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Comparative Analysis of Carbon Footprints from Away and Home Matches: A Study on Leading Basketball and Football Teams in Türkiye

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Abstract: Problem: Basketball and football teams in Türkiye have the capacity to travel hundreds of kilometres for league matches. In general, such major leagues and leading teams travelling from Türkiye have not been sufficiently researched in the context of Türkiye's leading leagues and teams. In this context, the aim of this study is to assess and compare the carbon footprint of the transport activities of basketball and football teams in Türkiye for their home and away matches for the 2023–2024 season. Methods: The research is based on EN 16258 and ICAO carbon emissions methodologies. This study aims to calculate and compare the carbon footprint of different transport methods, including bus and plane, used by five basketball and football teams in Türkiye. Results: The findings show that there are significant differences between the teams in terms of travelling distances and carbon footprints. Trabzonspor from the Black Sea region released the highest CO_2 emissions from air travel with a total of 91,667.1 $kgCO_{2e}$, while Fenerbahçe Beko had the lowest CO_2 emissions with 5316.72 $kgCO_{2e}$. In terms of bus travel, Gaziantep FK led the CO_2 emissions with 4356.45 $kgCO_{2e}$, while Türk Telekom was the team with the lowest CO_2 emissions with 1233.225 $kgCO_{2e}$. The findings also reveal a notable difference in the number of trees teams need to plant to offset their carbon emissions. Because of their travel patterns, Antalyaspor would need to plant 3481 trees, whereas Fenerbahçe Beko would only need to plant 348 trees. Conclusions: Air travel is emerging as the dominant source of CO_2 emissions and has a greater impact on the environmental impact of teams that rely heavily on airplanes. In this study, the league structure and duration play a critical role in shaping the carbon footprint of sports teams. The football season, which is longer compared to basketball, requires more frequent travel, especially for teams in more remote regions, resulting in higher carbon emissions than basketball. The dominance of Marmara region teams in basketball has a negative impact on the carbon footprint since these teams generally have shorter travel distances.

Keywords: carbon footprint; sustainability; travel emission; basketball; football

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1. Introduction

This study aims to determine the carbon footprint of Turkish basketball and football teams that hosted or travelled to away matches during the 2023–2024 season. This study sets a goal for the sports season. Additionally, it seeks to inform the development of sustainable policies awaiting teams' attendance after determining the number of trees needed per tree planting required to offset CO_2 emissions from travel. While teams and others involved in football have given considerable attention to the travel distances for league matches in various environments, often spanning thousands of kilometres, this

study aims to bridge a potential gap by focusing on the carbon footprints of Turkish football and basketball clubs and their carbon neutrality strategies.

For instance, there is a scarcity of extant literature regarding the environmental consequences of travel by sports teams in Turkish leagues or other leagues. Sporting activities generate considerable amounts of greenhouse gas (GHG) emissions primarily due to transportation, especially air travel, as well as bus transports [1–6].

Driving less-polluting vehicles, using alternative fuels, and optimizing travel itineraries to avoid as many thousands as possible of kilometres travelled in competitions would lead soccer clubs to neutrality or at least reduce carbon emissions [1,2,4,6]. Nevertheless, we lack knowledge about their implementation techniques and the evidence of their effectiveness in Türkiye.

Recently the environmental effect of sports team travel has received more attention, especially because we all want to address the issue of climate change. The nature of sporting events and activities means that much is taken on the responsibility for travel by teams, officials/umpires, and fans/spectators, all of which generate a large amount of greenhouse gas (GHG) emissions.

A systematic literature review conducted by Domański [1] using Scopus, the largest database of scientific publications, highlights the scarcity of detailed studies on the carbon footprint of sports team travel. There are a total of 18,527 articles on the carbon footprint, but only 164 focused on its assessment. Additionally, while there were 225,337 articles on sport (including transport), only 29,958 specifically addressed football. This underscores the need for more focused research in this area, particularly in the context of Türkiye.

A carbon footprint is the total effect an individual or organization has on the environment, including greenhouse gas emissions. Large organizations and the sports mega events are a significant contributor to carbon footprints. This includes both direct and indirect emissions from these types of events that are so degrading to the environment. Research has examined the cumulative impact on the sustainability of various carbon footprint management strategies used across many years of the Winter Olympics. Mega-events, such as the Olympics, are critical to address owing to substantial emissions associated with energy use, transportation, and waste management strategies [7].

