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Assessing the Carbon Footprint: Key Principles and Local Case Studies Based on Questionnaire Data

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Abstract

Due to growing concerns about global climate change and the role of carbon emissions as a contributing factor, numerous companies and organizations are initiating "carbon footprint" projects to assess their contributions to global climate change. This study aims to employ a comparative research design to investigate carbon footprint patterns within the Sulaymaniyah city of the Kurdistan Region of Iraq. To achieve this, survey samples were collected from strategically selected urban and rural locations. The questionnaire was structured into four main sections. Demographics, household activities, transportation, and lifestyle choices. Analysis reveals diverse carbon footprints across households, averaging 27.21 units, with transportation emissions at 15.34 units and lifestyle emissions at 54.61 units per household. Nationally, the per capita emissions in Iraq are 22.62 units, with air travel notably contributing 25.32 units. Demographic comparisons between urban and rural regions show clear differences in age, education levels, and occupations, pointing to significant demographic divides. Urban and rural areas differ markedly in environmental impacts; urban areas tend to have lower carbon footprints but higher overall emissions. This variation stems mainly from lifestyle and transportation differences, with urban areas facing unique environmental challenges despite having similar emission levels in certain categories.

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1. Introduction

Many At the start of the twenty-first century, it is evident that human societies exert a more substantial impact on the environment than at any previous point. Historically, our reliance on and interaction with the 'natural' environment has been constant [1]. The modern environmentalist movement, which expanded significantly in the last third of the twentieth century, mirrored widespread concerns among the public and academics about the local and global degradation of the physical environment. This degradation has been increasingly documented by scientists and is the focus of the companion series, Environ-mental Science [2]. There has been a consistent trend of populations moving towards coastal cities, which has put immense pressure on these coastal areas. Furthermore, the greatest challenges to coastal environments may still be forthcoming due to the accelerating rate of global sea-level rise and the intensifying effects of global warming on coastal weather and marine dynamics [3]. It is crucial to maintain a healthy environment, as human existence and fields such as physics, economics, medicine, engineering, and education depend on it [4,5]. Environmental impacts manifest in various forms, including global warming, acidification, the creation of photochemical ozone or smog, eutrophication, and toxicity affecting both humans and animals [6].

Environmental problems are identified as negative impacts on Earth and its ecosystems caused by human activities [7]. While there are natural factors that can cause climate change, it is human actions that have significantly boosted greenhouse gas emissions [8]. Although the issue of climate change has become a common topic recently, it has been progressively unfolding since the Industrial Revolution [9]. This phenomenon impacts all individuals and is noticeable through fluctuating temperatures and the frequency of severe natural events. It also leads to wider issues, such as increasing sea levels and de-creasing biodiversity within our food sources [10]. The issue of human-induced climate change brings up various ethical concerns. Specifically, as highlighted by the United Nations Framework Convention on Climate Change, it prompts critical discussions about fairness and equity [11].

Over the past decade, the reality of human-induced climate change and its profound impacts on Earth's ecological systems have been conclusively validated by respected scientists across the globe [12]. The phenomenon of global warming driven by climate change, particularly the more frequent and severe heat waves, is now linked to various health issues [13]. Adapting to these climate changes is a vital issue confronting humanity, necessitating a reassessment of our lifestyles and involving decisions at individual, societal, and governmental levels [14]. Notably, an increase in the average global temperature by 0.74°C has already been recorded, prompting climate scientists to emphasize the need for im-mediate action to mitigate global warming [15].

The warming of Earth's climate is primarily driven by human activities that release greenhouse gases, especially CO_2, from burning fossil fuels [16]. Other gases like methane, nitrous oxide, and sub-stances that deplete the ozone mostly from non-fossil fuel sources also play a significant role in heating the atmosphere. Many of these gases are shorter-lived than CO_2, and reducing their emissions can quickly impact climate change [17]. Globally, household consumption is responsible for 72% of green-house gas emissions, while government consumption and investments account for 10% and 18%, respectively. Food production contributes 20% to emissions, residential maintenance 19%, and transportation 17% [18]. In developing countries, food and services are major emission sources, whereas in wealthier nations, transportation and manufactured products are more significant. The role of public services and manufactured goods in emissions has been under-recognized in policy discussions, which should ideally vary by a country's economic status and specific characteristics [19].

