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Greenhouse Gas Emission and Water Footprint of the National Diet in Turkey: Results from Turkey Nutrition and Health Survey 2017

Azad Ilhan [1], Rumeysa Yenicag [1], Ece Yalcin Pehlivan [1], Ebru Ozturk [2], Sevilay Karahan [2] and Neslişah Rakıcıoğlu [1,*]

[1] Department of Nutrition and Dietetics, Faculty of Health Sciences, Hacettepe University, Sıhhıye, 06100 Ankara, Turkey; azadilhan@hacettepe.edu.tr (A.I.)
[2] Department of Biostatistics, Faculty of Medicine, Hacettepe University, Sıhhıye, 06100 Ankara, Turkey
* Correspondence: neslisah@hacettepe.edu.tr

Abstract: The study aimed to assess and characterize the sustainability of the national diet in Turkey and its association with diet quality, dietary requirements, and sociodemographic factors. Dietary intake was assessed using 24 h recalls from the Turkey Nutrition and Health Survey 2017 (TNHS-2017) (n = 12,527). The environmental footprints were assessed with two environmental indicators: greenhouse gas emissions (GHGEs) and water footprint (WF). Diet quality was assessed using the diet quality index (DQI) and dietary diversity score (DDS). The dietary GHGEs was 3.21 $\pm$ 2.07 kg CO_2-eq/person/day and the dietary total WF was 2832 $\pm$ 1378 L/person/day. The DQI and DDS were 62.26 $\pm$ 8.28 and 6.66 $\pm$ 1.31, respectively. Total energy intake was significantly higher in the highest GHGEs and total WF tertiles (2238 $\pm$ 722 and 2383 $\pm$ 701 kcal, respectively) compared to lower GHGEs and total WF tertiles. Individuals with higher diet-related GHGEs and total WF had a higher daily intake of nutrients with the exception of the percentages of energy supplied from carbohydrates, percentages of meeting nutrients according to the recommended dietary allowance (RDA), DQI (excluding DQI total, moderation, and overall balance score), and DDS scores ($p < 0.001$). GHGEs and total WF value of the national diet in Turkey are lower than the world average. The results would help develop dietary guidelines to encourage sustainable dietary choices.

Keywords: sustainable diet; greenhouse gas emission; water footprint; diet quality

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1. Introduction

The world population is predicted to reach 9.8 billion in 2050. Changing dietary patterns and increasing water demand will exacerbate the problem of water scarcity, with the impact of climate change. One of humanity's most pressing challenges is ensuring a sustainable future, including a sustainable food system [1]. A sustainable future, including a sustainable food system, is one of the most urgent issues of this era. The food system is under threat due to the rapid increase in the world population, climate change, and the decrease in natural resources such as arable land and freshwater [2]. To achieve the United Nations Sustainable Development Goal 2 (SGD 2) on food security and SGD 6 on water security [3], a transition to a sustainable and nutritious diet is required [4].

Food production and consumption have a major role in human health and environmental sustainability [5,6]. A sustainable healthy diet is defined as supporting all aspects of the health (having a low environmental impact; being accessible, affordable, safe, and fair; and being culturally acceptable) of individuals [4]. The EAT–Lancet report published a global reference diet that considers eating patterns' health and environmental sustainability [6]. This scenario contains higher amounts of cereals, vegetables, and fruits, a moderate amount of meats, milk, and dairy products, and a limited amount of added fats and sugars. Food production, processing, distribution, and consumption determine the environmental effects [7]. The food system is responsible for a significant amount of global greenhouse gas emissions (GHGEs) and contributes to water scarcity problems and water footprint (WF) [8].

Turkey is one of the typical Mediterranean countries with a high prevalence of overweight individuals, obesity, and non-communicable diseases as well as some micronutrient deficiencies [9]. Turkey's food system needs a transition to a healthy and sustainable diet as in other countries. Turkey's WF calculations reveal that 80% of production and consumption in the country is based on domestic water resources. This situation shows that the sustainability of freshwater resources will directly affect the country's economy due to climate change and trends in rainfall [10]. Individuals' dietary choices are critical determinants of human and planetary health [11]. Reducing the diet's environmental impact while simultaneously improving the diet quality is an important issue for countries.

Although it is known that the environmental effects of healthy diets are lower, the diet-related environmental effect has not been adequately investigated at the individual level, with some exceptions. Some studies modeled more environmentally friendly diets using food-based [12] or predictive public health models [13]. In other cases, the health and environmental consequences of adopting dietary patterns, such as Mediterranean and ketogenic diets, were explored [13,14].

The aim of this study was to assess and characterize the sustainability of the national diet in Turkey and its association with diet quality, dietary requirements, and sociodemographic factors. To the best of our knowledge, this is the first study to integrate all these aspects when analyzing the national diet in Turkey. Compared to similar research on the general population [15–17], this study uses cross-sectional national data to analyze the environmental footprint of individual diets, not just dietary scenarios. Since all dimensions related to sustainable nutrition (such as the economic status, sociocultural aspects, traditional meals, etc.) differ from country to country, each study that focuses on a country necessarily involves methodological novelty.

2. Materials and Methods

2.1. Study Population

People aged 15 years and older (n = 12,582) were used from the Turkey Nutrition and Health Survey 2017 (TNHS-2017), a cross-sectional study performed between 2017–2019 in this study. Under-(<500 kcal) and overconsumption (>5000 kcal) were excluded from the study, and analyses were conducted for the final sample size of 12,527. The TNHS-2017 is the most recent and comprehensive nutrition and health survey conducted by the Ministry of Health of Turkey and represents the whole of Turkey. The objectives and methodology of the TNHS-2017 have been described in detail before [9]. All data (educational, financial, nutritional status, etc.) were taken from the TNHS-2017. Permission was obtained from the T.C. Ministry of Health and approved by Hacettepe University Non-Interventional Clinical Researches Ethics Board (GO 19/1177) for data use.

