize water

usage, enhancing efficiency while minimizing environmental impacts (Sandalcılar, 2012: 68).

The intensive use of groundwater in agriculture results in the depletion of these resources and a decline in water quality. Overconsumption of water not only makes agricultural production unsustainable in the long term but also negatively affects communities and ecosystems in arid regions (Khan et. al., 2020: 5). Therefore, developing water management strategies and ensuring the sustainable use of water resources in agricultural activities have become critical for environmental sustainability (Giannakis et al., 2019: 895). Graph 7 compares the share of annual freshwater withdrawals for agriculture in Turkey, the global average, European Union, and OECD countries.



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Graph 7: Annual Freshwater Withdrawals in Agriculture (% of Total)

The graph shows that Turkey's agricultural water withdrawal ratio is around 90%, indicating that a large portion of the country's freshwater resources is allocated to agricultural activities. This high percentage highlights the significant importance of sustainable water resource use in Turkey's agricultural sector. Particularly in regions at risk of water scarcity, such a high proportion could threaten sustainability.

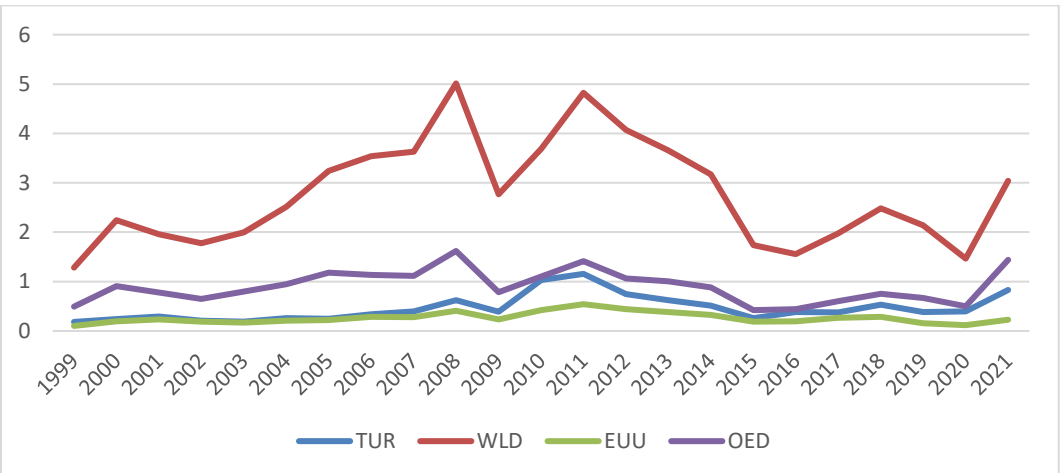
The global average freshwater withdrawal for agriculture is approximately 70%, significantly lower than Turkey's rate. This indicates a more balanced use of water for agriculture worldwide. In OECD and European Union countries, this ratio is much lower, ranging between 30% and 40%. These low rates suggest that agricultural water use in developed countries is more efficient and conservation-focused. In terms of water resource use, Turkey's high freshwater withdrawal rate underscores the importance of water management policies. The lower rates in other regions indicate policies that encourage more careful and sustainable water use. For Turkey to manage its water resources more sustainably, it is necessary to develop methods to increase water efficiency in agriculture.

4.2.5. Agriculture and the Use of Natural Resources

The agricultural sector is a highly resource-intensive field, heavily relying on natural resources such as water, soil, and energy. Agricultural production processes, particularly those requiring irrigation, account for a significant share of water consumption. In regions experiencing water scarcity, the intensive use of water resources poses a severe threat to sustainable development. Improving irrigation efficiency in water-scarce countries is essential for sustainability in agriculture (Qureshi et. al., 2016: 372). In this context, the efficient use of water resources in agriculture is a critical element for ensuring food security and achieving sustainable development goals (Singh et. al., 2023: 3).

The share of natural resource rents in a country's GDP indicates the degree to which its economy depends on natural resources and the importance of these resources in generating economic value. Natural resource rents typically include income derived from resources such as oil, gas, minerals, and forests, and these rates tend to be higher in resource-rich countries. Graph 8 compares the share of natural resource rents in GDP across Turkey, the global average, European Union, and OECD countries over the years.

According to the data, the global average shows a highly variable trend in natural resource rents, peaking at around 5% in 2008 and 2011. These fluctuations may be shaped by changes in oil prices and global market dynamics. In Turkey, the share of natural resource rents in GDP remains relatively low, generally below 1%. This suggests that Turkey's economy relies more on industrial and service sectors rather than income from natural resources. In OECD and European Union countries, the share of natural resource rents in GDP has remained low and stable. This reflects that developed economies have low dependence on natural resources and a high level of economic diversification.