Rising concerns over global climate change and the role of carbon emissions have prompted numerous companies and organizations to undertake projects to measure their "carbon footprint" and gauge their impact on global warming [20]. While some greenhouse gases are naturally occurring, a significant portion of these emissions result from human activities [21]. A person's carbon footprint is essentially a measure of the greenhouse gases they produce through their daily activities, such as driving and using electricity [22]. The situation becomes critical when our emissions of CO2 exceed what plants can absorb. Key contributors to high carbon dioxide levels include the consumption of electricity, especially from burning fossil fuels like coal, which releases double the CO2 compared to petroleum. Currently, fossil fuels are responsible for 85% of the world's electricity production [23].

A carbon footprint represents the total amount of greenhouse gases, especially carbon dioxide, that are emitted due to specific human activities. This measurement can apply to various scales, from individual or family activities to events, organizations, or even entire countries [24]. The term "carbon footprint" has gained significant traction in public discussions as a way to address individual and collective responsibility for mitigating global climate change [25]. With increasing worries about the effects of global climate change and the role of carbon emissions, numerous corporations and organizations are now evaluating their carbon footprints to understand their impacts on global warming [26]. Tools like carbon footprint calculators help individuals assess and reflect on how their actions affect the environment [27].

Conflicts arise over which gases to include, and the sequence of emissions considered in footprint calculations. Typically, greenhouse gas accounting standards serve as the foundational guidelines for these calculations, though verifying these footprints is not compulsory [28]. Carbon foot printing is de-signed as a method to direct appropriate emissions reductions and verifications, making its standardization at an international level essential. Numerous carbon footprint calculators exist online, most of which employ quantitative models to approximate the carbon emissions generated by an individual's actions [29]. National emissions inventories typically adopt a production-oriented approach, recording only those emissions that are released within a country's borders by industrial and domestic activities. This methodology aligns with the requirements of the United Nations (UN) Framework Convention on Climate Change and adheres to the protocols established by the Intergovernmental Panel on Climate Change (IPCC) [30].

This study adopts a comparative research methodology to examine carbon footprint patterns in Sulaymaniyah, located in the Kurdistan Region of Iraq. Survey data were collected from strategically selected urban and rural areas to ensure a comprehensive analysis. The questionnaire was structured into four main sections: demographics, household characteristics, transportation habits, and lifestyle choices. The primary hypothesis posits that carbon footprints differ significantly between urban and rural set-tings, as inferred from the responses to these categorized questions.

2. Methodology

The researchers in this study examined various key questions to gain insights into carbon emissions in the environment of Sulaymaniyah city in the Kurdish Region of Iraq. Detailed information about the location of the study, the participants involved, the size of the sample, and other relevant de-tails is provided in distinct sub-sections.

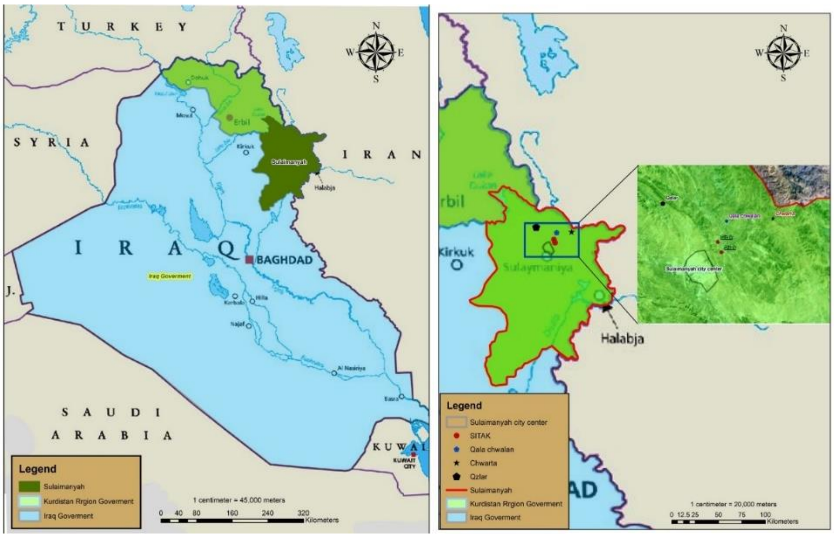
2.1 Study Site and Factors Considered

This study employed a comparative research design to investigate carbon footprint patterns within the Sulaymaniyah region of Iraq. To achieve this, survey samples were collected from strategically selected urban and rural locations.

