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Article

Greenhouse gas emissions of animal-based and plant-based products in Iran

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ABSTRACT

These days, one of the major threats in the world is climate change. It is already proven by a large number of strong evidence that human activities are responsible for these sudden changes. It is expected that in the future mankind will witness more severe consequences of climate change on the amount of precipitation and temperature levels in different regions of the world, and as a result of that, more both physical and economic water scarcity is anticipated to be seen. Each year food production industry produces a considerable amount of greenhouse gases which are the number one factor for global warming. By fluctuations in the groundwater, surface water, CO_2 fertilization, and extreme weather conditions such as floods and droughts, a drastic impact on agricultural practices is expected to occur in Iran if the current trends are not slowed down or reversed. Any disturbance in food security and quality could lead to malnutrition, food-borne illnesses, or even death. Crop cultivation and livestock have their own unique impact on the total emitted GHGs. Given this, in this study, we analyzed the food production (both animal-based and plant-based), consumption, and global warming potential (CO_2e) of 11 main dietary categories in the Iranian food industry from 2010 to 2019. Moreover, the population growth in the decade was included in the study. The results of this article revealed that vegetable consumption faced a downward trend in the decade while animal protein sources remained almost intact and animal-based food items produce a considerably higher amount of greenhouse gases than plant-based dietary options.

1. Introduction

The definition of climate change refers to the alterations in climate patterns caused by certain factors. Mainly, there are two types of factors involved in changing the climate. The first group is natural systems such as earthquakes, wildfires, and volcanoes. The other group is anthropogenic emissions which are caused by human activities. By accumulating more and more GHG (greenhouse gases) in the atmosphere, the earth's surface becomes warmer ultimately affecting the world's climate and leading to the phenomena we know as climate "change". There are already well-appointed documents that the majority of recorded warming over the half of the previous century can be directly linked to what human have done and their activities [1]. It is expected that in the future mankind will witness more severe consequences of climate change on the amount of precipitation and temperature levels in different regions of the world, and as a result of that, more both physical and economic water scarcity is anticipated to be seen [2]. According to the estimations, it is expected that the carbon dioxide concentration becomes double in comparison with the current emissions. It is also expected that the mean temperature in Iran goes up between 1.5°C to 4.5°C. In case of these trends, there will be drastic alterations in the aquatic resources, agricultural sector, food supply, and forest preservation and put further stress on the current environmental issues [3]. Given this, it is important for Iran to focus on climate change adaptations. The agricultural sector is the largest water consumer in Iran, and this fact makes this industry more prone to the consequences of climate change [4]. Due to the currently imposed sanctions, Iran has done limited actions towards decreasing the greenhouse gas emission levels. The country aimed for a 4% greenhouse gas emissions drop by 2030. It is projected that most of these changes would occur through shifting from fossil fuels to renewable energy sources. However, Iran heavily depends on international technological and financial support [5]. It is predicted that illness and injuries related to extreme heat exposure to rise in the upcoming decade in Iran. Symptoms such as heat cramps, sunburn, heat exhaustion, and frequent dehydration are only some of the heat-related diseases that would happen more frequently due to global warming in Iran. It is also predicted that with the current emission levels, by 2080, the heat-related death rates would be around 70 cases per every 100000 individuals older than 65. On the other hand, under a modeled scenario in which the emission levels dropped drastically, the heat-related death rates showed a decline as low as below 20 cases per every 100000 people over 65 years old [6]. Although there are still some arguments and debates regarding the impact of climate change on agriculture, there is also some relative agreement that the country's agricultural industry will be heavily affected by climate change [7]. By fluctuations in the groundwater, surface water, CO_2 fertilization, and extreme weather conditions such as floods and droughts, a drastic impact on agricultural practices is expected to occur in Iran if the current trends are not slowed down or reversed. Plus, a significant increase in population in Iran is linked to the lack of access to productive farming lands and water resources for the food production system [8]. Therefore, there is uncertainty about the Iranian farmers' economic well-being as well as the potential threats to sustainability in Iran. To ensure sustainable development of the Iranian agricultural sector, evaluating the effects of climate change on this industry and taking appropriate adaptations and mitigations are crucial [9].