2.2. Dietary Intake and Anthropometric Measurements

Information on Turkish people's dietary intake was collected using 24 h dietary recalls in the TNHS-2017 study. The 24 h dietary recall was taken two times at an interval of two weeks (10–14 days), as recommended by the European Food Safety Authority (EFSA) [18], and repeated on the phone or by face-to-face interview. The Turkish food photograph catalog was used to assist respondents in identifying the actual quantity of the foods [19]. Standard dish recipes were used to estimate the amounts of food in one portion consumed outside the institutions [20]. Gram amounts of nutrients consumed were entered into the BEBIS-8 (Nutrition Information Systems Software-8) computer program, and daily energy and other nutrients were analyzed. To determine the percentages of the adequacy of daily energy and nutrient intake, the Turkish recommended dietary allowance (RDA) [21] was used according to age and gender. Nutrient intake below two-thirds of the RDA was considered low (67%), and above one-third of RDA was considered high (133%). Furthermore, anthropometric measurements were evaluated according to gender [22].

2.3. Environmental Assessment

Calculating the diet-related environmental factors, an average of two daily consumptions was used. The WF and GHGEs were selected for the present study as environmental impact factors. The data on the WF were acquired from the WF Network for both plant-based [23] and animal-based foods [24]. Total WF was the sum of blue, green, and grey WF. Blue WF refers to the use of under-ground and surface water sources; green WF refers to the use of rainwater. The grey WF is an indicator used to express the pollution associated with the production process in the entire supply chain of a product. Data on the GHGEs came from the database of Food Impacts on the Environment for Linking to Diets (data FIELDs), which was based on an extensive review of the life cycle assessment literature [25]. In the calculation of the WF and GHGEs, the values of similar foods were used for the foods that are not available in the databases.

2.4. Assessment of Diet Quality

Diet quality was assessed using the diet quality index (DQI)-international, a validated method for assessing overall diet quality [26]. The index is divided into four main sections: variety (score 0 to 20), adequacy (score 0 to 40), moderation (score 0 to 30), and overall balance (score 0 to 10). Under each category, the diet's specific components were to be assessed. The DQI total score was obtained by adding up the scores of these four sections and ranges from 0 to 100. High scores indicate a good diet quality and vice versa.

Dietary diversity is one dimension of diet quality. To calculate the diet diversity score (DDS), the foods consumed were grouped and divided into nine food groups recommended by FAO, which included: (1) cereals, roots, and tubers; (2) dark green leafy vegetables and vitamin-A-rich sources; (3) other fruits; (4) other vegetables; (5) legumes, nuts, and seeds; (6) meats; (7) oils and fats; (8) dairy products; and (9) eggs. According to the consumption of the foods in these nine food groups, scoring was made and dietary diversity was assessed [27]. The consumption of at least 15 g of each food group was assigned one point (if consumed) or zero points (if consumption was less than 15 g) [28].

2.5. Statistical Methods

The data were analyzed with the SPSS 23 package software. Mean, standard deviation (SD), frequency, and percentages (%) were used as descriptive statistics. For comparisons of two independent groups in continuous variables, the results of the independent *t*-test or Welch's *t*-test were represented with effect size (Cohen's d) based on the variance homogeneity assumption. To compare more than two independent groups in continuous groups, they were given the results of the one-way analysis of variance (ANOVA) test or Welch's ANOVA with effect size ($\omega 2$) based on the variance homogeneity assumption. To indicate differences between pairwise groups, Tukey's post hoc test was applied. The association among two categorical variables was analyzed with Pearson's chi-square test with effect size Cramer's V. The p-value < 0.05 was considered statistical significance.

3. Results

This study included 6297 men and 6230 women with a mean age of 40.74 ± 17.31 years (Table 1). Diet-related greenhouse gas emission was 3.21 ± 2.07 kg CO_2-eq/person/day. Diet-related total water footprint was 2832 ± 1378 L/person/day. Of this amount, 82.2% came from green WF, which corresponded to 2329 ± 1188 L/person/day; 10.2% came from blue WF, which corresponded to 290.0 ± 141 L/person/day; and 7.6% came from grey WF, which corresponded to 213 ± 131 L/person/day without gender discrimination. The total and green WFs were found higher in men (2857 ± 1397 and 2351 ± 1205 L/person/day, respectively) than in women (2807 ± 1360 and 2307 ± 1171 L/person/day, respectively) ($p < 0.05$). The diet quality index score was 62.26 ± 8.28 out of a maximum of 100 in both genders. The DQI variety score was found higher in women ($p < 0.05$). Similarly, the dietary diversity score received 6.66 ± 1.31 out of a maximum of 9.00. It was seen that GHGEs, blue WF, grey WF, DQI total, DQI adequacy, DQI moderation, DQI overall balance, and dietary diversity score were not changed according to gender ($p > 0.05$).

The diet quality index scores were divided into tertiles and assessed (Table 2). There was a significant difference between diet quality index tertiles and dietary diversity scores ($p < 0.001$), greenhouse gas emissions ($p < 0.001$), and water footprint components (excluding the grey water footprint) ($p < 0.05$). The dietary diversity score was the highest in the Q3 tertile of the diet quality index. Relatedly, the highest mean values were determined for the greenhouse gas emissions, total and green water footprints in the Q1 tertile, and blue water footprint in the Q2 tertile.