Sulaymaniyah Province, positioned in northeastern Iraq, stands as one of the primary governorates within the Kurdistan Regional Government [31]. It rests at an elevation of roughly 830 m above sea lev-el and spans across an area of 17,023 km2. Its precise geographic coordinates are noted as 35° 33′ 40″N and 45° 26′ 14″E. The district and its divisions are depicted in Figure 1, highlighting the study's location within Sulaymaniyah Province. Climate-wise, Sulaymaniyah experiences dry and warm conditions during the summer months (June-August) with temperatures averaging 31.5 °C. In contrast, the winter season (December to February) is much colder, with more rain and wind and average temperatures around 7.6 °C. The annual rainfall varies from 400 to 600 mm, starting with occasional storms in October, becoming more frequent in November, and persisting until May [32].

Urban sampling focused on the city of Sulaymaniyah. Data collection targeted educational institutions, this approach aimed to capture diverse transportation habits among students, potentially influenced by socioeconomic disparities. Additionally, general population samples were obtained within the city to broaden the demographic representation. Whenever, rural sampling extends to towns and villages surrounding Sulaymaniyah city. This inclusion was crucial for comparing carbon footprint patterns be-tween populations residing in areas with potentially contrasting lifestyles and infrastructure. This strategic approach will facilitate a nuanced understanding of the factors contributing to regional carbon emissions, providing valuable insights for targeted sustainability initiatives tailored to specific population groups.

For this research, eligibility was limited to individuals living in the city center of Sulaymaniyah and its immediate surroundings within the Kurdistan Region of Iraq. This inclusion criterion was established to ensure that all participants were well-acquainted with the local environmental conditions. Anyone living beyond these specified areas was excluded from participating in the survey.



a) b)

Figure 1. Study site a) Iraq country and Sulaymaniyah City, b) Exact locations of data collection

2.2. Participants and Sample Size Technique

According to recent projections by the International Astronomical Union (IAU-2024), the population of Sulaymaniyah city is around 1.893 million people. A standard formula for calculating sample size was used to select an adequate number of participants for this study, consistent with recognized research methods outlined in scholarly articles [33, 34].

$$n = N/(1 + Nd^2)$$

Where, n = required sample size, N= Population size, d = margin of error which is considered to be 0.05.

$$n = \frac{1893000}{1 + (1893000 * 0.05^2)} = 399.92$$

The initial sample size calculation suggested a need for 400 participants; however, to enhance the accuracy of the results, 598 individuals were ultimately sampled. This research also emphasizes important demographic factors, such as age, due to its relevance to variables like education level, gender, and job type. To reduce bias and promote equitable representation, the selection of participants was deliberately inclusive. A balanced sampling approach was adopted, including individuals from different educational, gender, and professional backgrounds. This strategy ensures a diverse cohort, which helps provide a fuller understanding of the various elements that may affect carbon footprint differences among the population studied.

2.3. Questionnaire Design and Data Collection

This study focused on assessing carbon footprint emissions from urban and rural households and comparing which groups, those in the city center or the surrounding areas, emit more carbon. The main data for calculating the carbon footprint was derived from the United Nations carbon offset platform [35]. Data gathering for this research was carried out through face-to-face interviews with selected participants to capture detailed insights. The collection phase lasted about a month, during which a comprehensive dataset was assembled for subsequent analysis. A group of three to five persons conducted the interviews.

To make the interview process more credible, each session was attended by three to five interviewers. Typically, two interviewers pose questions, and at least one other person records key points from the answers. The team members were proficient in both Arabic and Kurdish, allowing participants to respond in the language they were most comfortable with. All the collected data was promptly recorded in an MS Excel spreadsheet on the day of the interview to maintain data integrity and address any gaps. This prompt recording process enabled the team to revisit any participant the following day to clarify incomplete or unclear responses.

The survey was organized into four main sections. Initially, we gathered demographic information, covering basic details like participants' residence, age, gender, and occupation. This demographic data provided insight into the backgrounds and perspectives of the respondents. The second part focused on household-related inquiries, including living arrangements and energy consumption. Next, we collected transportation data, querying participants on their weekly travel habits, annual private flight usage, and vehicle types. The fourth section delves into lifestyle choices, particularly waste management practices. To facilitate analysis, participants were categorized into generational groups—X, Y, Z, and Alpha—based on age trends. Before commencing the survey, experts scrutinized the questionnaire to ensure its coherence and relevance. This preparatory step was crucial in streamlining data collection and bolstering the credibility of the results.