Any disturbance in food security and quality could lead to malnutrition, food-borne illnesses, or even death. Since climate change directly affects the food security in Iran, the national dietary patterns are prone to forced changes, which could cause higher rates of metabolic disorders as well as changes in lifestyle most of which are not negative changes. Global warming, which is the leading consequence of climate change, increases the possibility of food spoilage, either in issues of providing the adequate energy for proper storage or damaging the necessary infrastructure of food production at the right time. In other words, water scarcity, higher temperatures, and more frequent droughts and storms would cause fundamental damage to food production in the country. Currently, food security in Iran is facing severe issues regarding adequate water resources, the lack of access to state-of-the-art technologies in the agriculture sector, and the old-fashioned mindset of the majority of Iranian farmers who are reluctant to follow more environment-friendly approaches to their farming strategies. It is anticipated that climate change would put even further stress on these currently existing issues and turn food security into an alarming national concern [9]. More frequent storms can result in desertification and a noticeable reduction in the quality of farmlands by worsening several factors together, such as groundwater level reduction or soil degradation. Reducing the overall emitted greenhouse gas levels could affectively prevent or decrease the intensity of such a situation from occurring [10]. One of the ways to control climate change is to make food demand more sustainable by improving the dietary habits of people. In recent years, Iranian diets have shifted from the so-called traditional diet to the western diet. Population growth, economic development, moving to cities, and social media were the main factors behind this shift. These dietary patterns have been linked with health problems, especially obesity and overweight, which could lead to a greater risk of chronic conditions and shorten the expectancy of life [11]. Besides the serious dangers for public health, a rising concern has been lately drawn to the impact of dietary patterns on greenhouse gas emissions. On a worldwide scale, alterations in dietary choices and a stronger tendency to meat and processed products consumption are likely to maximize the greenhouse gas emissions linked to the food supply by more than 80% in the year 2050 [12]. On the other side of the spectrum, a shift from the current common patterns to a more plant-based friendly diet could likely minimize the related greenhouse gas emissions by nearly 50% [13]. Given this, studying the global warming potential is of great importance. In this article, by utilizing the data of different groups of food products in Iran, the greenhouse gas emissions of main food sources consumed in Iran from 2010to 2019 are evaluated.

2. Literature Review

To this date, there are not many articles evaluating the total greenhouse gas emissions of crops and livestock production in Iran. The vast majority of such studies mainly focused on the limited number of agricultural items and less on the agricultural sector of the country as a whole. However, on a global scale, there are several articles that analyze the food supply in larger groups. In this section, both previous national and international literature have been reviewed. In a study in 2015 in the North of Iran, the researchers found an inverse relationship between the size of the farms and the amount of emitted greenhouse gases, meaning that larger farmlands tend to produce less GHGs during agricultural activities [14]. Moslem et al. [15], carried out research on greenhouse gas emissions and energy in corn and wheat production in a couple of farmlands in the south of Iran. They concluded that wheat production is completely more justifiable in terms of greenhouse gas emissions and the energy involved. The overall energy consumed for the corn farm was roughly 92000 MJ which emitted almost 20000 kg CO_2 equivalent per 10000 square meters. In contrast, for wheat production on the other farmland, the overall consumed energy was nearly 39000 MJ with a total emission of 7000 kg CO_2 equivalent per square meter.