In Table 3, greenhouse gas emissions and water footprint values were compared according to the different characteristics of individuals. Blue and grey water footprint values were lower in the elderly ($p < 0.05$). Individuals with high educational and financial status had higher GHGEs and WF values ($p < 0.001$). Similarly, individuals with lower waist–hip ratios had lower GHGEs and WF values ($p < 0.001$). In addition, the diet-related environmental factors which affect environmental health increased as dietary diversity increased ($p < 0.001$).

The percentages of meeting energy and nutrients intake according to the RDA (%), diet quality index, and dietary diversity scores were examined using tertiles of the greenhouse gas emissions and total water footprint. Total energy intake was significantly higher in the highest tertile (Q3) of GHGEs and total WF (2237 ± 722 kcal and 2383 ± 701 kcal, respectively) (Table 4). The highest mean values were determined for GHGEs and total WF in the Q3 tertile ($p < 0.001$), excluding carbohydrate (%), DQI total, DQI moderation, and DQI overall balance score. In addition, the highest percentages of meeting nutrients according to the RDA were found for GHGEs and total WF in the Q3 tertile. However, a low percentage of meeting energy intake (64.5 ± 24.90%) was observed in the lowest GHGEs tertile. As GHGEs and total WF increased, higher percentages of meeting energy, protein, fiber, iron, calcium, and vitamin C were determined ($p < 0.001$).

The contribution percentages of the food sources for greenhouse gas emission and total water footprint are shown in Figure 1. The two most contributing food sources were red meat and dairy products (40.1% and 16.9%, respectively) for GHGEs, while they were red meat and cereals (23.6% and 16.9%, respectively) for total WF.

Table 1. General characteristics, greenhouse gas emission, water footprint, diet quality index, and dietary diversity score of individuals.

	Men (n = 6297)	Women (n = 6230)	Total (n = 12,527)	p-Value	Effect Size
Age (year)	41.43 ± 17.78	40.04 ± 16.79	40.74 ± 17.31	**<0.001**	<0.001
Body mass index (kg/m^2)	28.38 ± 6.12	28.55 ± 6.21	28.47 ± 6.17	0.15	0.0262
Waist circumference (cm)	94.14 ± 14.65	94.11 ± 14.91		n/a	n/a
Hip circumference (cm)	105.53 ± 11.03	105.89 ± 11.13		n/a	n/a
Waist–hip ratio	0.89 ± 0.09	0.88 ± 0.09		n/a	n/a
Greenhouse gas emission (kg CO_2-eq/person/day)	3.23 ± 2.09	3.19 ± 2.04	3.21 ± 2.07	0.243	0.0202
Total water footprint (L/person/day)	2857.0 ± 1396.63	2807.1 ± 1359.85	2831.9 ± 1378.43	**0.043**	0.0224
Blue water footprint (L/person/day)	291.8 ± 141.36 (10.2%)	288.1 ± 140.95 (10.3%)	290.0 ± 141.16 (10.2%)	0.143	0.0184
Green water footprint (L/person/day)	2350.8 ± 1205.47 (82.3%)	2307.0 ± 1171.11 (82.2%)	2328.8 ± 1188.48 (82.2%)	**0.039**	0.0219
Grey water footprint (L/person/day)	214.4 ± 127.22 (7.5%)	212.0 ± 134.59 (7.5%)	213.2 ± 130.98 (7.6%)	0.32	0.0154
Diet quality index total score	62.18 ± 8.31	62.34 ± 8.25	62.26 ± 8.28	0.27	0.0196
DQI variety score	18.41 ± 2.27	18.51 ± 2.23	18.46 ± 2.24	**0.018**	0.0424
DQI adequacy score	30.03 ± 5.31	30.17 ± 5.18	30.10 ± 5.24	0.144	0.0261
DQI moderation score	12.32 ± 5.56	12.32 ± 5.69	12.32 ± 5.62	0.99	0.0047
DQI overall balance score	1.41 ± 2.05	1.34 ± 1.91	1.38 ± 1.98	0.06	0.035
Dietary diversity score	6.65 ± 1.32	6.67 ± 1.31	6.66 ± 1.31	0.58	0.001

p-values calculated with the independent samples t-test. Bold type indicates statistical significance (p < 0.05). (n%) contribution of water footprint components to total water footprint. Abbreviations: DQI: diet quality index, n/a: non-applicable.

Table 2. Characteristics of individuals according to diet quality index tertiles.

		Diet Quality Index			p-Value	Effect Size
		Q1	Q2	Q3		
Cut-off		≤58.54	|58.54–65.90|	≥65.90		
Gender †	Male	2123 (50.8)	2046 (48.9)	2128 (51.0)	0.106	0.019
	Female	2054 (49.2)	2135 (51.1)	2041 (49.0)		
Age (year) †	15–18	502 (12.0)	523 (12.5)	466 (11.2)	0.177	0.016
	19–64	3279 (78.5)	3235 (77.4)	3318 (79.6)		
	≥65	395 (9.5)	423 (10.1)	385 (9.2)		
Dietary diversity score *		6.26 ± 1.37 [a]	6.82 ± 1.25 [b]	6.90 ± 1.22 [c]	**<0.001**	0.045
Diet-related environmental factors						
Greenhouse gas emission (kg CO_2-eq/person/day) *		3.45 ± 2.40 [a]	3.21 ± 1.96 [b]	2.97 ± 1.76 [c]	**<0.001**	0.009
Total water footprint (L/person/day) *		2950.8 ± 1565.92 [a]	2848.8 ± 1324.14 [b]	2695.9 ± 1209.21 [c]	**<0.001**	0.006
Blue water footprint (L/person/day) *		285.0 ± 141.77 [a]	295.7 ± 149.65 [b]	289.1 ± 131.26 [ab]	**0.003**	0.001
Green water footprint (L/person/day) *		2455.6 ± 1366.91 [a]	2336.0 ± 1126.24 [b]	2194.5 ± 1032.79 [c]	**<0.001**	0.008
Grey water footprint (L/person/day) *		210.2 ± 125.08	217.1 ± 151.51	212.2 ± 113.28	0.074	<0.001

† p-values calculated with the chi-square test; * p-values calculated with one-way analysis of variance (ANOVA) test. [a,b,c] Values on the same row not sharing the same superscript letters were significantly different and bold type used for impression (p < 0.05). Values are means ± SD or n (%). Abbreviations: Q: tertile (Q1 is the lowest and Q3 is the highest).