2.4. Ethical Considerations

Maintaining ethical standards in research involves safeguarding participant confidentiality and honoring their autonomy. A key aspect of ethical research entails ensuring the confidentiality of participant data. In our study, we implemented various measures to achieve this. Firstly, we ensured complete anonymity of participant information, with no links between the data and individuals, thus preventing any identification of specific responses. This anonymity was upheld even in face-to-face surveys, where collected forms were thoroughly randomized before retrieval, further safeguarding participant privacy.

Equally important is obtaining informed consent from participants, ensuring they comprehend the study's nature and participate willingly. Each participant was explicitly asked for their consent, with a direct inquiry such as "Do you wish to take part in this survey?" Participation was entirely voluntary, and no coercion or pressure was applied to any participant. By prioritizing confidentiality, data privacy, and informed consent, we ensured that our research adhered to ethical principles and respected the rights of our participants.

2.5. Statistical Analysis

The study employed descriptive statistical analysis to summarize the outcomes, providing mean and standard deviation for variables with continuous distributions, along with maximum and minimum values. Categorical variables were presented with counts and percentages. Hypotheses regarding differences among categorical variables were evaluated using the chi-square test. The normal distribution assumption was confirmed using the Shapiro–Wilk and Kolmogorov–Smirnov tests [36]. We assessed the difference between two independent groups using the Mann-Whitney U test for variables that were not normally distributed. Statistical significance was determined with a threshold of a p-value less than or equal to 0.05. A p-value of 0.05 or lower was considered statistically significant in all tests. Box plots were used to visualize differences among two different groups. The analysis was conducted using version 27.0 of the SPSS program for Windows.

3. Results

3.1. Demographic

In this section, we illustrate the outcomes derived from the current study along with their interpretations. Table 1 provides a comprehensive overview of the dataset, revealing that out of the 598 recorded patients, 293 are male and 305 are female. The age distribution shows that the majority, 276 cases, fall within the 12-27 year range, followed by 162 cases in the 28-43 year range, and only 5 cases are over 79 years old. College completion makes up the biggest percentage of respondents 43.1%, followed by secondary school completion 7.2%, and high school completion 16.9%.

Table 1. Demographic Characteristics of Study Participants

Variables	Class	Frequency	Percent
Place	Inside Sulaymaniyah (Urban)	299	50
	Outside Sulaymaniyah (Rural)	299	50
Gender	Male	293	49
	Female	305	51
Age	12-27	276	46.2
	28-43	162	27.1
	44-59	95	15.9
	60-69	47	7.9
	70-78	13	2.2
	79-96	5	0.8
Education	Illiterate	24	4
	Read and write	42	7
	Primary School	42	7
	Secondary School	43	7.2
	High school	101	16.9
	College	258	43.1
	Master	43	7.2
	PhD	29	4.8
	Other	16	2.7
Work	Student	232	38.8
	Teacher	47	7.9
	Worker	55	9.2
	Engineer	34	5.7
	Doctor	20	3.3
	Employee	13	2.2
	Other	197	32.9
Capita per Household	1	6	1
	2	18	3
	3	86	14.4
	4	160	26.8
	5	183	30.6
	6	91	15.2
	7	27	4.5
	8	15	2.5
	9	4	0.7
	10	5	0.8
	11	3	0.5
Total		**598**	**100**

A substantial proportion of participants possess a primary education or are literate (able to read and write), accounting for 7% of the sample. Relatively fewer respondents 4% are illiterate, and fewer 4.8% have advanced degrees, such as a master's or a doctorate. The majority of respondents' occupations 38.8% are students, showing a sizable proportion of younger people in the sample. Though to a lesser degree, occupations including teaching 7.9%, engineering 5.7%, and healthcare 3.3% are also represented. Five people made up the bulk of respondents 30.6%, followed by four people 26.8% and six persons 15.2%. Larger households 7–11 capita are comparatively underrepresented in the sample, while smaller households 1-3 capita are less prevalent.