Moreover, manure, power for vehicles, and electricity were the most highlighted factors responsible for the greenhouse gas emission levels and overall energy consumption [15]. In broader research by Emadodin et al., the causes of soil degradation in Iran were evaluated. The findings of the research indicated that soil degradation due to human activities are more visible in Iran than natural degradation, and the management of natural resources plays a major role in soil degradation. Furthermore, the urban population in Iran grew by 70% from the 1930s to the 2010s, which was followed by the deforestation of well over 5 million hectares of woodland and giving its place to farmlands. During this period, the cultivation rate increased by four times, and the farm animal population was three times higher than the grazing capacity of the country [16]. In another study that was focused on soybean cultivation in Iran, it was concluded that declined output levels lead to a decrease in water, and the use of fertilization can also decrease the greenhouse gases emissions and also to lower the GHGs levels produced by the crops, the residue must not be burned on the farmlands [17]. In a different study, several scenarios and different models of rice cultivation were analyzed and it was discovered that utilization of organic fertilizer as well as replacing the older methods with more recent methods (conservation tillage) has a significant impact on minimizing the emission of GHGs [18]. Ghorbani et al. [19], also discovered that monitoring the use of fertilizers could play a major part in greenhouse gas emissions and identified Khuzestan province as the number of the province on the list of largest emitters of Iran [19]. Regarding other countries, a study in India was conducted to evaluate the greenhouse gas and water footprint of Indian dietary patterns. The data of this research was collected from questionnaires that were filled out by Indian immigrants in the North of India. The study showed that the patterns that were higher in rice and meat consumption also had higher GHG emissions than wheat and fruit center diets [20]. Another study analyzed the current food consumption and loss among Spanish citizens and compared it with Mediterranean and Spanish dietary guidelines. The study revealed that in case of a shift from the current diet to NAOS (a diet recommended by Spanish Dietary Guidelines) and the Mediterranean, 17% and 11% reduction in greenhouse gas emissions related to food production would occur. This reduction could be even more significant if nutritional values and priorities are met through these transfers. On the other hand, the contribution of food losses to this sector's total emissions was 21% [21]. A study in France evaluated the GHG of self-selected individual diets. The findings showed that when the total caloric intake is decreased to meet the person's energy needs and not exceed the necessary caloric intake, the greenhouse gas emissions of diets will fall between 10.7% and 2.4%. This variation depends on the physical activity levels of the nation. The meat and processed meat food groups occupied the largest share of GHG emissions. However, in this study, the scenarios which were designed to evaluate the meat replacement showed limited improvement in total GHG emissions [22].

Another study focused on the shifting from the current average United States diet to four substitute diets inside the 2010 Dietary Guidelines for Americans (DGA). They found that an omnivore diet (containing both animal and plant sources) that meets the requirements of DGA while in contrast with cost leaves the food-related greenhouse emissions almost unchanged compared to the current diet. That is two other diets (DGA compatible vegetarian diet and DGA omnivore diet also decrease the consumption of energy in the food production sector, and minimize the greenhouse emissions by 32% and 23%, respectively. The majority of these reductions were due to the alternations in quantity and composition in meat, fish, poultry, dairy products, and sugarcanes [23]. A study in China found the links between dietary patterns and greenhouse gas emissions. The study found that supplying food from other countries to China has a very modest impact on China's food-associated emissions. The increasing demand for meat and dairy products is very highlighted in the increase in emissions. The significant food demand in China indicates people's role in increasing the GHG levels. The analysis of the results indicated that food demand in China doubled from 1989 to 2009. Despite this sudden drastic increase, due to the technological improvements and the efficiency of the food sector, the emission levels were limited [24].

3. Methodology

The aim of this research was to evaluate the global warming potential for the food production sector in Iran. For this purpose, both the agricultural sector and livestock industry were included in this evaluation. The dietary data used in this paper is extracted from the Food and Agriculture Organization of the United Nations (FAOSTAT)'s Food Balance Sheets (FBS) [25]. The data dietary data include the entire last decade, which is from 2010 to 2019. Moreover, to follow the population trend and find its possible relation with food production and food consumption, the annual population of the decade was considered as well.

The data related to greenhouse gas emissions were collected from the Our World in Data database. The global warming potential data which include Carbon dioxide (CO_2), Methane (CH_4), and Nitrous oxide (N_2O) were also collected from the same source [26].

$$CO_{2e} = \underline{1} * CO_2 + \underline{25} * CH_4 + \underline{298} * N_2O \quad (1)$$

Each one of the underlined numbers is the Global Warming Potential (GWP) of that gas.

4. Results and Discussion

Figure 1 indicates the growth of the population from 2010 to 2019. As shown in the figure, the population increased by almost 10 million at the end of the decade. As a result, the consumption rates in some groups increased as well. The baseline population in 2010 was roughly 73 million, while at the end of the decade, in 2019, the population grew to nearly 83 million.