Table 3. Greenhouse gas emission and water footprint values of individuals according to different characteristics.

Characteristics		GHGEs x̄ ± SD	p1	Blue WF x̄ ± SD	p2	Green WF x̄ ± SD	p3	Grey WF x̄ ± SD	p4	Total WF x̄ ± SD	p5
Age (year) (n = 12,527)											
	15–18	3.27 ± 2.01		286.1 ± 119.90 [ab]		2350.6 ± 1182.32		210.2 ± 83.73 [ab]		2846.9 ± 1356.33	
	19–64	3.21 ± 2.07	0.32	291.8 ± 146.28 [a]	**0.01**	2333.5 ± 1189.36	0.11	214.7 ± 139.97 [a]	**0.03**	2840.0 ± 1384.28	0.08
	≥65	3.16 ± 2.08		279.7 ± 121.10 [b]		2263.0 ± 1187.72		204.7 ± 98.73 [b]		2747.5 ± 1355.77	
Educational status (n = 12,386)											
	Illiterate	2.35 ± 1.69 [a]		220.4 ± 102.82 [a]		1703.6 ± 911.82 [a]		165.6 ± 69.32 [a]		2089.5 ± 1053.88 [a]	
	Primary	2.92 ± 1.81 [b]		275.6 ± 134.84 [b]		2105.9 ± 1013.03 [b]		201.3 ± 134.55 [b]		2582.8 ± 1190.65 [b]	
	Middle	3.39 ± 2.12 [c]	**<0.001**	304.9 ± 128.67 [c]	**<0.001**	2457.5 ± 1226.01 [c]	**<0.001**	222.4 ± 91.77 [c]	**<0.001**	2984.8 ± 1411.56 [c]	**<0.001**
	High school	3.55 ± 2.24 [cd]		309.3 ± 147.61 [cd]		2614.0 ± 1306.46 [d]		229.2 ± 132.52 [cd]		3152.4 ± 1502.65 [d]	
	University	3.72 ± 2.26 [e]		321.6 ± 155.49 [e]		2674.3 ± 1247.88 [d]		236.2 ± 157.46 [d]		3232.1 ± 1449.39 [d]	
Financial situation (n = 12,298)											
	High	3.68 ± 2.39 [a]		311.4 ± 133.27 [a]		2620.7 ± 1339.28 [a]		227.3 ± 96.02 [a]		3159.4 ± 1523.00 [a]	
	Good	3.30 ± 2.04 [b]	**<0.001**	298.7 ± 152.35 [b]	**<0.001**	2402.7 ± 1162.15 [b]	**<0.001**	221.4 ± 161.11 [a]	**<0.001**	2922.8 ± 1356.75 [b]	**<0.001**
	Medium	3.04 ± 1.89 [c]		280.7 ± 129.48 [c]		2219.6 ± 1106.01 [c]		205.5 ± 111.93 [b]		2705.8 ± 1285.52 [c]	
	Low	2.81 ± 1.89 [d]		267.3 ± 154.42 [d]		2061.1 ± 1107.84 [d]		198.0 ± 155.19 [c]		2526.4 ± 1318.06 [d]	
Anthropometric measurement (n= 11,607)											
Waist–hip ratio [†]	Normal	3.04 ± 1.91	**<0.001**	281.0 ± 124.13	**<0.001**	2261.7 ± 1131.99	**<0.001**	205.3 ± 102.56	**<0.001**	2748.1 ± 1301.70	**<0.001**
	High risk	3.36 ± 2.18		297.6 ± 154.08		2392.4 ± 1228.92		219.8 ± 152.47		2909.8 ± 2644.91	
Diet quality (n = 12,527)											
DDS classification	Lowest (≤3)	1.29 ± 1.16 [a]		149.7 ± 88.72 [a]		1144.3 ± 801.67 [a]		107.2 ± 59.37 [a]		1401.2 ± 928.65 [a]	
	Medium (4–5)	2.48 ± 1.98 [b]	**<0.001**	224.1 ± 107.76 [b]	**<0.001**	1827.9 ± 1128.59 [b]	**<0.001**	166.1 ± 75.18 [b]	**<0.001**	2218.1 ± 1276.29 [b]	**<0.001**
	High (≥6)	3.41 ± 2.04 [c]		307.0 ± 142.71 [c]		2460.7 ± 1165.72 [c]		225.5 ± 138.15 [c]		2993.2 ± 1353.66 [c]	

p-values calculated with one-way analysis of variance (ANOVA) test; [†] p-values calculated with the independent samples t-test. [a,b,c,d,e] Values on the same column not sharing the same superscript letters were significantly different and bold type used for impression (p < 0.05). p1: GHGEs, p2: Blue WF, p3: Green WF, p4: Grey WF, and p5: Total WF. Abbreviations: GHGEs: greenhouse gas emission; WF: water footprint; DDS: dietary diversity score.

Table 4. Distributions of individuals' energy and nutrients intake, RDA (%), DQI score, DDS by GHGEs, and total water footprint tertiles.