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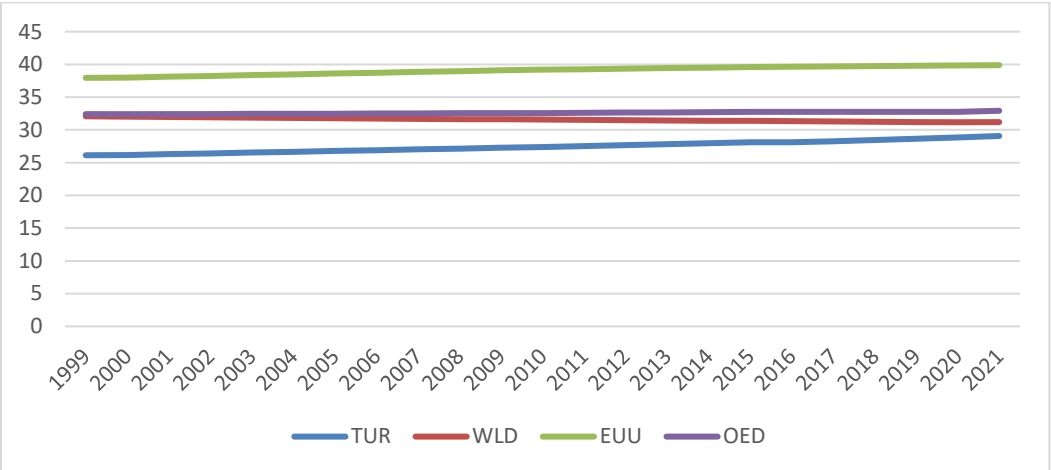
Graph 8: Total Natural Resource Rents (% of GDP)

The low ratios in Turkey, OECD, and European Union countries suggest that these economies are less dependent on natural resources, thereby possessing a more

sustainable structure. The proportion of forest area to total land area is an important indicator of a country's ecosystem health, biodiversity, and carbon sink capacities. Forests are fundamental components of environmental sustainability due to their carbon sequestration capacity and role in protecting natural habitats. Graph 9 compares the proportion of forest areas to total land areas in Turkey, the global average, European Union, and OECD countries between 1999 and 2021.



Source: https://databank.worldbank.org/source/world-development-indicators

Graph 9: Forest Area (% of Total Land Area)

The graph shows that the European Union's forest area ratio is around 40%, which is higher than in other regions. This indicates that forest conservation policies are effectively implemented in EU countries and that extensive forest areas exist in this region. The high proportion of forested land reflects the alignment of the European Union's structure with its environmental sustainability goals.

The forest area ratios for the global average, OECD, and Turkey are at lower levels compared to the European Union, though they show a slight upward trend over time. Turkey's forest area ratio has steadily increased from 1999 to 2021, yet it remains below the global average. It can be stated that efforts to protect and expand forest areas in Turkey are ongoing, but the current ratio is still limited.

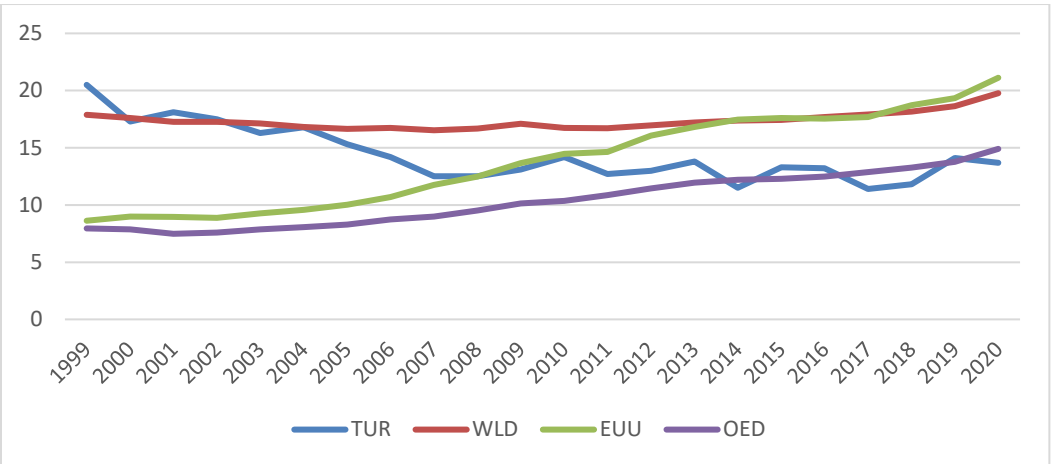
These data once again highlight the importance of forest areas for environmental sustainability. While the high forest area ratio in the European Union demonstrates the success of environmental protection policies, it emphasizes the necessity for Turkey to continue increasing its forest area. The similar upward trend observed in other regions also underscores the importance of global efforts to preserve forest areas.

4.3.1. The Importance of Renewable Energy Consumption

The use of renewable energy in the agricultural sector is becoming increasingly vital for achieving sustainable development goals. The intensive use of fossil fuels in agricultural activities increases environmental pollution and contributes to rising

greenhouse gas emissions. This, along with its adverse effects on climate change, necessitates a transition to renewable energy in agricultural production (Bauer et al., 2016: 5396). The utilization of renewable energy sources not only reduces the carbon footprint but also offers the potential to lower energy costs in the agricultural sector (Savci, 2012: 78).