Measuring the carbon footprint of sporting events is a key indicator within sustainability strategies. It is more than an accounting exercise on emissions. It is one of the profound proxies for sustainability attempts and translates the fragile impacts on human activities into tangible numerical data. We believe that sport organizations face a pivotal moment in which they must confront the environmental effect of their events and develop a strategy to mitigate this burden [8]. Enhancing mobility during sporting events is essential in this context. These estimates serve as a diagnostic instrument to illustrate the effects of human activity on ecosystems. One method for strategic enhancement is to identify specific areas with the most significant environmental impacts for sports organizations. An example may be a focused initiative to improve energy efficiency, either via the utilization of renewable energy sources or the implementation of more advanced technologies, which may significantly impact the carbon footprint [9]. Likewise, optimizing waste management strategies with an increased focus on prevention, reduction, recycling, and safe disposal can also increase the level of environmental mitigation; they collaboratively formulate a strategy for sustainability, positioning sport as a crucial component in recognizing and addressing our obligations to global environmental stewardship for current and future generations. The assessment of the carbon footprint is not only a step in this direction; rather, it serves as a fundamental pillar supporting our efforts to decrease environmental consequences [10].

Sporting events must work together to decrease their carbon footprint for the organizations that cover them, and those who are just attending. Players can increase or decrease their personal carbon footprint through the transportation approach or personal behaviour they choose [11]. Within these intricate tangles of interactions, educating individuals about environmental sustainability becomes a powerful influencer. A greater appreciation of the

carbon impact that individual actions have on decarbonising sport could therefore lead to more enlightened choices being made by individuals, resulting in pan-environmental legitimate damage reduction [12].

This gives the name carbon footprint to all the activities that make up any consuming activities related to sport. For this reason, it is an important metric for both individuals and organizations, regardless of their use case. The major actors of the sports world, including athletes, teams and federations, sponsors, and governing bodies, set important goals for the development and sustainable success of sport. While achieving these goals, they may have uncontrollable consequences on the environment. Therefore, stakeholders of sports should consider the environmental impact as well as the success achieved from the sport [13].

Carbon emissions from participants' travel significantly influence the environmental implications of events. Research indicates that 25.6 million spectators at large-scale sporting events in Europe generate a total of 210,000 tons of CO_2 emissions. A significant proportion of this pollution is attributed to transportation; it was shown that 70% of the emissions generated during the Vancouver 2010 Winter Olympics were a result of transportation. This findings illustrates the magnitude of the carbon footprint associated with sports travel [13].

In addition, one study puts forward a legal requirement that mandates a quest to reduce the carbon footprint associated with sports travel when sustainable transportation solutions are not available [8]. In another study, Guloglu et al. [13] explored multi-pronged practices, focusing on the idea of minimizing carbon emissions from mega sporting events. This indicates the expansion of public transport systems, as the "displacement of buses, trams, and trains by individual vehicles" not only results in reduced environmental impact from facility access but presents a secure alternative to designated cycling and walking paths that promote a more active lifestyle. Recommendations concerning sports travel represent a comprehensive but feasible strategy for mitigating environmental consequences and are progressing along a familiar route.

In Germany, the study was achieved by using the EN 16258 standard [14] to accurately measure emissions from team travel and showed that this accounted for more than one third of this total [15]. Research conducted in Poland analysed the effect of traveling to an away match on the carbon footprint of football teams [1]. An implication of this finding is the pressing need for seeking alternative transportation and emissions reduction from a co-location perspective. The long-term sustainability of a Finnish ice hockey team was achieved by persistent attempts to attain carbon neutrality, using recognized management practices such as minimizing transit distances and enhancing energy efficiency inside the facilities [16].

Research on the carbon footprint and environmental impact of sporting events shows that these organizations have significant sustainability implications. In the United States, the research calculated the 2019 National Collegiate Athletic Association Men's Basketball Tournament's carbon footprint based on spectator and team travel, food, trash, hotel, and stadium operations. The footprint was estimated at 210 million $kgCO_{2e}$, or approximately 500 kg per participant [17]. Similarly, research in China developed a model that gathered real-time carbon emission data from consumption, including game duration, lighting use, and air conditioning emissions from sporting events, and forecast carbon emissions from these activities using deep learning algorithms [18]. A study using air quality index data from NFL stadiums found that attendance increases ozone and nitrogen dioxide levels, with an average increase of about 2% in ozone levels due to increased attendance [19]. In addition, the research on the carbon footprint of the 2023 Europa League Men's semi-finals revealed that the aggregate carbon footprint of the four participating teams was 4560.25 kg, with a per capita average of 189.74 kg for the teams' overall carbon footprint. The entire carbon footprint of the supporters of the four clubs was 4065.686 kg, while the mean per capita carbon footprint of the followers was 3.003 kg [20]. Another study presents a comprehensive methodology for calculating GHG emissions from a major sporting event, analysing factors such as products purchased, energy consumption, waste generation, business travel and accommodation, and providing tools for professionals [21]. To control

this pollutant, strategic management and policy development are necessary, with a focus on proactive sustainable innovations and alternative transportation behaviours, particularly during sports events [22].