	Greenhouse Gas Emission				**Total Water Footprint**			
	Q1	**Q2**	**Q3**		**Q1**	**Q2**	**Q3**	
Cut-off	≤2.083	$\mid$2.083–3.516$\mid$	≥3.516		≤2115.4	$\mid$2115.4–3121.4$\mid$	≥3121.4	
Energy (kcal)	1471.1 ± 524.88 ^{a}	1868.6 ± 612.15 ^{b}	2237.5 ± 721.55 ^{c}	**<0.001**	1320.1 ± 429.33 ^{a}	1811.4 ± 496.29 ^{b}	2382.9 ± 700.71 ^{c}	**<0.001**
RDA (%)	64.5 ± 24.90 ^{a}	81.7 ± 28.84 ^{b}	97.8 ± 34.57 ^{c}	**<0.001**	58.0 ± 20.59 ^{a}	79.4 ± 24.74 ^{b}	103.9 ± 33.88 ^{c}	**<0.001**
Carbohydrate (%)	50.5 ± 9.73 ^{a}	47.3 ± 9.10 ^{b}	44.9 ± 6.55 ^{c}	**<0.001**	50.2 ± 10.08 ^{a}	47.6 ± 9.04 ^{b}	45.2 ± 8.73 ^{c}	**<0.001**
Protein (%)	18.5 ± 6.55 ^{a}	20.0 ± 6.72 ^{b}	21.5 ± 7.01 ^{c}	**<0.001**	18.7 ± 6.63 ^{a}	19.8 ± 6.72 ^{b}	21.2 ± 7.02 ^{c}	**<0.001**
RDA (%)	99.9 ± 58.31 ^{a}	135.8 ± 74.66 ^{b}	169.1 ± 90.64 ^{c}	**<0.001**	89.7 ± 49.20 ^{a}	131.1 ± 68.34 ^{b}	178.6 ± 91.97 ^{c}	**<0.001**
Fat (%)	31.0 ± 8.55 ^{a}	32.7 ± 7.79 ^{b}	33.6 ± 7.61 ^{c}	**<0.001**	31.0 ± 8.64 ^{a}	32.5 ± 7.86 ^{b}	33.5 ± 7.57 ^{c}	**<0.001**
Fiber (g)	19.6 ± 8.46 ^{a}	22.9 ± 9.82 ^{b}	24.6 ± 10.15 ^{c}	**<0.001**	18.1 ± 8.16 ^{a}	22.3 ± 8.46 ^{b}	26.2 ± 10.68 ^{c}	**<0.001**
RDA (%)	75.4 ± 34.26 ^{a}	87.6 ± 38.52 ^{b}	94.0 ± 40.33 ^{c}	**<0.001**	69.7 ± 32.39 ^{a}	85.5 ± 34.51 ^{b}	99.8 ± 42.16 ^{c}	**<0.001**
Iron (mg)	12.3 ± 14.71 ^{a}	15.4 ± 8.47 ^{b}	19.1 ± 10.25 ^{c}	**<0.001**	11.2 ± 15.25 ^{a}	14.9 ± 7.59 ^{b}	20.1 ± 10.48 ^{c}	**<0.001**
RDA (%)	101.3 ± 95.24 ^{a}	128.6 ± 79.76 ^{b}	159.7 ± 94.74 ^{c}	**<0.001**	93.2 ± 95.69 ^{a}	124.0 ± 71.59 ^{b}	168.3 ± 97.91 ^{c}	**<0.001**
Calcium (mg)	945.7 ± 506.59 ^{a}	1182.6 ± 629.33 ^{b}	1323.9 ± 681.33 ^{c}	**<0.001**	881.0 ± 477.18 ^{a}	1134.5 ± 564.91 ^{b}	1404.3 ± 708.51 ^{c}	**<0.001**
RDA (%)	87.7 ± 47.69 ^{a}	109.9 ± 60.17 ^{b}	122.9 ± 64.86 ^{c}	**<0.001**	81.7 ± 45.42 ^{a}	105.3 ± 53.80 ^{b}	130.4 ± 67.46 ^{c}	**<0.001**
Vitamin C (mg)	107.1 ± 94.04 ^{a}	125.8 ± 113.66 ^{b}	131.3 ± 102.51 ^{c}	**<0.001**	107.5 ± 111.09 ^{a}	120.1 ± 92.34 ^{b}	135.1 ± 108.65 ^{c}	**<0.001**
RDA (%)	121.7 ± 107.03 ^{a}	143.0 ± 128.03 ^{b}	149.7 ± 118.72 ^{c}	**<0.001**	121.9 ± 125.24 ^{a}	136.6 ± 105.12 ^{b}	154.0 ± 125.23 ^{c}	**<0.001**
Saturated fat (g)	16.50 ± 8.03 ^{a}	23.41 ± 9.81 ^{b}	30.35 ± 12.05 ^{c}	**<0.001**	15.10 ± 7.46 ^{a}	22.35 ± 8.14 ^{b}	31.86 ± 12.02 ^{c}	**<0.001**
Cholesterol (mg)	162.7 ± 125.71 ^{a}	245.1 ± 149.70 ^{b}	320.2 ± 183.70 ^{c}	**<0.001**	142.4 ± 111.66 ^{a}	231.8 ± 127.87 ^{b}	342.4 ± 189.68 ^{c}	**<0.001**
Diet quality index total score	62.55 ± 8.55 ^{a}	62.91 ± 8.25 ^{a}	61.31 ± 7.95 ^{b}	**<0.001**	62.30 ± 8.71 ^{a}	63.14 ± 8.10 ^{b}	61.23 ± 7.98 ^{c}	**<0.001**
DQI variety score	17.56 ± 2.91 ^{a}	18.90 ± 1.73 ^{b}	18.93 ± 1.59 ^{b}	**<0.001**	17.43 ± 2.97 ^{a}	18.87 ± 1.76 ^{b}	18.91 ± 1.63 ^{b}	**<0.001**
DQI adequacy score	28.14 ± 5.46 ^{a}	30.56 ± 4.95 ^{b}	31.60 ± 4.67 ^{c}	**<0.001**	27.43 ± 5.63 ^{a}	30.45 ± 4.60 ^{b}	32.04 ± 4.56 ^{c}	**<0.001**
DQI moderation score	15.25 ± 5.19 ^{a}	12.04 ± 5.03 ^{b}	9.68 ± 5.20 ^{c}	**<0.001**	15.87 ± 5.04 ^{a}	12.39 ± 4.75 ^{b}	9.13 ± 5.09 ^{c}	**<0.001**
DQI overall balance score	1.61 ± 2.15 ^{a}	1.42 ± 2.02 ^{b}	1.10 ± 1.70 ^{c}	**<0.001**	1.57 ± 2.12 ^{a}	1.44 ± 2.05 ^{b}	1.14 ± 1.73 ^{c}	**<0.001**
Dietary diversity score (DDS)	6.07 ± 1.37 ^{a}	6.90 ± 1.19 ^{b}	7.00 ± 1.16 ^{c}	**<0.001**	5.95 ± 1.36 ^{a}	6.85 ± 1.17 ^{b}	7.06 ± 1.16 ^{c}	**<0.001**