3.2. Descriptive statistics of continuous variables

Table 2 presents descriptive statistics for continuous variables. It appears that the variables provided do indeed represent carbon footprint measurements; the data shows a wide range of carbon footprints per household, with an average of approximately 27.21 units, indicating variations in the environmental impact of different households, most likely influenced by factors such as household size, energy consumption, and lifestyle preferences. The average emissions from transportation are roughly 15.34 units. This covers emissions from vehicles such as cars, motorbikes, and public transportation, emphasizing the role of mobility in the overall carbon footprint. The average emissions from lifestyle choices, such as energy usage, food preferences, and trash generation, are around 54.61 units per family. This category captures the overall effect of everyday activities on carbon emissions [37]. The average emissions per capita in Iraq are 22.62 units, and the figures on flight emissions show the carbon footprint connected with air travel per family, with an average of around 25.32 units.

Table 2. Descriptive statistics of continuous variables

Variables	N	Minimum	Maximum	Mean	SD
Household	598	4	73	27.207	6.077
Transport	598	2	37	15.341	6.782
Lifestyle	598	8	74	54.607	9.022
Total annual emissions	598	4	141	29.642	12.988
Iraq country average	598	5	53	22.619	7.339
World average	598	5	51	22.0351	6.986
Flight	69	6	86	25.320	18.692

3.3. Demographic Characteristics Distributions by Place

Table 3 purports to contain cross-tabulations and chi-square test results for various demographic factors by location. Each cell reflects the frequency and percentage of people who fall into distinct categories for each demographic category. The distribution of males and females is similar in urban and rural areas, with a p-value of 0.683 suggesting no significant difference in gender distribution between sites. The age distribution is significantly different between urban and rural areas (p-value < 0.001). Urban areas have a higher number of young people 12-27 years old [38, 39], whereas rural areas have a higher proportion of elderly people 44 years and older. Urban and rural areas have significantly different educational attainment rates (p-value < 0.001). Urban areas have a higher proportion of people with higher education levels (college, master's, and PhD), while rural areas have a higher proportion of people with lower education levels (illiteracy, reading and writing, primary school). Employment status is significantly different between urban and rural areas (p-value < 0.001). Urban areas have a higher proportion of students and professionals (engineers and doctors), while rural areas have a higher proportion of employees and teachers. Home sizes are distributed similarly in urban and rural areas, with no significant variation in the number of individuals per home between places (p-value = 0.544). Overall, the findings indicate significant demographic differences between urban and rural areas, particularly in terms of age, education, and occupation.

3.4. Test of Normality for Continues Variables.

Table 4 presents the outcomes of the normality tests applied to the continuous variables in our study, utilizing the Kolmogorov-Smirnov and Shapiro-Wilk tests as methods of analysis. For all the continuous variables assessed, the p-values obtained from both the Kolmogorov-Smirnov and Shapiro-Wilk tests were found to be less than the designated significance threshold of alpha = 0.05. Given these results, we conclude that the p-values are sufficiently small to lead us to reject the null hypothesis, which states that the variables are normally distributed (H_0: the variable is distributed normally). This indicates that the assumption of a normal distribution does not hold for these variables. The rejection of the null hypothesis implies that the distribution of these variables is skewed or deviates significantly from what would be expected under normal conditions. Thus, the data suggests that these variables exhibit non-normal distributions.