However, while research on the carbon footprint of sports travel has increased globally, there is a dearth of region-specific studies, especially in relation to Turkish sports teams. Many previous studies relate to European or North American sporting events, and thus their findings have only very limited relevance to Türkiye. Furthermore, there is a lack of specific information on Turkish basketball and football teams' travel habits and modes of transportation; this data is also necessary for the formulation of targeted mitigation strategies. To address this gap, this study presents a comparative analysis framework based on environmental impact assessment and sustainable transportation principles. The methodology of this study is to measure and evaluate the total distance travelled by selected basketball and football teams in Türkiye between 2023 and 2024, and to calculate the GHG emissions from these distances using neutralization methods. This study also helps to fill a gap in region-specific data and encourages dialog on sustainable sports governance more broadly.

2. Materials and Methods

The aim of this study is to calculate the carbon footprints and determine corresponding tree planting to offset CO_2 emissions resulting from transport methods used by basketball and football teams participating in away or return trips for home game/away game occasions occurring during the 2023–2024 season. Türkiye has basketball and football teams that can travel hundreds of kilometres away for their own league matches, but research in carbon footprint issues has assumed those trips or zero-carbon strategies are less when compared to other countries [16]. Major goals include measuring the travelled distances, estimating greenhouse gas (GHG) emissions related to flight transportation with EN 16258 standard model, determining major modes of transport used throughout, and evaluating tree planting needs, followed by possible environmental actions [1].

The EN 16258 standard, established in 2012, is titled, "Methodology for Calculation and Declaration of Energy Consumption and GHG Emissions Services (freight and passengers)" [14]. The EN 16258 standard was selected for this research because it is directly relevant to the primary problem examined in this study [1].

All calculations are capitalized for the following factors over four VOS ranges for each range of vehicle operation system:

- Well-to-wheels energy factors (E_w);
- Well-to-wheels emission factors (G_w);
- Tank-to-wheels energy factors (E_t);
- Tank-to-wheels emission factors (G_t).

To establish total energy and GHG emission, we applied equations from the EN 16258 standard (2012) [22].

For well-to-wheels energy consumption (E_w):

$$E_w(VOS) = F(VOS)xe_w$$

For well-to-wheels greenhouse gas emissions (G_w):

$$G_w(VOS) = F(VOS)xg_w$$

For tank-to-wheels energy consumption (E_t):

$$E_t(VOS) = F(VOS)xe_t$$

For tank-to-wheels greenhouse gas emissions (G_t):

$$G_t(VOS) = F(VOS)xg_t$$

where F(VOS) represents the total consumption of the energy source operated in the VOS, e_w is the volumetric coefficient of the consumption of a given type of well-to-wheels energy source, g_w is the volumetric coefficient of the greenhouse gas emissions from a given type of well-to-wheels energy source, e_t is the volumetric coefficient of the consumption of a given type of tank-to-wheels energy source, and g_t is the volumetric coefficient of the greenhouse gas emissions from a given type of tank-to-wheels energy source [14,23].

This research calculated CO_2 emissions from the teams' air travel by considering aircraft fuel usage and emission levels per passenger. The average fuel consumption value used in these calculations is based on aircraft fuel consumption values reported in the literature, which are 3–4 L per 100 km per passenger [24]. Based on the average fuel consumption of only 3.5 L per 100 km represented a very good example to this model's analysis.

CO_2 Emission Factor

Jet fuel emits 2.31 L of CO_2 per litre of fuel burned [24].

Fuel Consumption Calculations

Fuel consumption was reported on a team by total mileage basis with the following equation:

$$\text{Fuel Consumption (L)} = (\text{Total km}/100) \times (\text{Fuel Consumption (L}/100\text{ km)}$$

CO_2 Emission Calculations.

CO_2 emissions were calculated using the formula once the fuel consumption was determined:

$$CO_2\text{ Emissions (kg)} = \text{Fuel Consumption (L)} \times CO_2\text{ Emission Facto (kg } CO_2\text{/litre)}$$

Calculating Tree Planting Requirements to Offset CO_2 Emissions.

To quantify the total 26,087,355 kg of CO_2 emissions offset by trees planted (and loss multiplier) we must take one step further and determine how much CO_2 a tree can sequester over its lifetime. A mature tree, as defined by the US Environmental Protection Agency (EPA), can absorb one ton of CO_2 in 25 years [25].