p-values calculated with one-way analysis of variance (ANOVA) test. ^{a,b,c} Values on the same row with different superscript letters were significantly different and bold type used for impression ($p < 0.05$). p1: GHGEs; p2: Total water footprint. Abbreviations: Q: tertile (Q1 is the lowest, and Q3 is the highest); RDA: recommended dietary allowance; DQI: diet quality index.

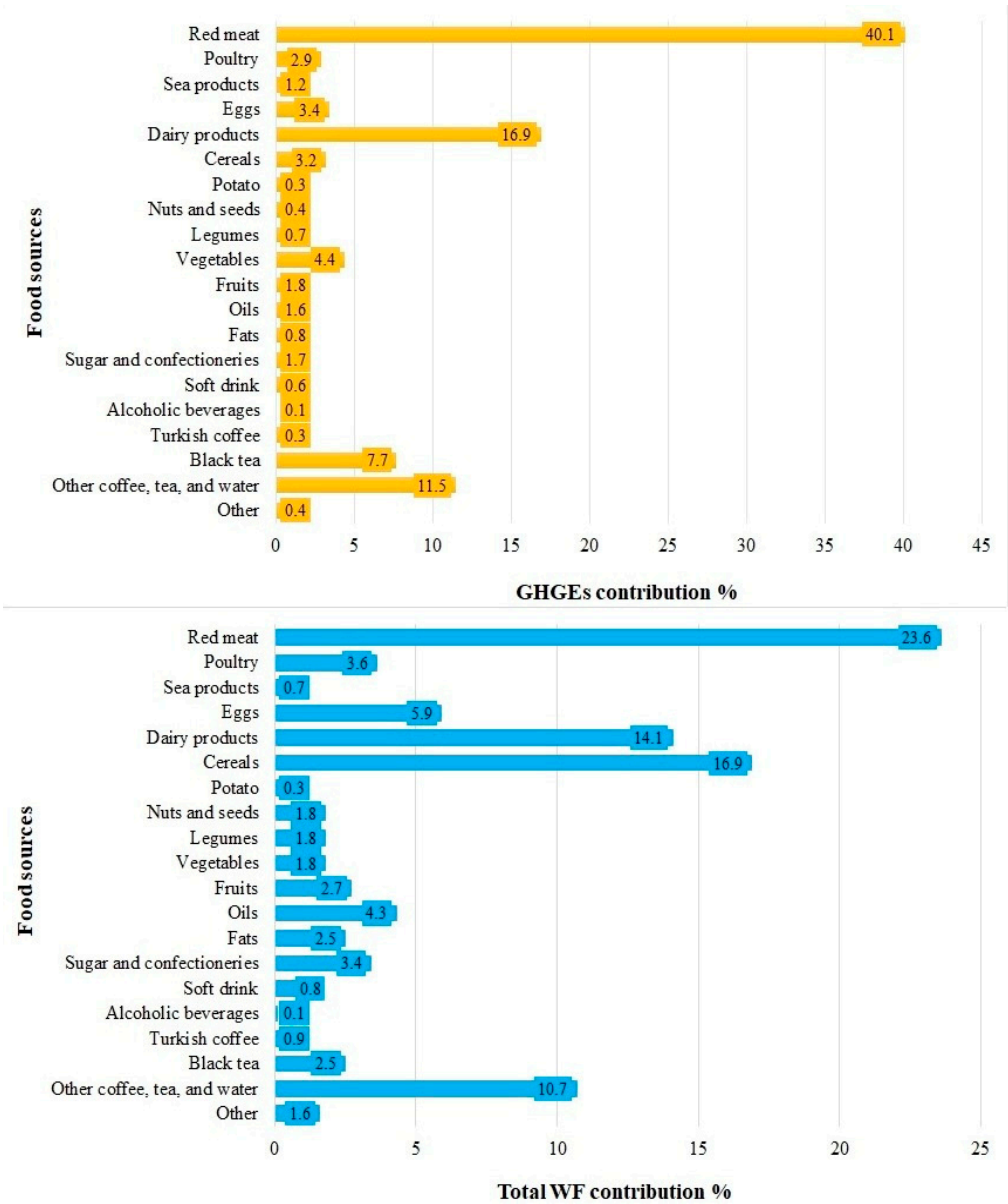

Figure 1. Contribution of food sources on GHGEs (yellow-stained chart) and total WF (blue-stained chart) (%).