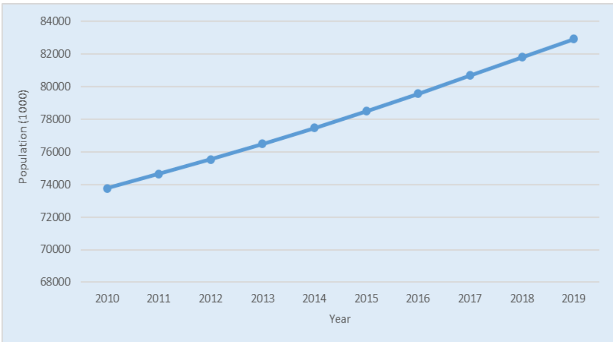

Figure 1. The population of Iran from 2010-2019 (1000)

Figure 2 demonstrates the CO_2e per kilogram for each food group. Simply put, the amount of greenhouse gases emitted for producing one kilogram of each food category. From the highest to the lowest: CO_2 equivalent of bovine meat (99.48 kgCO_2eq), mutton and goat meat (39.72 kgco2eq), poultry meat (9.87 kgCO_2eq), eggs (4.67 kgCO_2eq), rice and products (4.45 kgCO_2eq), sugar cane (3.2 kgCO_2eq), soybeans (3.16 kgCO_2eq), milk-excluding butter (3.15 kgCO_2eq), wheat and products (1.57 kgCO_2eq), vegetables (0.53 kgCO_2eq), citrus fruits (0.39 kgCO_2eq). What stands out the most is that animal source production, especially red met categories, considerably releases more greenhouse gases than cropping.

In Table 1 (Appendix) the data for the annual consumption per capita rate of each dietary category is listed, along with the annual population and CO_2 equivalent of the categories. In total, wheat and its products were the most consumed item among the analyzed dietary categories. Although vegetable consumption witnessed a significant drop, it was the second overall most consumed item on the list. The consumption of rice and products remained fairly steady during the decade. Among animal-based sources, poultry and milk-excluding butter had the highest consumption rate, while mutton and goat meat was the least consumed in this category.

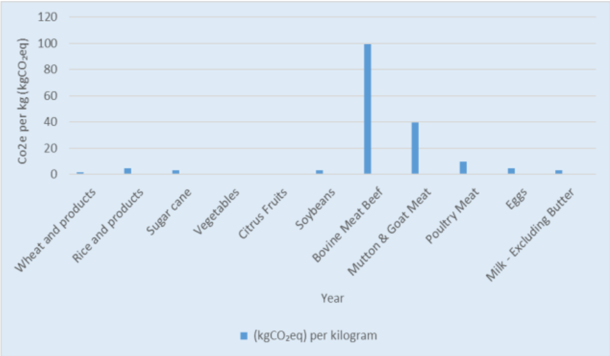

Figure 2. Carbon dioxide equivalents ($kgCO_2eq$) per kilogram for food groups

Table 2 (Appendix) indicates the final evaluation of GHG emissions related to the 11 selected food items. Bovine meat with 514.142 (100 tons) emitted the largest amount of greenhouse gas among all the other items. After bovine, poultry meat with 201.513 (1000 ton) gas placed as the second-largest emitter on the list. Wheat and products produced the highest amount of GHGs among plant-based items and were the third-largest emitter with a total of 186.446 (1000 ton) released gas. Mutton and goat meat, rice, and products released almost the same amount of greenhouse gases, 147.009 (1000 tons) and 144.532 (1000 tons), respectively. Moreover, milk-excluding butter 53.186 (1000 tons), vegetables 44.026 (1000 tons), and eggs 33.723 (1000 tons) emitted greenhouse gases. On the other hand, producing sugar cane, soybeans, and citrus fruits emitted the least GHGs amount with a total of 25.118 (1000 tons), 15.869 (1000 tons), and 11.573 (1000 tons), respectively.