To calculate the number of trees needed to offset the total 26,087,355 kg of CO_2 emissions, we need to consider how much CO_2 a single tree can absorb over its lifetime. According to the US Environmental Protection Agency (EPA), a single mature tree can absorb an average of 22 kg (0.022 metric tons) of CO_2 per year [25]. Based on this information, we can calculate the number of trees needed to offset 26,087,355 kg of CO_2 emissions as follows:

$$\text{Number of trees required} = \text{Total } CO_2 \text{ emission (kg)}/CO_2 \text{ absorbed by one tree per year (kg)}$$

Selection of Teams

The teams in this study were selected according to the regions of the Football and Basketball Super Leagues participating in the 2023–2024 season. There were no teams from the Aegean and Eastern Anatolia regions in football, and no teams from the Mediterranean and Eastern Anatolia regions in basketball. Therefore, 5 teams each from 5 regions were selected for both leagues. In this context, the teams determined for this study provide full representation for both leagues.

The football teams in different regions of Türkiye are Galatasaray from the Marmara region, Trabzonspor from the Black Sea region, Ankaragücü from the Central Anatolia region, Antalyaspor from the Mediterranean region, and Gaziantep FC from the Southeastern Anatolia region.

The basketball teams in different regions of Türkiye are Fenerbahçe Beko from the Marmara region, Samsunspor from the Black Sea region, Türk Telekom from the Central Anatolia region, Pınar Karşıyaka from the Aegean region, and Çağdaş Bodrum Spor from the Mediterranean region.

Data Collection Process

The data collection process follows four main sub-stages; the first three stages are adapted from the methodology used by Domański [1].

Stage 1: Selection of the Vehicles of Service (VOS) and Analysis of Travel Data.

Data were collected on the distances travelled for all away and home matches of both football and basketball teams during the 2023–2024 season. This data includes the location of the stadium where each home match was played and the location of the teams' facilities. The distances between the stadium and team headquarters were calculated on a shortest path basis. For away matches, the primary mode of transportation used by each team for away matches was identified, including buses and planes, which are the most common modes of transportation for teams. At this point, the distances between the teams' arrival and departure from their home city to the airport, from their home city to the city centre, and from the city centre to the stadium were calculated on a shortest path basis. A study conducted by the International Council on Clean Transportation [26] highlights intercity buses, which operate more consistently at higher speeds and with fewer stops, typically consume less fuel, averaging around 25 to 30 L per 100 km.

Stage 2: Determination of the Total Energy Source Consumption for the Selected VOS.

To ensure accurate emission calculations, information was collected on the types of vehicles used. For buses, data included fuel type (e.g., diesel, LNG), average fuel consumption, and emission standards (e.g., Euro VI). For air travel, data included aircraft type, average fuel consumption per kilometre, and emission factors per passenger-km.

Stage 3: Estimation of energy consumption from the combustion of the energy source and CO_2 emissions along the entire route.

Stage 4: Determination of tree planting requirements for the teams.

3. Results

Tables 1 and 2 show the total distances travelled by football teams for home and away matches during the 2023–2024 season by region, team, and city. The distances are further categorized into km travelled by bus for home matches and by both plane and bus for away matches.

Table 1. Total distances travelled by football teams for home and away matches during the 2023–2024 season.

Region	Sport	Team	City	Total km Home Matches by Bus-km *	Total km Away Matches by Bus-km **	Total km Away Matches Plane-km ***
Marmara	Football	Galatasaray	Istanbul	1075	2114	13,590
Black Sea	Football	Trabzonspor	Trabzon	2889	1973	24,564
Central Anatolia	Football	Ankaragücü	Ankara	821	2979	15,574
Mediterranean	Football	Antalyaspor	Antalya	555	2795	19,796
Southeastern Anatolia	Football	Gaziantep FK	Gaziantep	407	4203	21,632

* Total km home matches by bus-km refers to total distance travelled by teams for home matches. ** Total km away matches by bus-km refers to total distance travelled by teams for away matches where travel by plane is not possible. *** Total km away matches by plane-km refers to the total distance travelled by teams for away matches.

Table 1 shows that Trabzonspor, from the Black Sea region, has the highest total travel distance by both plane and bus. By contrast, Galatasaray, from the Marmara region, has relatively lower travel distances due to the high number of Istanbul-based rival teams.

Table 1 shows the total distances travelled by football teams in different regions of Türkiye for home and away games during the 2023–2024 season. The distances travelled by bus and plane to attend the matches are specified individually. Data indicate that Trabzonspor, situated in the Black Sea region, covers the most distance (26,537 km) for away matches; while Galatasaray, located in the Marmara region, travels the least distance of 15,704 km. For home matches, Trabzonspor, from the Black Sea region, covers the most distance (2889 km); while Gaziantep FK, from the Southeastern Anatolia region, travels the least distance of 407 km.

Table 2. Total distances travelled by basketball teams for home and away matches during the 2023–2024 season.