4. Discussion

To the best of our knowledge, the present study was the first to estimate diet-related environmental factors (greenhouse gas emission and water footprint components) of the national diet in Turkey in conjunction with nutritional outcomes. We researched the diet quality of individuals with different characteristics and the effect of their diets on diet-related environmental factors.

Compared with other studies that used environmental indicators calculated from similar methods, the national diet of Turkey has the lowest GHGEs (3.21 kg CO_2-eq/day). GHGEs are 6.5 kg CO_2-eq/day in Ireland [29], 4.70 kg CO_2-eq/day in the USA [25], 3.98 kg CO_2-eq/day in Canada [30], and 3.495 kg CO_2-eq/day in China [31]. In addition, the total WF of the national diet in Turkey was 2832 $\pm$ 1378 L/person/day (82.2% green WF, 10.2% blue WF, and 7.6% grey WF) in this study. Compared to the study in which Harris et al. evaluated the WF data of different countries, it was found that Turkey's total WF is lower than most of them [15]. For example, only the green WF mean values of countries on the Asian continent are higher than Turkey's green WF. Cereal products are one of the food groups that make the most significant contribution to the total WF, and the green WF is particularly relevant in crop production [32]. The main food of the national diet in Turkey was bread (179.8 g/d) and other cereal products (73.6 g/d) [9]. In addition, 99.8% of individuals consumed 15 g or more of cereals per day (Table S1). GHGEs and total WF are below the world average because Turkey has a cereal-based diet. Furthermore, the total WF and green WF were higher in men. This is because men had a higher consumption of bread and other cereal products than women (226.3 vs. 133.9 g for bread and 81.9 vs. 65.5 g for cereal, respectively) [9]. Relatedly, the DQI variety score was higher in women. This is related to the fact that women have a higher food group and protein sources variety, which was also seen in the DQI subcomponent scores.

Diet quality and diet-related environmental factors are not interdependent, and improving diet quality and reducing environmental impact are efforts that should be pursued concurrently [33]. The results of studies on diet quality and diet-related environmental factors are controversial. While some studies showed a negative relationship between diet quality and diet-related GHGEs [30–34], a study also showed a positive relationship [35]. Incidentally, Curi-Quinto et al. found a negative relationship between GHGEs and diet quality and a positive relationship between blue WF and diet quality [36]. In Table 2, the assessment was made according to the diet quality index total score tertile. The absence of differences according to age and gender indicated that distributions were homogeneous. Individuals with higher dietary diversity scores had higher diet quality. The highest mean values were seen for GHGEs, green WF, and total WF in the Q1 tertile; for blue and grey WF in the Q2 tertile. While ensuring sustainability, it is important to meet the diet quality, dietary diversity, and individual's daily energy and other nutrients requirements.

Another key finding of this study is that the GHGEs and WF components of the national diet in Turkey vary according to the different characteristics of individuals. The diet-related environmental factors were lower in the elderly, and the differences were statistically significant for the blue and grey WF (Table 3). During the aging process, food consumption changes lead to less energy and nutrient intake. Similarly, it can be explained using different energy requirements. This may be the reason why GHGEs and WF components were low. Further, we found that individuals with lower educational and financial status had more environmentally friendly diets. This may be related to the fact that individuals with higher educational and financial status have more opportunities to access food sources (especially meat and dairy products). The data in the literature are not similar. Travassos et al. [37] found that women and individuals with higher educational status had more environmentally friendly diets. However, Lopez Olmedo et al. showed that women and individuals with lower educational and financial status had more environmentally friendly diets [38]. Finally, another study showed that age, gender, and educational status were not associated with consuming a more sustainable diet [35]. More studies are needed to determine the effect of demographic and socioeconomic factors on diet-related environmental factors because demographic and socioeconomic, and even cultural and geographical structures of countries, affect their nutrition.

Obesity is defined as abnormal and excessive fat accumulation, and a WHO expert consultation stated that waist–hip ratio measurements reflect body fat distribution. Waist–hip ratios increased the risk of chronic diseases (such as diabetes and cardiovascular diseases) and obesity-related morbidity and appear to be a stronger independent risk factor than BMI [22]. It was found that higher energy intake and higher consumption of total fat, saturated fat, and cholesterol increased diet-related environmental factors assessed in this study (Table 4). Therefore, it was not surprising that GHGEs and WF components were higher in the high-risk group of the waist–hip ratio (Table 3).

The diet-related environmental factors were higher in the high dietary diversity group (Table 3). In addition, the overall assessment of the diets showed the highest mean values for the DQI total score in the Q2 tertile (Table 4). The highest DQI adequacy and dietary diversity scores were determined in the highest GHGEs and total WF tertile. This is probably owing to the higher consumption of animal foods, meats, and dairy products, which was also seen in the DQI subcomponent scores. The highest DQI moderation and DQI overall balance scores were seen in the lowest GHGEs and total WF tertile. Similarly, this is likely due to the higher consumption of nuts and seeds, higher compliance with the recommended macronutrient distribution range, and lower consumption of total fat, saturated fat, and empty calorie foods, which was also seen in the DQI subcomponent scores. This study showed that diet quality and its subcomponents had different effects on diet-related environmental factors. The results can inform dietary guidance and other policies that seek to address the goals of improved dietary intakes and reduced the diet-related environmental factors. While increasing the dietary diversity to meet the energy and nutrients requirement, food groups with lower environmental impacts (such as vegetables, fruits, legumes, nuts, and seeds) should be selected for more environmentally friendly diets. Nutritional recommendations should be given by considering health benefits and environmental effects.