Renewable energy sources such as solar and wind energy can be employed in the agricultural sector for activities like irrigation systems, greenhouses, and operating agricultural machinery. Renewable energy applications meet the energy needs of agricultural activities in an environmentally friendly manner, promoting sustainable farming practices (Çakmak and Acar, 2022: 5). For instance, solar-powered irrigation systems reduce both energy costs and carbon emissions (Zhou et. al., 2022: 8).



Source: https://databank.worldbank.org/source/world-development-indicators

Graph 10: Renewable Energy Consumption (% of Total Final Energy)

Graph 10 illustrates the share of renewable energy consumption in total final energy consumption in Turkey, the global average, European Union, and OECD countries. The graph shows that the European Union has surpassed other regions in renewable energy consumption, exceeding 20% in 2020. The emphasis on the use of renewable energy sources in EU countries stems from energy policies focused on combating climate change. This increase demonstrates that EU countries play a leading role in the energy transition process. Both the global average and OECD countries exhibit a parallel upward trend in renewable energy consumption. By 2020, both regions had steadily increased their renewable energy shares. This trend reflects the global acceleration of the transition to renewable energy and the adoption of environmentally friendly approaches in energy policies.

In Turkey, there has been a significant increase in the proportion of renewable energy consumption, although it still remains below the levels of other regions. Turkey's renewable energy share was above 20% in 1999 but declined until 2005, after which it started to rise again.

This situation suggests that Turkey may have faced challenges in transitioning to

renewable energy within its energy policies or that the energy transition process has progressed slowly. The graph highlights the growing importance of renewable energy consumption worldwide and shows that countries are taking steps in this area. The European Union's leadership stands out as a notable effort in environmental protection and sustainable energy use, while Turkey and other regions are also making progress in increasing their shares in this field.

5. DISCUSSION

This study provides a comparative analysis of indicators such as CO_2 emissions, renewable energy consumption, agricultural GDP, agricultural methane emissions, and freshwater withdrawals in the context of sustainable development for Turkey, the European Union, OECD countries, and the global level. While revealing the relationships between the economic, environmental, and social dimensions of sustainable development, the study details differences in levels of development and environmental policies among countries through graphical analyses. Compared to similar studies in the literature, some findings align with previous research, while others exhibit differences.

Findings focusing on the relationship between CO_2 emissions and renewable energy consumption are consistent with the results of studies by Giannadaki et al. (2018) and Giannakis et al. (2019) Both studies emphasize that reducing agricultural emissions provides health and economic benefits, and this study compares emission levels between Turkey and OECD countries. Turkey's CO_2 emissions are particularly high compared to developed OECD and EU countries. This aligns with the Environmental Kuznets Curve hypothesis examined by Charfeddine (2017) and Kızılgöl and Öndes (2022), which predicts that economic growth initially increases environmental degradation but leads to improvements in environmental quality upon reaching a certain level of wealth. Turkey's high emission levels indicate the need for stronger policies to manage the environmental impacts of economic growth.

The findings on renewable energy consumption align with studies by Khan et al. (2020) and Alvarado et al. (2021), which show that renewable energy usage improves environmental quality. However, Turkey's renewable energy consumption remains below EU and OECD averages, indicating the need for Turkey to enhance environmentally conscious energy policies. These findings suggest that Turkey should restructure its energy policy and invest more in sustainable energy sources.

6. CONCLUSION

The analysis of agricultural methane emissions highlights the need for Turkey to advance its sustainable agricultural practices. Methane emissions from intensive livestock activities emerge as a critical issue in combating climate change. In this context, developing policies to reduce methane emissions is strategically important for managing the environmental impacts of the agricultural sector.

A significant limitation of this study is that the data used pertain to specific years and may not fully reflect current developments. The lack of data, particularly for Turkey, poses a challenge in evaluating long-term trends in sustainable development indicators.

Access to more up-to-date data sources would enhance the accuracy and scope of sustainable development research. Additionally, the inability to conduct a more detailed analysis of variable differences among countries limits the generalizability of the study.

In conclusion, comprehensive policy reforms focused on environmentally friendly energy policies and reducing agricultural emissions are necessary for Turkey to achieve its sustainable development goals. By increasing renewable energy consumption, Turkey can reduce carbon emissions, representing a significant step for both economic growth and environmental sustainability. Promoting sustainable practices in the agricultural sector will be effective in mitigating environmental impacts.

This study recommends that researchers in sustainable development address data limitations by seeking more current and comprehensive data sources. Long-term analyses and evaluations of the effectiveness of environmental policies will advance sustainable development research. In developing countries like Turkey, the establishment of a robust data infrastructure and the implementation of strong environmental policies are critical to achieving sustainable development goals.

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