Region	Sport	Team	City	Total km Home Matches by Bus-km *	Total km Away Matches by Bus-km **	Total km Away Mathes Plane-km ***
Marmara	Basketball	Fenerbahçe Beko	Istanbul	492	1976	5480
Black Sea	Basketball	Samsunspor	Samsun	249	2627	20,496
Central Anatolia	Basketball	Türk Telekom	Ankara	153	3840	10,768
Aegean	Basketball	Pınar Karşıyaka	Izmir	90	4061	7780
Mediterranean	Basketball	Çağdaş Bodrum Spor	Mugla	240	4447	10,394

* Total km home matches by bus-km refers to total distance travelled by teams for home matches. ** Total km away matches by bus-km refers to total distance travelled by teams for away matches where travel by plane is not possible. *** Total km away matches by plane-km refers to the total distance travelled by teams for away matches.

Table 2 shows the total distances travelled by basketball teams in different regions of Türkiye for home and away games during the 2023–2024 season. The distances travelled by bus and plane to attend the matches are specified individually. Data indicate that Samsunspor, situated in the Black Sea region, covers the most distance (23,123 km) for away matches; while Türk Telekom, located in the Central Anatolia region, travels the least distance of 14,608 km. For home matches, Fenerbahçe Beko, from the Marmara region, covers the most distance (492 km); while Pınar Karşıyaka, from the Aegean region, travels the least distance of 90 km.

Table 3 shows that Trabzonspor covered the highest total distance (4862 km) and accordingly had the highest fuel consumption (1458.6 L). Gaziantep FK covered the second highest total distance (4610 km) and had the highest fuel consumption (1382.94 L). Galatasaray and Antalyaspor have lower values in terms of total distance and fuel consumption by bus.

Table 3. Total distance and fuel consumption for home and away matches in football teams.

Team	Total km Home Matches Bus-km	Total km Away Matches Bus-km	Total km	Total Litre
Galatasaray	1075	2114	3189	956.64
Trabzonspor	2889	1973	4862	1458.6
Ankaragücü	821	2979	3800	1139.85
Antalyaspor	555	2795	3350	1004.82
Gaziantep FK	407	4203	4610	1382.94

Table 4 shows that Çağdaş Bodrum Spor covered the highest total distance (4687 km) and accordingly had the highest fuel consumption (1406.1 L). Pınar Karşıyaka travelled a similarly high total distance (4151 km) and had the second highest fuel consumption (1245.24 L). Türk Telekom travelled a significant distance for away matches (3840 km) and also had a high fuel consumption (1197.9 L). Fenerbahçe Beko and Samsunspor have lower total distance and fuel consumption than the other teams.

Table 5 shows that Trabzonspor covered the highest total distance (4862 km) and consequently the highest total team emissions of 3617.328 kgCO_{2e}; while Galatasaray travelled the least total distance (3189 km) and had the lowest total team emissions of 2372.616 kgCO_{2e}.

Table 6 shows that Çağdaş Bodrum Spor covered the most total distance (4687 km) and had the highest total team emissions of 3487.128 kgCO_{2e}; while Türk Telekom covered the least total distance (1305 km) and had the lowest total team emissions of 970.92 kgCO_{2e}.

Table 4. Total distance and fuel consumption for home and away matches in basketball teams.

Team	Total km Home Matches Bus-km	Total km Away Matches Bus-km	Total km	Total Litre
Fenerbahçe Beko	492	1976	2468	740.34
Samsunspor	249	2627	2876	862.74
Türk Telekom	153	3840	1305	1197.9
Pınar Karşıyaka	90	4061	4151	1245.24
Çağdaş Bodrum Spor	240	4447	4687	1406.1

Table 5. Energy and emissions calculations for home and away matches in football teams.

Team	Total km	Total Litres *	Ew (MJ)	Gw ** ($kgCO_{2e}$)	Et (MJ)	Gt *** ($kgCO_{2e}$)
Galatasaray	3189	956.7	42,573.1	3013.6	34,154.2	2372.6
Trabzonspor	4862	1458.6	64,907.7	4594.6	52,072.1	3617.3
Ankaragücü	3800	1139.85	50,730	3591	40,698	2827.2
Antalyaspor	3350	1004.82	44,722.5	3165.7	35,878.5	2492.4
Gaziantep FK	4610	1382.94	61,543.5	4356.4	49,373.1	3429.8

* Total liters refer to total amount of fuel consumed by transportation of football teams during their home and away matches. ** Gw is the greenhouse gas emissions produced over a fuel's entire lifespan. *** Gt solely refers to the emissions generated by a power source during its operational phase.

Table 6. Energy and emissions calculations for home and away matches in basketball teams.