5. Conclusion

Based on the findings of this research, it can be concluded that Iranian people's dietary patterns are changing since the vegetable consumption trend faced a significant downward trend during the decade, and fruit consumption also witnessed a decrease in the last decade. On the other hand, the consumption of animal-based protein sources remained fairly stable with some fluctuations. Poultry meat consumption, however, increased in the studied time period. These trend lines could be a good indicator of a swift shift from the traditional dietary patterns toward the western dietary pattern. Regarding greenhouse gas emissions, the livestock industry has the most significant pressure on the country's total GHG emission levels. Given the noticeable population growth in the country, which the government's current policies support, it is expected that in the future, the food demand will increase which undoubtedly, requires a higher food supply and could lead to higher food production since the overwhelming percentage of Iran's food supply is produced in the country. One solution to minimize the environmental impact of food production is to decrease the animal-based proteins and replace them with other suitable alternatives, such as soybean, which has almost the same nutrient values but considerably lower greenhouse gas levels as evaluated in this research. The second solution for lowering the greenhouse gas levels is to import some of these high emitters instead of producing them in the country.

Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere in any language.

Data availability statement

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Conflict of interest

The authors declare no potential conflict of interest.

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Appendix

Table 1. Population 2010-2019 (1000), Co2eq per kilogram of food groups (kgCO_2eq), and annual consumption per capita (kilogram)

Population	PRODUCTS	Wheat and products	Rice and products	Sugar cane	Vegetables	Citrus Fruits	Soybeans	Bovine Meat Beef	Mutton & Goat Meat	Poultry Meat	Eggs	Milk - Excluding Butter
	(kgCO_2eq) per kilogram	1.57	4.45	3.2	0.53	0.39	3.16	99.48	39.72	9.87	4.67	3.15
73763	2010	150.63	43.14	10.54	130.77	43.06	5.54	7.46	5.35	22.81	9.39	23.66
74635	2011	139.5	38.29	10.86	129.57	45	6.53	6.88	5.34	24.56	9.05	22.75
75540	2012	145.93	39.28	9.86	128.42	44.39	6.33	5.85	5.04	24.99	11.24	22.91
76482	2013	142.23	45.25	17.26	142.3	45.63	6.73	6	4.92	25.7	10.87	25
77466	2014	155.66	41.25	10.09	124.32	33.87	6.53	5.78	5.18	26.98	9.63	23.02
78492	2015	158.48	40.95	3.06	111.94	32.17	6.48	6.36	4.44	26.54	9.01	17.63
79564	2016	158.42	42.25	4.59	106.95	29.87	6.69	6.96	4.79	28.27	9.27	18.04
80674	2017	156.62	42.55	13.56	67.08	31.26	6.31	7.47	4.83	27.14	7.6	20.47
81800	2018	154.81	42.38	9.69	62.09	36.85	6.7	6.61	4.24	26.82	8.29	19.78
82914	2019	155.95	40.29	11.13	69.35	39	6.38	6.75	3.42	27.04	8.33	23.24

Table 2. Carbon dioxide equivalents (kgCO_2eq) of product production (1000 tons)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	**Total**
Wheat and products	17.444	16.346	17.307	17.079	18.932	19.530	19.789	19.837	19.882	20.301	186.446
Rice and products	14.161	12.717	13.204	15.401	14.220	14.303	14.959	15.275	15.427	14.866	144.532
Sugar cane	2.488	2.594	2.383	4.224	2.501	0.769	1.169	3.501	2.536	2.953	25.118
Vegetables	5.112	5.125	5.141	5.768	5.104	4.657	4.510	2.868	2.692	3.048	44.026
Citrus Fruits	1.239	1.310	1.308	1.361	1.023	0.985	0.927	0.984	1.176	1.261	11.573
Soybeans	1.291	1.540	1.511	1.627	1.598	1.607	1.682	1.609	1.732	1.672	15.869
Bovine Meat Beef	54.741	51.082	43.961	45.651	44.543	49.661	55.089	59.950	53.789	55.676	514.142
Mutton & Goat Meat	15.675	15.830	15.122	14.946	15.939	13.843	15.138	15.477	13.776	11.263	147.009
Poultry Meat	16.607	18.092	18.632	19.400	20.629	20.561	22.200	21.610	21.654	22.128	201.513
Eggs	3.235	3.154	3.965	3.882	3.484	3.303	3.444	2.863	3.167	3.225	33.723
Milk - Excluding Butter	5.497	5.349	5.451	6.023	5.617	4.359	4.521	5.202	5.097	6.070	53.186