Table 3. Demographic Characteristics Distributions by Place

Variables	Class	Place		Total	P-value*
		Inside Sulaymaniyah (Urban)	Outside Sulaymaniyah (Rural)		
Gender	Male	144(48.2%)	149(49.8%)	293(49%)	0.683
	Female	155(51.8%)	150(50.2%)	305(51%)	
Age	12-27	190(63.5%)	86(28.8%)	276(46.2%)	<0.001
	28-43	70(23.4%)	92(30.8%)	162(27.1%)	
	44-59	26(8.7%)	69(23.1%)	95(15.9%)	
	60-69	10(3.3%)	37(12.4%)	47(7.9%)	
	70-78	2(0.7%)	11(3.7%)	13(2.2%)	
	79-96	1(0.3%)	4(1.3%)	5(0.8%)	
EDU	Illiterate	2(0.7%)	22(7.4%)	24(4%)	<0.001
	Read and write	6(2%)	36(12%)	42(7%)	
	Primary school	6(2%)	36(12%)	42(7%)	
	Secondary school	10(3.3%)	33(11%)	43(7.2%)	
	High school	57(19.1%)	44(14.7%)	101(16.9%)	
	College	173(57.9%)	85(28.4%)	258(43.1%)	
	Master	19(6.4%)	24(8%)	43(7.2%)	
	PhD	14(4.7%)	15(5%)	29(4.8%)	
	Other	12(4%)	4(1.3%)	16(2.7%)	
Work	Student	154(51.5%)	78(26.1%)	232(38.8%)	<0.001
	Teacher	15(5%)	32(10.7%)	47(7.9%)	
	Worker	6(2%)	49(16.4%)	55(9.2%)	
	Engineer	17(5.7%)	17(5.7%)	34(5.7%)	
	Doctor	10(3.3%)	10(3.3%)	20(3.3%)	
	Employee	1(0.3%)	12(4%)	13(2.2%)	
	Other	96(32.1%)	101(33.8%)	197(32.9%)	
People	1	3(1%)	3(1%)	6(1%)	0.544
	2	7(2.3%)	11(3.7%)	18(3%)	
	3	43(14.4%)	43(14.4%)	86(14.4%)	
	4	83(27.8%)	77(25.8%)	160(26.8%)	
	5	94(31.4%)	89(29.8%)	183(30.6%)	
	6	50(16.7%)	41(13.7%)	91(15.2%)	
	7	9(3%)	18(6%)	27(4.5%)	
	8	6(2%)	9(3%)	15(2.5%)	
	9	1(0.3%)	3(1%)	4(0.7%)	
	10	1(0.3%)	4(1.3%)	5(0.8%)	
	11	2(0.7%)	1(0.3%)	3(0.5%)	
Total		**299(100%)**	**299(100%)**	**598(100%)**	

*: Chi-square test

Table 4. Test of Normality for Continues Variables.

Variables	Place	Kolmogorov-Smirnova			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	Df	Sig.
Household	Urban	0.088	299	<0.001	0.905	299	<0.001
	Rural	0.086	299	<0.001	0.969	299	<0.001
Transport	Urban	0.069	299	0.002	0.98	299	<0.001
	Rural	0.062	299	0.008	0.976	299	<0.001
Lifestyle	Urban	0.086	299	<0.001	0.943	299	<0.001
	Rural	0.104	299	<0.001	0.915	299	<0.001
Total Annual Emissions	Urban	0.164	299	<0.001	0.703	299	<0.001
	Rural	0.127	299	<0.001	0.798	299	<0.001
Iraq Country Average	Urban	0.181	299	<0.001	0.916	299	<0.001
	Rural	0.189	299	<0.001	0.934	299	<0.001
World Average	Urban	0.201	299	<0.001	0.909	299	<0.001
	Rural	0.208	299	<0.001	0.928	299	<0.001
Flight	Urban	0.25	38	<0.001	0.745	38	<0.001
	Rural	0.235	31	<0.001	0.848	31	<0.001

3.5. Test for difference of continuous variables across different locations

Table 5 and Boxplots give and display statistical analysis results for various variables classified by location (within Sulaymaniyah-urban vs. outside Sulaymaniyah-rural). These findings shed light on the disparities in carbon footprints and emissions between urban and rural locations. Urban households had a substantially smaller mean carbon footprint 26.2609 than rural households 28.1538, with a p-value < 0.001, indicating statistical significance. The standard deviation (SD) for urban families is 6.14196, and for rural households, it is 5.87193. There is a statistically significant difference in mean transportation emissions between urban 15.8294 and rural areas 14.8528, with a p-value of 0.032. However, the difference in means is modest, and the SDs are comparable. The average lifestyle emissions in urban regions are somewhat higher 55.1003 than in rural areas 54.1137, but the difference is not statistically significant (p-value = 0.196). The SDs for urban and rural areas are fairly similar. Urban households had significantly higher mean total annual emissions 31.3846 than rural households 27.8997, (p-value < 0.001). The SD for urban households is greater at 14.02572 than for rural ones at 11.62342. There is no statistically significant difference in mean emissions compared to the national average between urban 22.3445 and rural 22.893, with a p-value of 0.589. Similarly, there is no statistically significant difference in mean emissions compared to the global average between urban 21.7726 and rural areas 22.2977, with a p-value of 0.554. There is no statistically significant difference in mean flight emissions between cities 22.89 and rural areas 28.29, with a p-value of 0.443. However, average flight emissions are higher in rural areas, and there is significant fluctuation, as evidenced by the larger SD, 21.203 compared to urban areas 16.254. Overall findings indicate that in a comparison between urban and rural location, the urban areas generally showing lower carbon footprints but higher total emissions. The data suggests significant location-based differences in environmental impacts, mainly due to variations in lifestyle and transportation habits. Although some emission categories show comparable averages, the profound distinctions underline unique ecological challenges faced by each sector.