Team	Total km	Total Litres *	Ew (MJ)	Gw ** ($kgCO_{2e}$)	Et (MJ)	Gt *** ($kgCO_{2e}$)
Fenerbahçe Beko	2468	740.4	32,947.8	2332.3	26,432.3	1836.192
Samsunspor	2876	862.8	32,947.8	2717.8	30,802.0	2139.744
Türk Telekom	1305	391.5	17,421.75	1233.2	13,976.6	970.92
Pınar Karşıyaka	4151	1245.3	55,415.85	3922.7	44,457.2	3088.344
Çağdaş Bodrum Spor	4687	1406.1	62,571.45	4429.2	50,197.8	3487.128

* Total liters refer to total amount of fuel consumed by transportation of basketball teams during their home and away matches. ** Gw is the greenhouse gas emissions produced over a fuel's entire lifespan. *** Gt solely refers to the emissions generated by a power source during its operational phase.

Table 7 shows that Trabzonspor had the highest CO_2 emissions per capita (1986 kg) and total team emissions (91,667.1 $kgCO_{2e}$); while Galatasaray had the lowest CO_2 emissions per capita (1098.75 kg) and lowest total team emissions (23,073.75 $kgCO_{2e}$). The overall impact of all teams resulted in a total distance travelled of 95,156 km, a cumulative fuel consumption of 3330.46 L, and 326,103.96 kg of CO_2 emissions for a total of 105 football players.

Table 7. CO_2 emissions for football teams' away matches-plane.

Team	City	Total km	Fuel Consumption (Litres)	CO_2 Emissions (kg for One Person)	Total Team (Only Football Players)	Total of CO_2 Emission (Only Football Players)
Galatasaray	İstanbul	13,590	475.65	1098.75	21	23,073.75
Trabzonspor	Trabzon	24,564	859.74	1986	21	91,667.1
Ankaragücü	Ankara	15,574	545.09	1259.16	21	57,565.62
Antalyaspor	Antalya	19,796	692.86	1600.51	21	73,406.34
Gaziantep FK	Gaziantep	21,632	757.12	1748.95	21	80,391.15
Total		95,156	3330.46	7693.36	105	326,103.96

Table 8 shows that Samsunspor had the highest CO_2 emissions per capita (1657.10 kg) and total team emissions (19,885.2 $kgCO_{2e}$); while Fenerbahçe Beko had the lowest CO_2 emissions per capita (443.06 kg) and lowest total team emissions (5316.72 $kgCO_{2e}$). The total impact of all teams resulted in a total distance travelled of 54,918 km, a cumulative fuel consumption of 1922.13 L, and total CO_2 emissions of 53,281.32 kg for a total of 60 basketball players.

Table 8. CO_2 emissions for basketball teams' away matches-plane.

Team	City	Total km	Fuel Consumption (Litres)	CO_2 Emissions (kg for One Person)	Total Team (Only Basketball Players)	Total of CO_2 Emission (Only Basketball Players)
Fenerbahçe Beko	İstanbul	5480	191.80	443.06	12	5316.72
Samsunspor	Samsun	20,496	717.36	1657.10	12	19,885.2
Türk Telekom	Ankara	10,768	376.88	870.59	12	10,447.08
Pınar Karşıyaka	İzmir	7780	272.30	629.01	12	7548.12
Çağdaş Bodrum Spor	Muğla	10,394	363.79	840.35	12	10,084.2
Total		54,918	1922.13	4440.12	60	53,281.32

Table 9 shows that Trabzonspor had the highest CO_2 emissions from air travel (91,667.1 kgCO2e), and Fenerbahçe Beko had the lowest emissions (5316.72 $kgCO_{2e}$); Gaziantep FK led in CO_2 emissions from bus travel (4356.45 $kgCO_{2e}$) and Türk Telekom had the lowest emissions (1233.225 $kgCO_{2e}$). The team with the highest total CO_2 emissions per team was Antalyaspor (76,572.09 $kgCO_{2e}$); the team with the lowest emissions was Fenerbahçe Beko (7648.98 $kgCO_{2e}$). In terms of tree planting required to offset these emissions, Antalyaspor is the team that needs to plant the most trees (3481) and Fenerbahçe Beko the least (348).

Table 9. Emissions and tree planting requirements for leading basketball and football teams.

Team	Total of CO_2 Emission-Plane	Total of CO_2 Emission-Bus	Total of CO_2 Emission per Team	Tree Planting Requirements
Galatasaray	23,073.75	3013.60	26,087.35	1186
Trabzonspor	91,667.10	4594.60	96,261.69	4376
Ankaragücü	57,565.62	3591.00	61,156.62	2780
Antalyaspor	73,406.34	3165.75	76,572.09	3481
Gaziantep FK	80,391.15	4356.45	84,747.60	3852
Fenerbahçe Beko	5316.72	2332.30	7648.98	348
Samsunspor	19,885.20	2717.80	22,603.02	1027
Türk Telekom	10,447.08	1233.22	11,680.30	531
Pınar Karşıyaka	7548.12	3922.70	11,470.81	521
Çağdaş Bodrum Spor	10,084.20	4429.21	14,513.41	660
Total	379,385.28	33,356.61	412,741.89	18,761

4. Discussion

The purpose of this study is to determine the carbon footprints for transportation methods that basketball and football teams used for home and away games, carrying them from various cities across Türkiye during the 2023–2024 season. It also searches for countermeasures to climate change and neutralization measures like tree planting planned, measured, and implemented against carbon dioxide emissions.