Turkish cuisine is characterized by a high preference for animal protein and low plant protein consumption, which may represent a sustainability challenge for the country [9]. Avoidance or lower intake of animal foods may contribute to the nutritional inadequacy of several micronutrients such as Fe, Zn, and vitamin B_{12} [39]. Therefore, a holistic approach should be considered. Meats have an important role in Turkish cuisine, and meat consumption increased approximately 2.3 times per capita between 1961 and 2019 [40]. It was determined that 78.9% of individuals consumed 15 g or more of meat per day (Table S1). To our knowledge, this is the first study to assess the association between greenhouse gas emission, water footprint, and nutritional adequacy among Turkish individuals. We determined a higher percentage of meeting nutrients among higher GHGEs and total WF tertiles than lower tertiles (Table 4). Individuals in the higher tertile had a higher daily energy intake and higher intakes of most nutrients. Higher daily energy intake may be why other nutrients were also taken in higher quantities. However, carbohydrate (%) was higher in the lowest tertile for GHGEs. This is likely due to the lower consumption of animal-derived foods. Thus, according to the national diet in Turkey, the diet-related environmental factors were positively associated with nutritional adequacy. The percentage of meeting protein and iron were far above the adequacy level for both GHGEs and total WF in the Q3 tertile (Table 4). Considering that the highest contribution to both GHGEs and total WF comes from red meat (Figure 1), reducing red meat consumption may be a good strategy, taking the possible risks (especially anemia) into account. Perignon and colleagues showed that reducing the percentage of protein RDA (from 154% to 141%), along with an adequate intake of other nutrients, could significantly reduce the diet-related environmental factor [41]. The 2500 kcal healthy reference diet published by the EAT–Lancet commission contains 84 g/day (7 g beef and lamb, 7 g pork, 29 g poultries, 13 g egg, and 28 g fish) animal-derived protein in addition to other food groups [6]. Compared to the reference diet, these amounts in the national diet in Turkey were 43.3 g of red meat, 0 g of pork, 25.2 g of poultry, 14.1 g of eggs, and 14.1 g of seafood (Table S3). Pork is not consumed for religious reasons. Bringing high consumption amounts closer to the amounts in the reference diet and changing to more sustainable protein sources (such as nuts and legumes) will make the national diet in Turkey more sustainable. Similarly, increasing the consumption of vegetables, fruits, legumes, nuts, and seeds and limiting the consumption of red meat to a moderate level will both improve the diet quality and reduce the diet-related environmental factors.

Red meat is the most contributing food source for both GHGEs and total WF [25,30,37,42]. The second food source differs according to the country where the research was conducted and may be dairy products [25,30,42], corn products [38], rice, or legumes [37]. In this study, red meat and dairy products were food sources that contributed the most to GHGEs, while red meats and cereals were the ones that contributed the most to total WF (Figure 1). In addition, black tea is a traditional Turkish drink. The daily black tea consumption was 494 mL/person (Table S3), contributing 7.7% to GHGEs and 2.51% to total WF. Considering the high prevalence of anemia in Turkey [9], it may be recommended to drink weak tea to reduce the effect of black tea on the diet-related environmental factors.

Some strengths of our study can expand the literature. The use of the TNHS-2017 as a nationally representative survey, assessment of actual food consumption, and reporting of diet-related environmental factors of the national diet for the first time in Turkey were the strengths of this study.

Our study has several limitations worth noting. First, the data on dietary habits were self-reported, which is assumed to introduce some degree of under-reporting, especially in specific groups of the population defined by weight or gender [43]. Secondly, having limited information on the location of the irrigated areas within the countries, a lack of detailed (sub-national) information on harvesting dates for the different crops and country-specific data, and irrigation water demanding assumptions related to GHGEs and WF calculation databases are all limitations. Tea consumption was recorded as mL in dietary recalls. When calculating the diet-related environmental factors, 5 g of tea per 100 mL of water was taken as a reference. The use of reference values led to the fact that individual consumption differences could not be determined.

5. Conclusions

This study provides the first assessment of diet-related environmental factors (greenhouse gas emission and water footprint components) of the national diet in Turkey and the relationship between low and high diet quality and environmental factors. High-GHGEs diets contained more red meat and dairy products, while high-total-WF diets contained more red meat and cereals in this study. In addition, daily energy and nutrients intake, excluding carbohydrate (%); diet quality index (excluding DQI total, DQI moderation, and DQI overall balance score); and dietary diversity scores were higher for high-GHGEs and high-total-WF diet respondents. In general, the dietary pattern of Turkish society is based on cereals, so the GHGEs and WF of the national diet of Turkey are lower than the world average.

Diet quality and environmental sustainability are linked issues. However, reducing environmental impact should also be considered while improving diet quality. In this study, the highest mean values for GHGEs, green WF, and total WF were determined in the DQI lowest tertile and for blue and grey WF in the middle tertile. However, as dietary diversity increased, it was seen that the diet-related environmental factors increased. Therefore, sustainability should also be considered while planning adequate and balanced diets for a healthy life. Environmental and health sustainability assessments can help policymakers set targets for improving dietary guidelines at the national level. Considering the cultural acceptability included in the definition of sustainable nutrition, future diets should be modeled at a national level in Turkey.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15129768/s1, Table S1: Diet quality index (DQI) and dietary diversity score of individuals; Table S2a: Energy and nutrients intake, RDA (%), DQI, dietary diversity score by GHGEs, and total water footprint tertiles, among 6230 women; Table S2b: Energy and nutrients intake, RDA (%), DQI, dietary diversity score by GHGEs, and total water footprint tertiles, among 6297 men; Table S3: The contribution of foods to greenhouse gas emission and total water footprint values (n = 12,527).

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data sharing is not applicable.

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