Table 5. Test for difference of continuous variables across different locations

Variables	**Place**	**N**	**Mean**	**SD**	**Min**	**Max**	**P-value***
	Urban	299	26.2609	6.14196	7	73	
Household	Rural	299	28.1538	5.87193	4	45	<0.001
	Total	598	27.2074	6.07771	4	73	
	Urban	299	15.8294	6.74271	3	37	
Transport	Rural	299	14.8528	6.79704	2	37	0.032
	Total	598	15.3411	6.78189	2	37	
	Urban	299	55.1003	8.97255	9	74	
Lifestyle	Rural	299	54.1137	9.05874	8	71	0.196
	Total	598	54.607	9.02172	8	74	
	Urban	299	31.3846	14.02572	5	141	
Total annual emissions	Rural	299	27.8997	11.62342	4	116	<0.001
	Total	598	29.6421	12.98752	4	141	
	Urban	299	22.3445	6.85554	5	53	
Iraq country avg.	Rural	299	22.893	7.79532	5	53	0.589
	Total	598	22.6187	7.33947	5	53	
	Urban	299	21.7726	6.49381	5	51	
World avg.	Rural	299	22.2977	7.44702	5	51	0.554
	Total	598	22.0351	6.98578	5	51	
	Urban	38	22.89	16.254	9	78	
Flight	Rural	31	28.29	21.203	6	86	0.443
	Total	69	25.32	18.692	6	86	