Trabzonspor (2889 km) is the team that must travel the most distance for home matches. On the other hand, Gaziantep FK (407 km) travelled the least distance for home matches. In addition, Trabzonspor (24,564 km) travelled the most distance by air travel, while Galatasaray (13,590 km) travelled the least distance. The shortest air travel distance for Galatasaray, a Marmara region team, can be explained by the fact that this region is centrally

located and there are more teams in Istanbul. Trabzonspor (Black Sea) and Gaziantep FK (Southeastern Anatolia), which are far from the centre, have obviously travelled more distance by air travel than other regions. In Table 2, Fenerbahçe Beko (492 km) was the team to travel the most distance for home matches. In addition, Pinar Karsiyaka (90 km) was the team that travelled the least distance. On the other hand, Samsunspor (20,496 km), from the Black Sea region, was the team that travelled the most distance in plane trips; while Fenerbahce Beko, from the Marmara region, was the team that travelled the least distance. The factor affecting this situation is thought to be the increase in the number of teams from the Marmara region, especially Istanbul, in the league. These data are consistent with other studies in the literature for the carbon emission data released by teams located in the centre and far from the centre [1,3,5,27–30].

In football, Trabzonspor was the club that travelled the longest distance in total (4862 km) and was therefore the club that consumed the most fuel (1458.6 L). In basketball, Çağdaş Bodrum Spor was the team that travelled the most kilometres with 4687 km; in total, 1406.1 L of fuel were consumed on these trips. On the other hand, the total distance travelled and fuel requirement for Galatasaray and Antalyaspor in football, and Fenerbahçe Beko and Samsunspor in basketball, by bus are significantly lower. It is considered that there are two factors that contribute to this situation. The first factor is the low emission consumption of Galatasaray, a Marmara region team in football, and Fenerbahçe in basketball, which are in the same region, due to the abundance of teams close to the centre or in the same region. On the other hand, since Çağdaş Bodrum Spor and Antalyaspor are far from the centre and prefer air travel rather than road travel, carbon emissions from buses have remained at a low level. This indicates that, in football, teams travel greater distances for away matches. In basketball, this trend has diminished owing to the dominance of teams from the Marmara region. These results align with the research undertaken in Germany regarding soccer and handball leagues. This research revealed a distinct trend in soccer, indicating that clubs travel greater distances for away matches as the league level escalates. In handball, the trend is less distinct; still, at both premier levels, teams travel more distances for away matches than those teams in lower levels. During a single season, soccer teams for both men and women travelled an average distance ranging from 277 to 3131 km for away matches, whilst handball teams travelled between 111 and 2314 km [31].

Trabzonspor (1986 kg) had the highest carbon emissions per person from aircraft travel, with a total emission of 91,667.1 kgCO_{2e}. By contrast, the total carbon emissions per person for the five football teams were 7693.36. The total carbon emissions from all football teams were 326,103.96. Table 8 shows the carbon emissions caused by air travel by basketball teams. As in football, another Black Sea region team, Samsunspor, caused the most carbon emissions. The total carbon emissions per capita for five basketball teams were 4440.12. The carbon emissions caused by all football teams were 266,407.2. Therefore, basketball teams cause less carbon emissions than football teams. There are two reasons for this difference. The first is the duration of the leagues. The basketball season consists of a 30-week period, while football consists of a 38-week period. For this reason, this difference may have arisen because football teams travel more. The second factor is that the Marmara region, especially the Istanbul-based teams, are more dominant in basketball than football. There are a total of 16 teams in the basketball league, 9 of these teams are in the Marmara region; while 7 of the 9 teams are Istanbul-based teams. In football, 8 of the 20 teams are based in the Marmara region and Istanbul. A study examining the carbon footprint of basketball teams in Türkiye and Lithuania determined a total carbon footprint of 53,029 tons for both countries [2]. Moreover, football and basketball teams must track their travel to improve their outcomes. Joining the Fly Green Alliance (FGA) under the sustainable aviation fuel (SAF) initiative, creating green travel programs, and overseeing offtake agreements, can help them meet climate action goals and reduce their carbon footprint [32]. Football's popularity is causing disproportionate GHG emissions [33]. If football teams adopt an effective climate mitigation strategy, which is vital to their reputation, their activities will be acknowledged [34]. Finally, football clubs should oversee more thorough carbon footprint

evaluations that better comprehend emission scope. Football teams could improve their reputation marketing [35].

The highest CO_2 emissions from air travel are from Trabzonspor (91,667.1 $kgCO_{2e}$), and the lowest emissions are from Fenerbahçe Beko (5316.72 $kgCO_{2e}$). The highest CO_2 emissions from bus travel are from Gaziantep FK (4356.45 $kgCO_{2e}$), and the lowest emissions are from Türk Telekom (1233.225 $kgCO_{2e}$). The team with the highest total CO_2 emissions per team is Antalyaspor (76,572.09 $kgCO_{2e}$), and the lowest is Fenerbahçe Beko (7648.98 $kgCO_{2e}$). In terms of tree planting required to compensate for these emissions, it is seen that Antalyaspor is the team that needs to plant the most trees (3481), and Fenerbahçe Beko is the team that needs to plant the fewest trees (348). The total carbon emissions from all football and basketball teams' travels are 412,741.89 $kgCO_{2e}$. To neutralize carbon emissions, the teams must plant 18,761 trees. We engage in tree planting initiatives for significant athletic events. To mitigate carbon emissions from the development of the sports facility for the 2014 Brazil World Cup, we employed forestry-based carbon offsets [36]. In 2008, the National Football League (NFL) initiated urban tree planting to offset carbon emissions during the season [37]. The use of trees to mitigate carbon emissions is a multifaceted subject, although it is being employed by sports leagues and events in their carbon footprint neutralization initiatives. The TSG Hoffenheim club has implemented a climate ticket initiative that incentivizes supporters to plant a tree in Africa upon purchasing a match ticket [38]. Likewise, these strategies are used in mass participation athletic events. In 2019, the Paris Marathon planted 140,000 trees as part of their comprehensive carbon neutrality initiatives [39].

5. Conclusions

This study aims to analyse the carbon footprint generated by the transportation methods employed by basketball and football teams in Türkiye during the 2023–2024 season and to quantify the tree planting necessary to offset carbon emissions. The data indicates disparities in travel distances, fuel consumption, and CO_2 emissions across the teams, primarily attributable to their geographical proximity to the league's core hubs.

Trabzonspor, located in the Black Sea region, has the most significant travel requirements regarding distance and fuel consumption, leading to the highest overall emissions. Conversely, teams situated in the central Marmara region, such as Galatasaray and Fenerbahçe Beko, capitalized on their proximity to other teams, leading to markedly reduced travel demands and emissions.

Furthermore, the league's configuration and length have a significant impact on the carbon footprint of the sports teams included in this study. The extended duration of the football season, in contrast to basketball, necessitates more frequent travel, particularly for teams in remote regions, leading to greater carbon emissions than basketball. Due to their typically shorter travel distances, the prominence of Marmara region basketball teams has an adverse effect on the carbon footprint.

Moreover, sports federations and clubs, as stakeholders, must methodically and professionally confront the effects of climate change and devise mitigation strategies for the future. As a result, sports federations and clubs should establish sustainability departments within their organizations and implement measures to reduce and offset carbon emissions from their activities.

Given the substantial travel emissions of teams, particularly those located far from the country's centre, it is imperative to implement solutions that reduce travel schedules and distances. Leagues may invest in technologies like linear programming or network optimization to reduce total travel, thereby generating a fixture where clubs compete in successive possible away matches against nearby rivals. The literature shows that league designers use linear programming and network analysis to reduce the overall travel distances for contests and teams. The Argentine professional basketball league developed a model for the 2013–2014 season that reduced the average trip distance per away game by almost 30%, resulting in lower travel expenses [40]. Also, they developed linear programming models

to minimize the overall trip distance in U12 basketball league scheduling, thereby reducing the distance travelled by each team during league matches [41]. Another study developed a double round-robin schedule wherein each team competes against every other team at both home venues, thereby minimizing the aggregate distance travelled by all teams while adhering to the constraint that no team may have more than two consecutive home or away games, as dictated by the Linear Distance Traveling Tournament Problem [42].

Tree planting, seen as a way for mitigating carbon emissions, may also be assessed in collaboration with public institutions. The "Breath for the Future" Afforestation Project, initiated by the Turkish Ministry of Agriculture and Forestry in 2019, established a foundation for extensive afforestation initiatives in this scope. Moreover, seedlings contributed by participants of the Istanbul Marathon were used for afforestation efforts around a dam in collaboration with local authorities in 2015. These collaborations will guarantee that tree planting initiatives are sustainable, administered judiciously, and successfully contribute to national and global environmental objectives.

Future research may evaluate the applicability of these mitigation techniques in Türkiye and the feasibility of regional collaborations with other areas for sustainable sports management. We must investigate whether carbon reduction strategies implemented by sports teams effectively decrease total emissions and the duration over which they achieve full impact.

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