*: Mann-Whitney U test

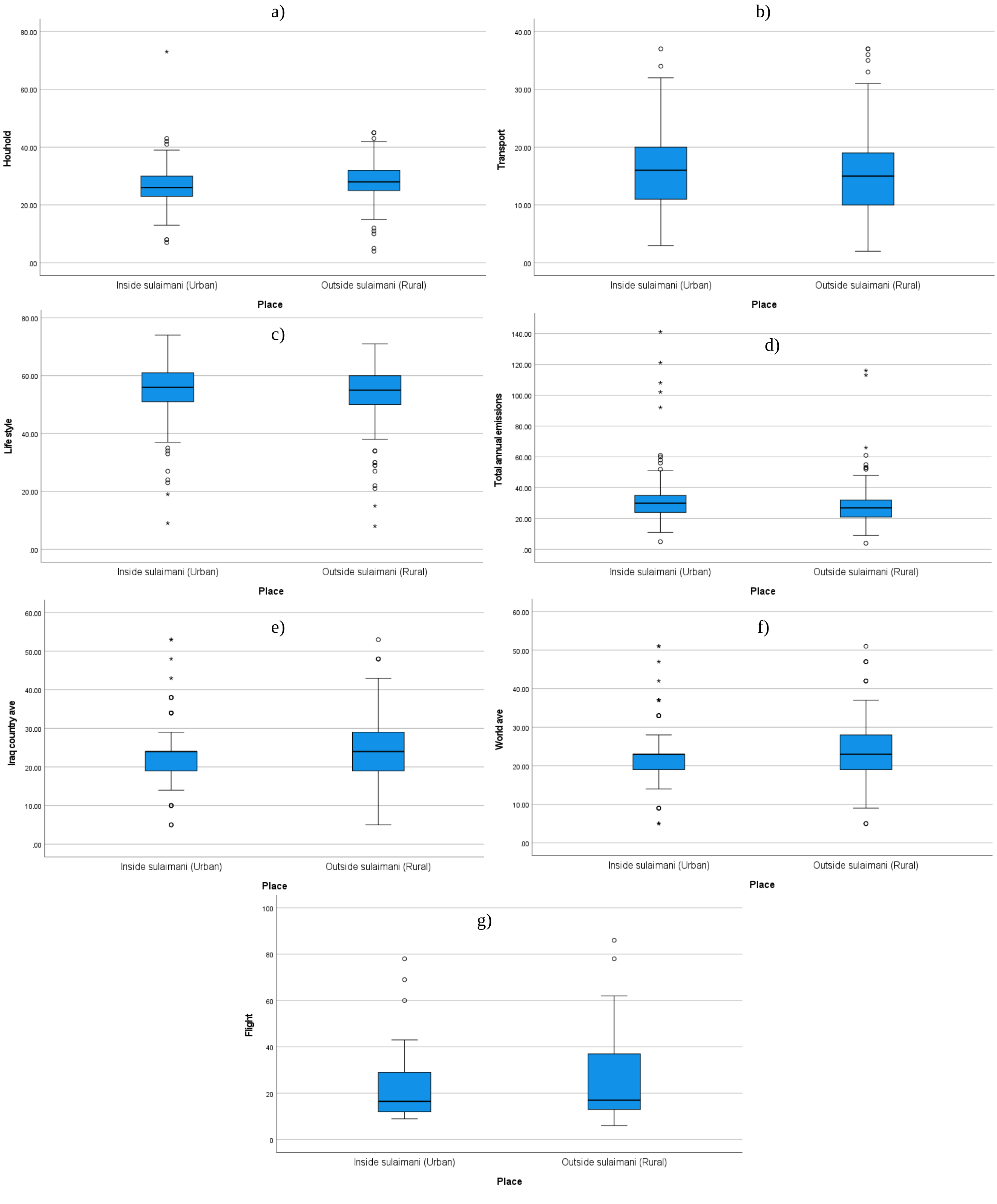


Figure 2. Comparison of urban and rural area for a) households, b) transportation, c) lifestyle, d) total annual emission, e) Iraq country average, f) world average, g) flight.

In almost all case scenarios, urban areas had a higher carbon footprint than rural areas, but the difference was not significantly different from each other. This can be explained by the fact that, due to globalization, rural areas now have almost the same technology access as urban areas, and their only difference may be in the amount of those means. Another reason may be the interlinkages between rural and urban areas. In other words, rural areas are aware of the lifestyle of urban areas, and they also have access, so the gap between urban and rural areas decreases. In terms of total annual emissions across areas, it's quite visible that urban emissions are higher than rural ones. A possible explanation can be the higher number of transportations means, more waste, and pollution in urban areas, as shown in the Figures 2a-g.

In the comparison between Sulaymaniyah, and other places in Iraq, we can see that the carbon footprint of Sulaymaniyah is slightly lower. The same result can be detected within the comparison with the rest of the world. A possible explanation in terms of air travel is maybe a lack of using air travel more frequently and making it less accessible due to the economic crisis in the region.

4. Conclusion

This study employed a comparative research design to investigate carbon footprint patterns within the Sulaymaniyah region of Iraq. To achieve this, survey samples were collected from strategically selected urban areas. The distribution of males and females is similar in urban and rural areas, with a p-value of 0.683 suggesting no significant difference in gender distribution between sites. The age distribution is significantly different between urban and rural areas (p-value < 0.001). Urban areas have a higher number of young people 12-27 years old, whereas rural areas have a higher proportion of elderly people 44 years and up. Overall, the findings indicate significant demographic differences between urban and rural areas, particularly in terms of age, education, and occupation. Analysis reveals a varied range of carbon footprints across households, with an overall average of 27.21 units. Specifically, transportation emissions average 15.34 units, while lifestyle emissions which include energy consumption, dietary choices, and waste production average 54.61 units per household. Across Iraq, the average per capita emission stands at 22.62 units, complemented by data on air travel emissions, which average 25.32 units per household, highlighting the carbon impact of flying. Urban households had a substantially smaller mean carbon footprint 26.2609 than rural households 28.1538, with a p-value < 0.001, indicating statistical significance.

Demographic analysis shows distinct differences in age, education, and occupations between urban and rural areas, underscoring significant disparities. Urban regions tend to have smaller carbon footprints but higher overall emissions, mainly due to lifestyle and transportation choices. Despite some emission similarities, urban areas face unique environmental challenges.

To create a carbon management hierarchy in the study area, start by identifying high-emission sectors from the carbon footprint data, such as transportation, construction, and administration. Implement targeted strategies such as enhancing public transport, promoting green building standards, and optimizing energy use in public buildings. Encourage sectors to collaborate and share best practices, while continuously monitoring the effectiveness of these strategies to ensure they effectively reduce emissions based on the study's insights.

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